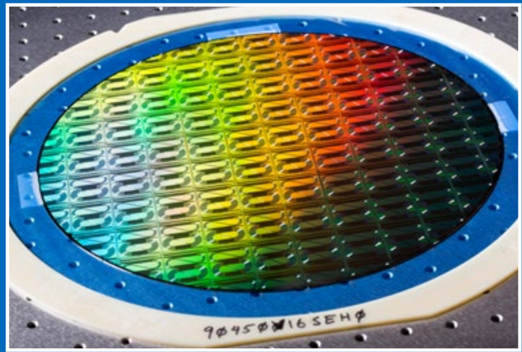
2016

CONNECTOR

News from the MIT Department of Electrical Engineering and Computer Science

Spring 2016

CONNECTOR



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A LETTER FROM THE DEPARTMENT HEAD

Whether it is through groundbreaking research or creating the next generation of global innovators, our faculty, students, and staff are working to make a better world through transformative technologies and new approaches to learning. In this issue of the MIT EECS *Connector*, we invite you to find out more about the initiatives we've launched recently, some of which are described below.

Anantha Chandrakasan

Computational thinking is an essential skill in all engineering and scientific disciplines, and important beyond these as well. We are proud to announce that beginning in Fall 2016 MIT will offer a minor in computer science. The minor will give students a strong background in the fundamentals of programming, algorithms, and discrete mathematics, enabling students to acquire the knowledge and skills needed to make effective use of computer science concepts and computing technologies in their future careers.

Undergraduate enrollment in Course 6 is at an all-time high. As of October 2015, 1,204 sophomores, juniors, and seniors, were enrolled in Course 6 majors. We are especially pleased that undergraduate women are increasingly choosing to study electrical engineering and computer science; women now account for 43 percent of sophomores enrolled in Course 6. As enrollment increases, EECS is developing new ways for its students to ask questions and access information about our curriculum. One example is the recently launched 6.AcAd Advising Forum, which gives MEng and undergraduate students a comfortable online forum in which to raise questions and issues, and provides quick access to authoritative answers and suggestions—about department curriculum, courses, degree requirements, opportunities, and more. Hosted on the academic forum service Piazza, the "instructors" for the forum include the members of the department's Academics and Advising Committee, the staff of the Undergraduate Office, peer advisors, and faculty volunteers.

SuperUROP, or the Advanced Undergraduate Research Opportunities Program, is an undergraduate research program that gives students the research toolkit they need to tackle real-world problems. Students in the program participate in a year-long research experience, and enroll in 6.UAR (Preparation for Undergraduate Research). We are pleased to be able to offer access to this popular program to an increasing number of students. For the first time this year SuperUROP has expanded to include students throughout the School of Engineering, and enrollment has more than doubled in the four years since program began, from 80 students to 178.

Entrepreneurship plays a vital role in deploying new ideas and technologies. To give our students more exposure to the elements of entrepreneurship, EECS launched Start6, a two-and-a-half-week IAP course, in 2014. This year Start6 has had a makeover as StartMIT, and the program has expanded to include other disciplines. Students from all five of MIT's schools had the opportunity to work closely with successful entrepreneurs and innovators, including Ethernet co-inventor and 3Com founder Bob Metcalfe, the 2015–2016 MIT Visiting Innovation Fellow. StartMIT students also received first access to the MIT Sandbox Innovation Fund, a program that launched in January 2016 to connect students with tailored educational experiences, mentoring, and up to $25,000 to help qualified students and teams nurture their ideas.

The innovation pipeline becomes stronger when it includes a diversity of voices. In November 2015, EECS hosted the annual Rising Stars in EECS workshop, which brought 61 women graduate students and postdocs considering careers in academic research to campus for three days of academic talks, networking, and skill-building sessions. In addition to introducing participants to the skills they need to navigate the early stages of an academic career, participants were able to expand their network and make lasting connections, opening the doors for collaborations and professional support in years to come. We are pleased to announce that Carnegie Mellon University will host Rising Stars in EECS in Fall 2016.

For new ideas to take root, they first have to be heard. In Fall 2015, EECS launched the Graduate Communications Lab to offer writing, speaking, and visual design support for scientists by scientists. The lab's communication advisors are EECS graduate students and postdocs who have been trained rigorously so that they are both content experts and communication coaches. The EECS communication advisors are available to help EECS students, staff, and researchers with individual coaching for any scientific communication tasks they are working on—from publications to conference talks.

Other initiatives that continue to play major roles in the important work of keeping EECS responsive to its students and community members include the Undergraduate Student Advisory Group in EECS (USAGE), and Postdoc6. The efforts of USAGE this year are deeply important to understanding and addressing workload balance; and their input on undergraduate curriculum is providing crucial feedback to our faculty curriculum committee. Postdoc6, entering its fourth year, is committed to ensuring that postdocs across EECS-affiliated labs have access to the resources they need to build a vibrant postdoc community—opening the door to the many opportunities available to them at MIT. This year, we created a new workshop to develop leadership and teamwork skills for postdocs.

In April, I announced that the 2015–2016 academic year would be my final one as department head of EECS. Throughout the five years that I have been privileged to serve in this capacity, I have been most impressed with the drive, creativity, and leadership of the members of our community. We have collaborated to not only support a historic increase in undergraduate enrollment, but also to expand and enhance the student and faculty experience through more than twenty-five new initiatives. I am especially proud of the advances we have made in enhancing student advising to meet our growing needs, expanding undergraduate research opportunities (with SuperUROP), exposing our students to entrepreneurship (through StartMIT), supporting women interested in an academic career (through the Rising Stars Workshop), hiring faculty in strategic areas, and other changes that have strengthened the EECS community (such as student input to faculty hiring, USAGE, the undergraduate lounge, GEECS hour, and Postdoc6). As our undergraduate enrollment has grown, so has our reach beyond MIT. Our efforts to expand access to course materials through MITx/edX have created new ways for people worldwide to learn about electrical engineering and computer science. I believe that—together—we have made MIT EECS a stronger and more welcoming place for everyone.

As always, we are eager to engage our alumni in exploring ways for them to share their expertise with current students and faculty. I welcome your input and hope that you will stay in touch directly or through our website and social network channels.

Sincerely,

Anantha P. Chandrakasan

Vannevar Bush Professor of Electrical Engineering and Computer Science

Department Head, Electrical Engineering and Computer Science

FEATURES

Course 6 senior Nicole Glabinski and postdoctoral researcher Guy Rosman work on her SuperUROP project, a "smart" 3-D scanner with the ability to change resolution and other paramaters on-the-fly.

LEARNING TO SOLVE

Hallmark program "SuperUROP" lets undergrad engineers dive into a year-long research experience.

By Audrey Resutek, MIT EECS

From developing smart 3-D scanners, to refining desalination techniques, to designing football helmets that can prevent concussions—undergraduates across the School of Engineering are putting the finishing touches on their year-long research projects that are part of the Advanced Undergraduate Research Opportunities Program, or SuperUROP.

Students participating in the now school-wide program, which was launched in 2012 in the Department of Electrical Engineering and Computer Science (EECS), are immersed in a graduate-level research experience. Taking a deep dive into a single problem, participants work under the supervision of an MIT faculty member or researcher, and their projects often lead to published research or a prototype.

"Engaging in research gives our undergraduates the confidence to push boundaries and solve problems that no one has ever solved before—and that's the very definition of research," says Ian Waitz, dean of the School of Engineering. "The skills that students gain from SuperUROP and other research-based programs continue to impact their lives well after research is finished."

Tackling the hard problems

The 177 students enrolled in SuperUROP are not shying away from hard-hitting problems.

Bradley Walcher is working on a football helmet design to reduce the risk of concussion. Walcher, a junior studying aeronautics and astronautics, notes that concussions are a growing issue for football players — an estimated 15 percent of football players get a concussion every year. The prototype Walcher and his colleagues are developing uses an inverted cushioning structure and 3-D printing to produce a snug fit.

"I took SuperUROP because I want to go to grad school," Walcher says, "and this has given me the experience of doing higher-level research, which is hard to do as an undergraduate."

Christian Argenti, a junior studying mechanical engineering, is tackling another health problem, investigating a compression bandage design for treating venous leg ulcers. Currently, health care professionals don't have a good indication of the pressure being placed on a wound and may thus miss the ideal pressure range for the healing process. Argenti's potential solution is a bright one: employing polymer-coated fibers that change colors as stretched, indicating the amount of pressure the bandage applies.

He has been working in the Lab for Bio-inspired Photonic Engineering in the Department of Mechanical Engineering for two years and says SuperUROP gave him an opportunity to be immersed in a research setting: "I love SuperUROP because it gave me a bigger project to work on. It really helped me be independent as well as challenging me with projects like the poster session and writing papers."

Course 6 junior Ashley Wang presents her project, "Visualizing Big Data in Mobile Application Development," at the SuperUROP Research Preview in December. Photo: Gretchen Ertl

In addition to completing the research project, students round out their experience by enrolling in a yearlong course, 6.UAR (Preparation for Undergraduate Research), where assignments include conducting a literature review, writing a journal or conference-style research paper, and presenting a research poster.

Flora Tan, a senior studying computer science, is applying machine learning to financial data—an idea that is just taking hold in the finance sector. Tan's project uses deep-learning techniques to identify and perhaps predict trends in currency exchange rates such as Bitcoin.

"I'm interested in how technology can disrupt industries like finance, and I'd like to start a company or technology team in the future," Tan says. "SuperUROP has given me a chance to spend time getting a deep understanding of the technologies being used today."

An interdisciplinary community of scholars

Expanding SuperUROP to include students from departments across the School of Engineering has already shown great promise, creating community and exposing undergraduates to new fields.

"We hope to create an interdisciplinary community of scholars," says Anantha Chandrakasan, the Vannevar Bush Professor of Electrical Engineering and Computer Science and EECS department head. "It is amazing to see the enthusiasm and innovative ideas that emerge as they interact with their peers in their own and other areas."

One of the new departments participating in SuperUROP this year is the Department of Aeronautics and Astronautics (AeroAstro), in which students are working on projects ranging from biometric telemonitoring for astronauts to airfoil-enabled heat exchangers that reduce fuel burn in advanced aeropropulsion systems.

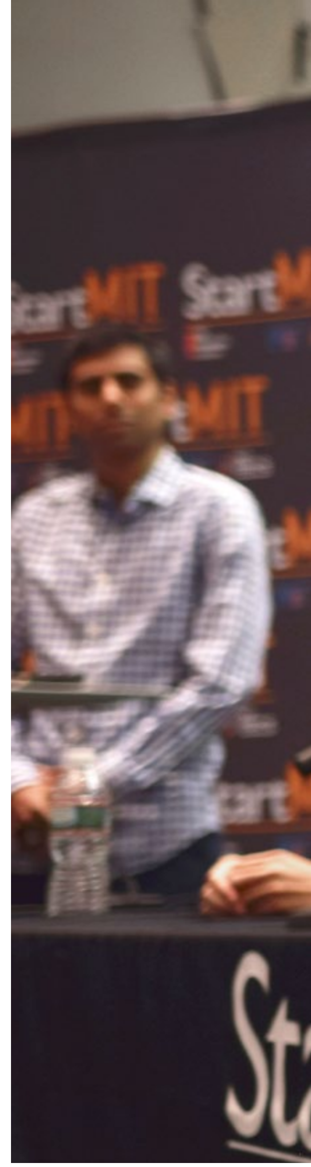
"SuperUROPs are a fantastic opportunity for AeroAstro undergraduates to step 'outside the box' and work with industry, faculty, and grad students on exciting, real-world challenges," said Jaime Peraire, AeroAstro department head and the H.N. Slater Professor Aeronautics and Astronautics.

"When we say, 'only at MIT,' SuperUROP is exactly what we are talking about," adds Waitz. In fact, nearly 90 percent of undergraduate students participate in research during their time at MIT, a hallmark of MIT's motto, "mens et manus" ("mind and hand").

"I think that's profound," Waitz says. "Our emphasis on research and hard problems exemplifies how we train our engineers, and that has become a magnet for the kinds of fearless students we attract."

Watch online: http://bit.ly/SuperUROPtalk

A JUMPSTART FOR ENTREPRENEURS



Intensive IAP course helps students navigate early challenges in starting a company.

By Rob Matheson, MIT News Office

There are myriad challenges for entrepreneurs when first starting a company: fundraising, recruiting talent, developing an innovative product, networking, scaling, and — not least of all — finding customers.

StartMIT, a course offered during MIT's Independent Activities Period between semesters, aims to help engineering students navigate those early challenges, with advice from founders who have been through it all. The course is co-organized by the Department of Electrical Engineering and Computer Science (EECS) and the MIT Innovation Initiative.

Held this year from Jan. 11 to Jan. 26, StartMIT (formerly Start6) organized an extensive schedule of talks and panel discussions that focused on a broad range of topics, including product development, founders' stories, MIT's entrepreneurial resources, networking, common startup mistakes, and creating company culture. The lineup of speakers was equally diverse, ranging from startup novices to serial entrepreneurs, and spanning multiple industries. Additional activities — such as mock customer interviews and creating a pitch — focused on honing basic entrepreneurial skills.

"The aim is to give our students and postdocs ... a rich view of what it means to be an entrepreneur," says StartMIT head organizer and EECS department head Anantha Chandrakasan. "In three weeks, [participants] walk away with an understanding of what entrepreneurship is all about, the different views, and learning how to put a pitch together, among other things."

During the final two days, student groups were required to deliver brief pitches for commercial ideas they formed during the course. These included hacking-recruitment services, smart windows, new airplane-de-icing technologies, various apps, and waterproof purses, among other ideas. The course also included field trips to local companies — including iRobot, Ministry of Supply, and Kayak — as well as the Cambridge Innovation Center and MassChallenge startup incubators.

Around 100 MIT students participated in this year's StartMIT, now in its third year. On Jan. 14, President L. Rafael Reif dropped by Building 34-101, where most of the talks were held, to stress the importance of StartMIT in carrying out the Institute's mission of using commercial innovations to make tangible impact on society.

"There are many ways in which we can do good ... and one of those ways is to start companies," he said, adding: "By learning from experts and by learning from one another, you're on your way to fulfilling not just ... the MIT mission, but fulfilling your own mission in starting companies."

In three years, more than 100 projects have been developed through StartMIT, including Smarking (2014), now a successful company that uses big data analytics to help parking-garage managers maximize pricing and availability; GelSight (2014), which is commercializing sensors that can make 3-D maps of surfaces and could be used for more sensitive robotics fingertips; and Belleds Q (2015), which is developing a consumer product that uses streaming music to control wireless smart LED bulbs in homes.

Seasoned entrepreneurs

Eight days of talks and panel discussions saw seasoned MIT-affiliated entrepreneurs and innovators offering sage advice to students about starting companies.

In her Jan. 13 talk, MIT professor Sangeeta Bhatia, who has launched several biotech companies, gave a behind-the-scenes look at the sometimes-arduous process of taking innovations from lab to market — "to highlight everything you don't see in the press," she said.

In 2008, Bhatia, the John J. and Dorothy Wilson Professor in the Institute for Medical Engineering and Science and the Department of Electrical Engineering and Computer Science, spun out 14 years of MIT research into Hepregen, now a successful company.

Hepregen's "micro-liver" platform allows liver cells to function outside the body for up to six weeks, for use by researchers and pharmaceutical firms. Among other topics, Bhatia discussed struggles of developing the technology for commercial use, manufacturing hassles, and anxieties of dealing with big-name pharmaceutical customers.

A panel of MIT alumni who shared their experiences with starting and working at young companies included Alice Brooks (speaking), cofounder of Roominate. Other speakers were (l to R): moderator Arun Saigal, cofounder and CEO of Rappidly; Wei Li, a principal engineer at Eta Devices; Amrita Saigal, co-founder of Saathi; and Theodora Koullias, founder and CEO of Jon Lou. photo: Audrey Resutek

"What did we learn? We learned it takes a long time [to start a biotech company]," Bhatia said. However, "as engineers and scientists, translation of your technology to make an impact through commercialization is actually imperative."

In a kickoff talk on Jan. 11, EECS lecturer Christina Chase, a former Entrepreneur-in-Residence at the Martin Trust Center for MIT Entrepreneurship and founder of several tech companies, detailed key reasons tech startups fail. Among these, she said, are scaling a company too soon by hiring too many employees, splurging on machinery, or renting unnecessarily large office space.

"Ultimately, understand 'what can I not spend my money on,' because cash is oxygen to your company," said Chase, who also led activities on discovering value propositions and conducting mock customer interviews.

Other speakers included: David H. Koch Institute Professor Robert Langer, founder of more than 20 companies, who discussed commercializing breakthrough technologies; Ethernet co-inventor and 3Com founder Robert Metcalfe '68 who discussed forming Internet companies and led an activity on writing effective press releases; Michael Stonebraker, a pioneer in database management systems with three big data companies under his belt, who gave students five easy steps for starting a company; and co-founder and CEO of Dropbox Drew Houston '05, who gave advice to budding entrepreneurs via satellite.

Fresh faces

While hearing from seasoned entrepreneurs was certainly informative, electrical engineering and computer science senior Keertan Kini connected most with a panel of recent MIT alumni entrepreneurs.

That panel, held on Jan. 19, included four MIT alumni who shared their experiences of starting or working at young companies: Alice Brooks '10, co-founder of Roominate, which is developing STEM-focused toys; Theodora Koullias '13, founder and CEO of luxury fashion-tech brand Jon Lou; Wei Li SM '09, PhD '13, a principal engineer at Eta Devices, which is making mobile communications more efficient; Amrita Saigal '10, co-founder of Saathi, which manufactures sanitary pads

MIT President L. Rafael Reif (right) holds the latest addition to his T-shirt collection with EECS Department Head Anantha Chandrakasan (left).

"By learning from experts and by learning from one another, you're on your way to fulfilling not just ... the MIT mission, but fulfilling your own mission in starting companies."

—L. Rafael Reif, President of MIT

made from waste banana tree fiber, for girls in rural India; and moderator Arun Saigal '13, SM '13, co-founder and CEO of Rappidly, a startup that makes drag-and-drop programming tools to build apps.

"Hearing from people who are just recently out of MIT ... was incredibly meaningful and incredibly impactful," he says. The alumni could "relate easily to our experiences, or some of the doubts we have about our own abilities, or discuss how certain classes might actually make an impact, or relate to the challenges we'd faced as first-time founders because we don't have the track record that a lot of the other professionals have."

With support from MIT's Sandbox Innovation Fund, Kini and his partner are now prototyping their StartMIT project, called Ember, an interactive cooking app that uses voice commands to walk people through recipes.

A talk by MIT alumnus Jeremy Conrad '06, founding partner of Lemnos Labs, a seed-stage investment firm and incubator in San Francisco, resonated with freshman Anelise Newman, who developed a sewing-education startup for StartMIT.

Conrad's talk, Newman said, introduced her to one important and sometimes overlooked facet of entrepreneurship: networking. In his talk, Conrad discussed how he'd rush around to make sure he was in the same room as an investor, or build relationships with people that could provide an introduction to a person of interest.

"It opened my eyes to the hustle that you have to get used to if you want to be an entrepreneur," Newman said. "Not only do you need to define your product ... you have to define your goals and go about them and vigorously pursue them in whatever way possible."

Jeremy Wertheimer, SM '89, PhD '96, VP, Google, talks with students enrolled in StartMIT following a talk on creating company culture. Photo credit: Rose Lincoln

EMPOWERING INNOVATION

Panel highlighting female innovators from a range of fields aims to encourage student entrepreneurs.

By Terri Park, MIT Innovation Initiative

Left to right: Jesse Draper, Helen Greiner, Susan Hockfield, Payal Kadakia, Dina Katabi. Photo credit: Rose Lincoln

An all-star panel of entrepreneurs shared their experiences as part of the evolving innovation ecosystem at "Empowering Innovation and Entrepreneurship," the capstone event of StartMIT, an Independent Activities Period class aimed at exposing students to the elements of entrepreneurship.

Moderated by Jesse Draper, creator and host of the Emmy-nominated "Valley Girl Show," the all-female panel included Susan Hockfield, president emerita of MIT; Helen Greiner '89, SM '90, CEO and founder of CyPhy Works and co-founder of iRobot; Payal Kadakia '05, CEO and co-founder of ClassPass; and Dina Katabi, the Andrew and Erna Viterbi Professor of Electrical Engineering and Computer Science (EECS) at MIT.

Draper, a former Nickelodeon star, brought her trademark approachable style to the event, encouraging panelists to jump in to the discussion with a question on how MIT has touched their careers.

"The key critical characteristic I think I found in myself and in other entrepreneurs is the ability to problem-solve, and that's the thing I learned here the most in my curriculum," Kadakia shared. She emphasized that this skill has seen her through the development of many phases of ClassPass, a fitness membership startup that she launched in 2013. "It taught me to always take something and figure out the solution; I never got stuck."

The advice hit home for the audience made up of alumni and students enrolled in StartMIT, a program developed by the Department of Electrical Engineering and Computer Science and supported by the Innovation Initiative, and chaired by EECS department head Anantha Chandrakasan. Over the last two weeks, the undergraduates, graduate students, and postdocs in the program have heard from founders and innovators in startups, industry, and academia about challenges they faced in their own careers.

For Greiner, it was the power of the MIT network that proved to be most valuable. "I met my business partners at MIT and many other people in my network. You want to use this opportunity while you're at MIT to meet the professors, meet other people that are in your field, because you never know where people will end up."

Shifting the focus to MIT's history and its involvement in creating the current ecosystem of entrepreneurship in greater Boston, Hockfield shared that during her tenure as president, she saw a new wave of innovation rising in the region. She knew MIT could foster it, leading the Institute to "participate in accelerating the development of Kendall Square by being a really good partner to the city and to the companies. My role was to pour a little gasoline on the flames."

Addressing the topic of raising funding, Draper asked the panel whether it was the idea, the product, or the user base that was most important.

To Katabi, who has seen a couple of startups out of her lab at MIT, it was your promise to the investor that mattered the most. "People don't see much at the beginning. Your promise is in the future. So it's you, it's the idea, and it's the market. It's also that the promise once delivered it will make a difference."

An audience member asked the panel to share what catalyzed their decision to leap into entrepreneurship. Greiner replied that she made the move early on in her career, co-founding iRobot shortly after graduating from MIT. She continued that

Left to right: Susan Hockfield, Payal Kadakia, Dina Katabi, Helen Greiner, Jesse Draper, Anantha Chandrakasan. Photo: Rose Lincoln

Watch online: http://bit.ly/StartMITInnovation

it took the company 12 years to move into market, calling it "the longest overnight success story you've ever seen." She further explained that her experience developing iRobot had its low points as well when funded projects couldn't move forward, and that "it's really not always about the idea, it's about the timing of the idea, which is just as critical."

When asked about the challenges of being a woman in technology, Greiner answered, "You have to look at everything for what it is. It can be a double edge sword. Back in 1990, there were even fewer women in technology. That was bad, but on the other hand when I would go meetings, people would remember me as the 'robot lady.' Everything's a double edge sword and if you look at the positive, you keep going forward because we need women in tech."

Joi Ito, director of the MIT Media Lab, offered the panel closing remarks on the innovative research happening at the lab. Ito, who spent much of his career as an entrepreneur and venture capitalist, commented on the complementary roles that academia and startups play in developing new technology.

The difference between the mindset at startups and in the academic world was particularly interesting to Ito, who joined MIT in 2011. Whereas startups must focus on short-term goals and the marketability of their products, academics can spend time thinking about long-term goals and the math and science underpinning new technology, he remarked, and both ways of thinking play a role in deploying new technologies.

"I've spent the last five years trying to understand how technology makes it out into the real world," Ito said. "Having done that, I see the importance of translation of technology into the real world, and the role that startups have in that."

Check out what people are saying about StartMIT on Twitter

@KyleGross_: Former MIT Prez @SusanHockfield "When you know you're right it doesn't matter what everyone else thinks" @medialab #StartMIT @olivia_vanni

@olivia_vanni: .@Joi describes the @medialab as "the Department of None of the Above" and "Antidisciplinary" #StartMIT

@dharmesh: Had a good time speaking to a bunch of entrepreneurial students about marketing at MIT at the #StartMIT event. Great questions!

@cchase: Bob Langer on deck! Most cited engineer in history, 300+ patents seeded companies, founder of 26+ startups #StartMIT

@JesseDraper: Looking forward to visiting @mit today & talking w/@helengreiner #susanhockfield #dinakatabi & @PayalKadakia @miteecs for #startmit #wit

@DanielDickey: "You lead people, you manage things." The leadership advice of Grace Hopper being evoked at #StartMIT

@MalenaOhl: Thanks @drewhouston for your advice about "starting the clock early" by working at small companies #StartMIT

Read the rest at: http://storify.com/MITEECS/startmit-2016

MIT LAUNCHES INSTITUTE FOR DATA, SYSTEMS, AND SOCIETY

Landmark multidisciplinary effort brings together engineering and social sciences.

IDSS director Munther Dahleh. Photo: Lillie Paquette

The complex, interconnected systems that shape our daily lives incorporate both technological and human elements. With more and more data becoming available, researchers are now able to observe and understand these systems in unprecedented ways. The challenge lies in determining how best to interpret and apply the data with innovative approaches that can help us model and predict when and why systems might fail, make improvements, and create better systems in the future.

On July 1, 2015, MIT officially launched the new Institute for Data, Systems, and Society. IDSS uses tools and methodologies in statistics, information and decision systems, and social sciences to address challenges and opportunities in complex systems. IDSS research encompasses a variety of domains, including finance, social networks, urbanization, energy systems, and health analytics.

"IDSS is creating a new paradigm—bringing together engineering and social sciences," says IDSS director Munther Dahleh, William A. Coolidge Professor in EECS. "We are focused on addressing major societal challenges using rigorous data analytics approaches."

Spanning all five MIT schools, IDSS is supporting and developing a range of cross-disciplinary academic programs advancing its mission. In Fall 2016, IDSS will welcome its first cohort in the Doctoral Program in Social and Engineering Systems. IDSS also hosts the Technology and Policy Program (TPP), which has offered the Master of Science in Technology and Policy at MIT since 1976, and prepares students for leadership in government and industry. Emphasizing the need to analyze data in order to make informed decisions, IDSS is also working to offer academic programs in statistics to MIT's undergraduate and graduate students. In May 2015, IDSS hosted a two-day symposium, "21st-Century Statistics at MIT" (statsconf.mit.edu).

The formation of IDSS creates a larger set of MIT alumni that includes people from information and decision sciences, statistics, engineering systems, and policy. IDSS alumni will belong to a broader and deeper community whose benefits include an ever-richer world of resources and connections for faculty, students, researchers, and alumni, resulting in expanding IDSS's reach and inviting new areas for collaboration.

IDSS's rigorous computational and analytical approaches for analysis and design of complex systems are anchored in research developed at the Laboratory for Information and Decision Systems (LIDS), forming the research backbone of this new institute. The longest running research lab at MIT, LIDS is a global leader in advancing information and decision sciences. Its research cuts across core engineering disciplines building foundational knowledge for research and applications across many different domains and application areas.

LIDS director and EECS professor Asuman Ozdaglar is associate director of IDSS, as is Professor Ali Jadbabaie, a visiting professor from the University of Pennsylvania who is also interim director of the Sociotechnical Systems Research Center.

A new undergraduate minor in statistics and data science will launch in fall 2016. More information about IDSS and its mission, people, research, and academic programs can be found at idss.mit.edu.

Creating Postdoc CONNECTIONS

EECS pilots new ways to build leadership and teamwork skills for its postdocs.

By Patsy Sampson, MIT EECS

"What I liked the most about the Postdoc6 Workshop was the playback theater!" says Zizhuo Zhang, postdoctoral associate in the Computational Biology Group with Manolis Kellis, professor of computer science.

Improv theater is just one of the tools the Department of Electrical Engineering and Computer Science (EECS) is using to help its postdocs beef up their leadership and teamwork skills as part of an initiative called Postdoc6. The program aims to knit together the often disperse postdoc community, while helping postdoctoral associates and fellows train for their future careers.

With over 200 postdoctoral associates in its labs, EECS under the direction of Department Head Anantha Chandrakasan, created Postdoc6 in late 2012. "Postdocs are a key part of EECS," notes Chandrakasan, the Vannevar Bush Professor of Electrical Engineering and Computer Science. "We are committed to ensuring that they have access to the resources they need to succeed in their research and achieve their goals. With Postdoc6, we hope to build a vibrant postdoc community — opening the door to the many opportunities at MIT."

Increasing collaboration

In mid-January, Zhang and fifteen other EECS postdocs participated in a two-day leadership workshop held at MIT's Endicott House. The sixteen EECS postdocs received training based on transactional analysis to build communication and self-management skills. Transactional analysis is a system of popular psychology based on the study of relationships as individuals shift among the roles of parent, child, and adult. This method can be mastered in two- to three-day sessions with the goal of building trust and openness.

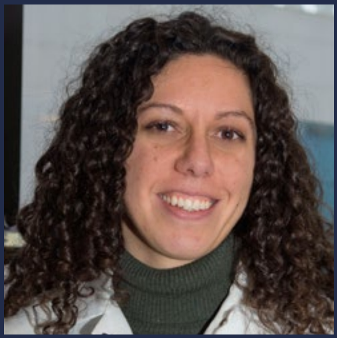
The workshop also featured training for follow-up peer groups to provide supportive networks that last long after the workshop ends.

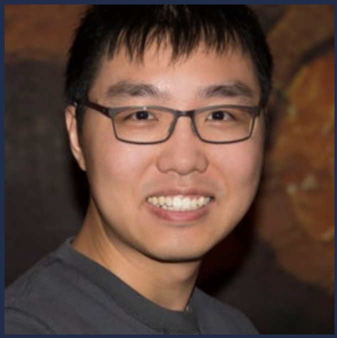
"Since WWII, science has become increasingly collaborative," says Nir Shavit, professor of electrical engineering and computer science and Postdoc6 faculty coordinator. "Now, authorship on major papers includes multiple authors and sometimes research groups. There is more and more need for collaborative and interdisciplinary work," he adds. "The goal is to build a new generation of scientists that are more aware of human interactions, allowing for real communication in the labs."

Learning to lead

Shahin Kamali, postdoctoral researcher in computer science under Charles Leiserson, the Edwin Sibley Webster Professor of Computer Science, was upbeat following the experience. "Now I feel that MIT cares about me," he says. With plans to join a peer group, Kamali says that the workshop also revealed his interest in helping people understand each other.

Judith Birkenfeld, postdoctoral associate in the Madrid M+Vision Consortium at the Research Laboratory of Electronics and Research Fellow at Brigham and Women's Hospital and Harvard Medical School, says she was impressed with the takeaway. "The Monday after the workshop, I could go to my office and apply what I learned right away," she says. She is also impressed by how the facilitators at the workshop were able to engage all participants. "They recognized your strengths and shortcomings quickly, and gave concrete advice on how to improve. Through subtle suggestions, I was amazed to see how people could appear completely different by applying minimal changes."



Left to right: Ziawasch Abedjan, Sara Cleto, Shahin Kamali, and Zhizhou Zhang. Photos: Patsy Sampson

"You are not alone in struggling through a project," says Dan Congreve, who earned his PhD under Mark Baldo, professor of electrical engineering. Congreve will be completing his postdoctoral position in the Research Laboratory of Electronics in several months to lead a research group as a Fellow in the Rowland Institute at Harvard. He joined the workshop knowing the issues of communication to lead a group were universal. "Finding a way to effectively say 'This is why I am frustrated'," he says, "was a major takeaway for any member of a team."

"We didn't focus on playing a 'boss'," says Ziawasch Abedjan, postdoc with Michael Stonebraker, adjunct professor in computer science and 2014 Turing Award winner. "Instead," Abedjan adds, "it was implied to inherently lead by acting as an adult who treats the other person as an adult. We wanted to avoid or break the inner-attitudes that resemble the roles of parent and child."

Nir Shavit led an additional part of the workshop known as playback theater — using improv theater techniques to train groups of scientists to enhance collaborative and communication skills. "The playback process," says Shavit, "is actually a microcosm of what's happening in the lab."

"Performing spontaneously is not a native skill for most serious researchers including postdocs," notes Sara Cleto, postdoc in the Synthetic Biology Group with Tim Lu, associate professor of electrical engineering. "But, we could be as goofy as we wanted, since we felt no one would sit and judge us. We all participated."

Recognizing the challenge to express and manage emotion as a tool critical for focused research, Zhizhuo Zhang found the workshop including the improve theater was eye-opening. "In order to accomplish high impact research, it is necessary for a researcher to understand self motivation — to open your heart," he says. "How to express yourself, to perform," he adds, "was not only important in communicating your work, but it was the fun part of the workshop."

Building community

"Postdocs explore new areas as they launch their professional careers and create vital connections among groups within MIT and in other institutions," says Muriel Médard, the Cecil H. Green Professor in EECS at MIT. As head of the Network Coding and Reliable Communication Group, Médard also notes that the contribution of postdocs in research groups in her field is growing in importance and complexity. "I see with pleasure that postdocs are increasingly collaborating with each other, creating a vibrant community of the next generation of researchers."

As the 16 workshop participants resumed their daily research paths with new tools to apply to the challenges ahead, Postdoc6's steering committee members launched a new social activity for all EECS postdocs. Tea Time, a weekly tea and cookie social gathering, will provide EECS postdocs an opportunity for community in a relaxed environment.

"The focus of Postdoc6 planning is all about forming community and making postdocs' time at MIT better through workshops and community meetings such as Tea Time," says Shavit. He adds that no matter what the mechanism to build community, EECS is seeking to build a positive experience for its postdocs.

Ship in a bottle

MIT.nano is one of the most ambitious—and challenging—construction projects in Institute history.

MIT.nano will be a 200,000-square-foot building that houses state-of-the-art cleanroom, imaging, and prototyping facilities that can support fabrication and characterization processes on the nanoscale. It will also be located in the heart of the MIT campus, surrounded on all four sides by existing buildings.

The project's leadership, planners, project managers, and contractors recently reached the "one-third" mark in the 1000 day construction project, sometimes referred to as building a ship in a bottle.

The new nanoscale characterization and fabrication facility is due to open in June 2018.

Right: Cross-section of the new building.
Backgroud photo: MIT.nano construction site in early April. Photo credit: Audrey Resutek


Sixty-one women from 25 institutions attended the 2015 Rising Stars in EECS workshop.Photo: Gretchen Ertl

IT TAKES A NETWORK

Rising Stars workshop helps female electrical engineers and computer scientists build a professional network, find jobs in academia.

By Audrey Resutek, MIT EECS

Success in higher education, especially for women in computer science and electrical engineering, takes a network. And while some connections are only a text message or tweet away, the personal touch still matters, and it works differently.

For graduate students like Judy Hoffman, who studies adaptive learning algorithms at the University of California at Berkeley, there is no substitute for actually meeting fellow female engineers and computer scientists in person. To make this happen, the Department of Electrical Engineering and Computer Science (EECS) hosts "Rising Stars in EECS," a three-day workshop for graduate students and postdocs who are considering careers in academic research.

"Rising Stars helped me connect with current and future leaders in our field, all within a very supportive environment," says Hoffman, one of 61 attendees who came to campus this year. "I have a good sense of where I want to go with my research," she adds, but "the workshop provided me with the insights I needed to successfully navigate the process."

Network effect

Created in 2012 by EECS head Anantha Chandrakasan, Rising Stars has nearly doubled in size since its inception. More than just a meet-up, Rising Stars offers women in EECS the opportunity to learn by doing, with sessions focused on landing a faculty job, gaining tenure, and building a professional support network.

Participants and speakers candidly discussed how to tackle common issues such as dual-career hiring (when an applicant's spouse is also seeking a job in academia), work-life balance, and family leave policies. Attendees also presented their research at a poster session and gave talks about their research (Hoffman presented her work on the performance of deep visual models). All sessions are designed to help demystify what many young female faculty describe as the "black box" of academic hiring and the tenure process.

"We hope to give them the information they need to be successful as they explore job opportunities," says Chandrakasan, the Vannevar Bush Professor of Electrical Engineering and Computer Science. "But we also feel very strongly about giving participants a chance to get to know each other and make lasting connections. These connections can open doors for collaborations and provide professional support for years to come."

While MIT and other institutions have had success in attracting an increasing number of female students to EECS — 43 percent of sophomores studying EECS at MIT are women — the journey can still be a lonely one. Many of the participants at Rising Stars shared a common experience: being one of only a handful of women at their home lab.

Precious Cantú, a Fulbright Postdoctoral Fellow at the Swiss Federal Institute of Technology in Lausanne, says, "It was amazing to see such a large group of women in one room, but once we got into the talks and presentations, we were all just scientists and engineers together in a room doing fantastic science."

"It's great to listen to so many presentations. It has really motivated me to work even harder," adds Kun (Linda) Li, a graduate student at the University of California at Berkeley.

Professional launching pad

In her remarks at Rising Stars' opening reception on Nov. 8, MIT Chancellor Cynthia Barnhart spoke about the rewards of a career in academia, such as the freedom to stretch and grow across disciplines, the opportunity to conduct original research, and the chance to mentor and inspire other students, including women.

"This workshop is designed to be a professional launching pad," said Barnhart, who is also the Ford Professor of Engineering. Barnhart encouraged the women to speak with MIT faculty present at the workshop about their experiences in academia.

Institute Professor Mildred Dresselhaus, who delivered the workshop's keynote, spoke of her own circuitous journey in science and engineering. The first female tenured professor in engineering at MIT, Dresselhaus arrived in campus in 1960 and is widely regarded as the "queen of carbon" for her pioneering work in nanoelectronics.

Dresselhaus shared insights from many stages of her life — from her time as student at Hunter College, where she was studying to become a teacher, to her time studying physics with Nobel Laureate Enrico Fermi at the University of Chicago, to her early tenure at MIT. Her primary message was persistence. While studying with Fermi, she said, three-quarters of the students in her program failed to pass rigorous exam requirements. "It was what you did that counted, and that followed me through life."

Rising Stars also featured a presentation by Michael Stonebraker, a Turing Award winner and adjunct professor of computer science at MIT who led a session on how to start a company. Paula Long, CEO and cofounder of Boston-based DataGravity, offered lessons on leadership and management — skills that are equally relevant whether you're running a lab or a company.

Charles Leiserson, the Edwin Silbey Webster Professor of Computer Science and Engineering, led a session on developing a research statement. John Guttag, the Dugald C. Jackson Professor of Computer Science and Engineering, led a session on how to give a job talk and get a faculty job. Katherine Yelick, a professor of electrical engineering and computer sciences at the University of California at Berkeley, led a session on the faculty search process.

"This workshop complemented my prior experiences in academia well, so that when the hiring music plays, I'll know the steps!" said Elena Glassman, a graduate student in EECS at MIT. "I feel far less intimidated now, because I'm armed with more knowledge — and professors I can reach out to again with questions in the future as they inevitably arise."

Associate Professor Michael R. Watts (left) and Professor Lionel C. Kimerling (right). Photo: Bryce Vickmark

Consortium including MIT awarded $110M national grant to promote photonics manufacturing

Partnership of government, industry, and academia will pursue integration of optical devices with electronics.

By David Chandler, MIT News Office

MIT is a key player in a new $600 million public-private partnership announced by the Obama administration to help strengthen high-tech U.S.-based manufacturing.

Physically headquartered in New York state and led by the State University of New York Polytechnic Institute (SUNY Poly), the American Institute for Manufacturing Integrated Photonics (AIM Photonics) will bring government, industry, and academia together to advance domestic capabilities in integrated photonic technology and better position the U.S. relative to global competition.

Federal funding of $110 million will be combined with some $500 million from AIM Photonics' consortium of state and local governments, manufacturing firms, universities, community colleges, and nonprofit organizations across the country.

Technologies that can help to integrate photonics, or light-based communications and computation, with existing electronic systems are seen as a crucial growth area as the world moves toward ever-greater reliance on more powerful high-tech systems. What's more, many analysts say this is an area that could help breathe new life into a U.S. manufacturing base that has been in decline in recent years.

The public-private partnership announced today aims to spur these twin goals, improving integration of photonic systems while revitalizing U.S. manufacturing. The consortium includes universities, community colleges, and businesses in 20 states. Six state governments, including that of Massachusetts, are also supporting the project.

MIT faculty will manage important parts of the program: Michael Watts, an associate professor of electrical engineering and computer science, will lead the technological innovation in silicon photonics. Lionel Kimerling, the Thomas Lord Professor in Materials Science and Engineering, will lead a program in education and workforce development.

"This is great news on a number of fronts," MIT Provost Martin Schmidt says. "Photonics holds the key to advances in computing, and its pursuit will engage and energize research and economic activity from Rochester, New York, to Cambridge, Massachusetts, and beyond. MIT faculty are excited to contribute to this effort."

An ongoing partnership

MIT's existing collaboration with SUNY Poly led to the first complete 300-millimeter silicon photonics platform, Watts says. That effort has led to numerous subsequent advances in silicon photonics technology, with MIT developing photonic designs that SUNY Poly has then built in its state-of-the-art fabrication facility.

Photonic devices are seen as key to continuing the advances in computing speed and efficiency described by Moore's Law — which may have reached their theoretical limits in existing silicon-based electronics, Kimerling says. The integration of photonics with electronics promises not only to boost the performance of systems in data centers and high-performance computing, but also to reduce their energy consumption — which already accounts for more than 2 percent of all electricity use in the U.S.

Kimerling points out that a single new high-performance computer installation can contain more than 1 million photonic connections between hundreds of thousands of computer processor units (CPUs). "That's more than the entire telecommunications industry," he says — so creating new, inexpensive, and energy-efficient connection systems at scale is a major need.

The integration of such systems has been progressing in stages, Kimerling says. Initially, the conversion from optical to electronic signals became pervasive at the network level to support long-distance telecommunication, but it is now moving to circuit boards, and will ultimately go to the level of individual integrated-circuit chips.

"Europe is ahead in industry coordination right now," following a decade of government investment, Kimerling says. This new U.S. initiative, he says, is "one of the first of this kind in the U.S., and the bet is that the innovation and research here, combined with the manufacturing capability, will allow our companies to really take off."

Leadership in technological innovation

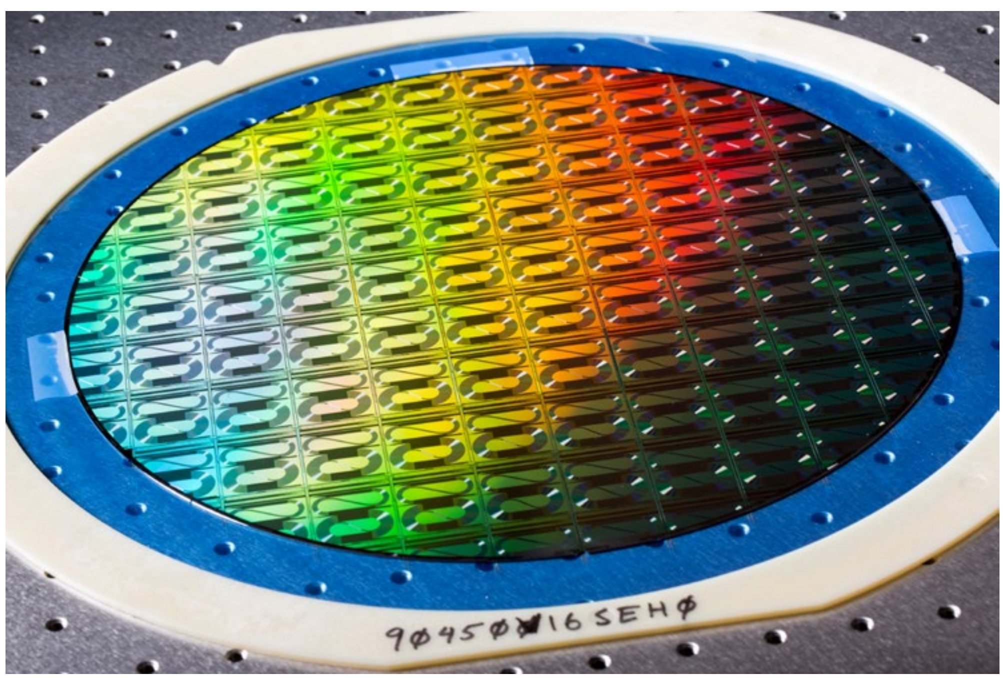
Within the new alliance, MIT will lead technological innovation in silicon photonics. That task will be managed by Watts.

The evolving integration of photonics and electronics will have a great impact on many different technologies, Watts says. For example, LIDAR systems — similar to radar, but using light beams instead of radio waves — have great potential for collision-avoidance systems in cars, since they can provide greater detail than radar or sonar. Watts has worked to develop single-chip LIDAR devices, which could eliminate the moving parts in existing devices — such as tiny gimbaled mirrors used to direct the light beams in a scanning pattern — replacing them with fixed, electrically steerable phased-array systems, like those now used for cellphone tower antennas.

"LIDAR systems that exist today are both bulky and expensive, because they use mechanically scanned lasers," Watts says. But doing the same thing at the nanoscale, using phased-array systems on a chip, could drastically reduce size and cost, providing high-resolution, chip-scale, 3-D imaging capabilities that do not exist today, he says.

There are many other areas where integration of photonics and electronics could lead to big advances, including in biological and chemical sensors that could have greater sensitivity than existing electronic versions, and in new kinds of medical imaging systems, such as optical coherent tomography.

"The goal of this initiative is to lower the barriers to entry in this field for U.S. companies," Watts says. It is intended to



A photonics wafer. Photo: Bryce Vickmark

Associate Professor Michael R. Watts (right) and Vice President Joe Biden at the AIM Photonics Launch in July, 2015.

function much like a major public-private initiative that helped pave the way, decades ago, for the development of electronic chip manufacturing in the U.S.

Significant photonic chip manufacturing capabilities have been developed at SUNY Poly, in Albany, New York. That facility has already made the world's largest silicon-based photonic circuit, a chip designed at MIT, and built using industry-standard 300-millimeter-wide silicon wafers, Watts says.

Contributions in education and training

MIT will also host AIM Photonics' program in education and workforce development, which Kimerling will direct. This will include developing educational materials — ranging from K-12 through continuing education — to prepare future employees for this emerging industry, including teaching on the design of integrated photonic devices. MIT will also lead workforce development, with an emphasis on including veterans, underrepresented minorities, and other students, by developing a variety of materials to teach about the new technologies.

MIT will work to support internships, apprenticeships, and other forms of hands-on training in a national network of industry and university partners. The effort will also support an industry-wide roadmap to help align the technology supply chain with new manufacturing platforms.

Kimerling says that a significant issue in developing a robust photonics industry is the need to develop a trained workforce of people who are familiar with both electronics and optical technology — two very different fields. Educational programs that encompass these disparate fields "are important, and don't exist today in one organization," he says.

One expected impact of the new initiative is the development of a corridor along Interstate 90, from Boston to Rochester, New York, of industrial firms building on the base of new technology to develop related products and services, much as Silicon Valley emerged in California around companies such as Intel and their chip-making technology.

Other major members of AIM Photonics include the University of Arizona, the University of Rochester, and the University of California at Santa Barbara. In addition to the Department of Defense, federal funding for the project will come from the National Science Foundation, the Department of Energy, the National Institute for Standards and Technology, and NASA.

Roots in the Advanced Manufacturing Partnership

Today's news flows from the work of the Advanced Manufacturing Partnership (AMP), a White House-led effort begun in 2011 with the aim of bringing together industry, universities, and the federal government to identify and invest in key emerging technologies, with the idea of stoking a "renaissance in American manufacturing."

AMP was inaugurated with former MIT President Susan Hockfield as co-chair; MIT President L. Rafael Reif subsequently served in that same capacity as part of "AMP 2.0." Those groups' work led to President Barack Obama's commitment to establish a National Network of Manufacturing Innovation, to consist of linked institutes such as the one announced today.

"Massachusetts' strong role in the AIM Photonics team stems from a collaboration involving MIT and many other partner organizations across the Commonwealth: universities, community colleges, and large and small manufacturers throughout the integrated photonics supply chain," says Krystyn Van Vliet, a professor of materials science and engineering and biological engineering, and MIT faculty lead for AMP 2.0. "The support of Gov. Charlie Baker and Secretary of Housing and Economic Development Jay Ash was key to the success of the AIM Photonics team, and we appreciate their efforts. This manufacturing institute will help Massachusetts inspire and prepare the next generation of integrated photonics manufacturing careers, businesses, and leaders."

"Today's announcement is a testament to the outstanding team of industrial and academic leaders assembled by AIM Photonics and its plan to establish the U.S. as a global leader in this emerging technology," says Michael Liehr, AIM CEO and SUNY Poly executive vice president of innovation and technology and vice president of research. "This would not have been possible without the critical support of Gov. Andrew Cuomo, whose pioneering leadership in establishing New York state's globally recognized, high-tech R&D ecosystem has enabled historic economic growth and innovation and secured our partnership with the state of Massachusetts. SUNY Poly is excited to be working with partners such as MIT on this initiative, which will be truly transformational for both the industry and the nation."

CSAIL joins with Toyota on $25 million research center for autonomous cars

Seeking to reduce traffic casualties, center will focus on robotics and artificial intelligence systems.

The World Health Organization estimates that 3,400 people die each day from traffic-related accidents. Could autonomous cars be part of the solution?

Today MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) announced a new $25 million research center funded by Toyota to further the development of autonomous vehicle technologies, with the goal of reducing traffic casualties and potentially even developing a vehicle incapable of getting into an accident.

Announced at a press conference in California, the Toyota-CSAIL Joint Research Center will be part of a combined $50 million that Toyota has committed to dual centers at MIT and Stanford University to advance the state of autonomous systems.

Led by CSAIL director Daniela Rus, the new center will focus on developing advanced decision-making algorithms and systems that allow vehicles to perceive and navigate their surroundings safely, without human input.

"We are excited to mark the start of our partnership with Toyota, and hopefully the beginning of the end for traffic fatalities," says Rus, the Andrew and Erna Viterbi Professor in MIT's Department of Electrical Engineering and Computer Science. "Together we have developed some research directions that have the potential to be game-changers in the field, and we look forward to working closely with Toyota and Stanford to make them real."

Toyota's larger academic collaboration with MIT and Stanford will be coordinated by Gill Pratt PhD '89, a former MIT professor who most recently served as program director at the Defense Advanced Research Project Agency (DARPA)'s Defense Sciences Office.

The Toyota-CSAIL Joint Research Center

Traditionally, companies have focused on developing systems in which either the human driver must pay attention and be ready to take control, or one in which an automated system is always in control of the vehicle.

MIT to offer minor in computer science

Computational thinking is an essential skill in all engineering and scientific disciplines. The Minor in Computer Science will give students a strong background in the fundamentals of programming, algorithms, and discrete mathematics. In addition, students will complete two courses in the advanced areas of their choice: computer systems, software engineering, artificial intelligence, and/or theoretical computer science. Upon completion of the minor students will have the knowledge and skills needed to make effective use of computer science concepts and computing technology in their future careers.

The Minor in Computer Science is open to all undergraduates except those in courses 6-1, 6-2, 6-3, 6-7, 7, and 18C. Students will normally apply online by the end of their sophomore year but no later than Add Date one full term before the term in which they expect to receive the SB degree.

For more information see:
http://www.eecs.mit.edu/csminor

CSAIL researchers plan to start by exploring a new alternative approach, in which the human driver pays attention at all times with an autonomous system that is there to jump in to save the driver in the event of an unavoidable accident. This type of system could not only improve safety by reducing the number of accidents, but could also enhance the overall driving experience, Rus explains. She envisions creating a system that could prevent collisions and also provide drivers with assistance navigating tricky situations; support a tired driver by watching for unexpected dangers and diversions; and even offer helpful tips such as letting the driver know she is out of milk at home and planning a new route home that allows the driver to swing by the grocery store.

"A highly advanced system like this would be a major advance in the field of autonomy and an important step on the way to creating a safer world for drivers," Rus says.

On the technical front, CSAIL's new center will focus on pressing challenges in autonomy, from computer vision and perception to planning and control to decision-making.

Taking on the "moonshot" challenges

Research at the new center will be aimed at improving vehicular transportation by advancing the science of autonomous systems. Researchers will tackle challenges integral to the development of advanced automated vehicle systems, including building new tools for collecting and analyzing navigation data with the goal of learning from human driving; creating perception and decision-making systems for safe navigation; developing predictive models that can anticipate the behavior of humans, vehicles, and the larger environment; inventing state-of-the-art tools to handle congestion and high-speed driving in challenging situations including adverse weather; improving machine-vision algorithms used to detect and classify objects; and creating more intelligent user interfaces.

Among the CSAIL principal investigators involved will be John Leonard, the Samuel C. Collins Professor in MIT's Department of Mechanical Engineering, who has pioneered algorithms that allow robots to navigate unknown environments, and Russ Tedrake, an associate professor of computer science and engineering, who oversaw MIT's DARPA Robotics Challenge team. The researchers say that they are eager to work on solutions that could completely transform the way that humans get around.

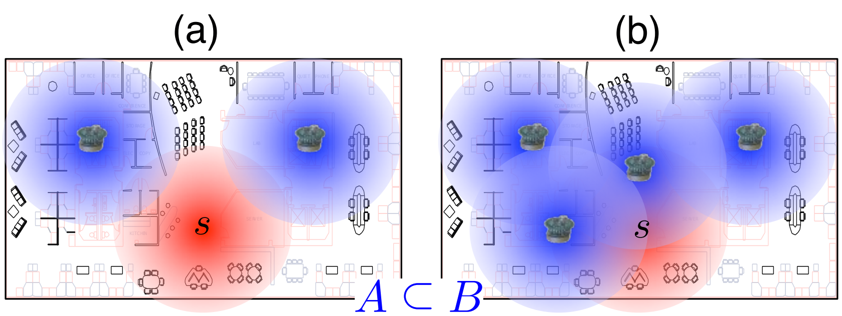
"Solving these challenges will require combining our knowledge of data-driven and model-based approaches to decision making and perception," Rus says. "Developing a vehicle that's incapable of having an accident is an ambitious goal, but at CSAIL we've always focused on the moonshots."

RESEARCH UPDATES

Diminishing returns and Machine Learning

By Stefanie Jegelka, Assistant Professor, MIT Computer Science and Artificial Intelligence Laboratory

Making sense of data" nowadays underlies progress in technology, science, healthcare, and business. This term is multifaceted, as some example scenarios illustrate. In a string of DNA, we may be looking for the regions that predict a certain disease. In a social network, we are interested in a small set of people who are most influential and will spread a piece of information most rapidly. For environmental monitoring or the IoT, we are faced with the question of which measurements to take to obtain the maximum amount of information possible. To understand or present a collection of images, e.g., from a recent vacation, we may select a few presentable ones, or automatically identify the objects displayed in those images.



$$F(A \cup \{s\}) - F(A) \quad \geq \quad F(B \cup \{s\}) - F(B)$$

Figure 1: Diminishing returns in sensing. Adding a new sensor (red) to the smaller set A (blue) yields a larger increase in information than adding it to the larger set B.

Answering such questions relies on a spectrum of tools, from mathematical modeling to optimization and algorithms. Having identified the questions to ask, the next step is to formulate a mathematical model that guides computational methods for solving the task — often by optimizing a loss or utility function. The resulting procedure needs to be both accurate and efficient enough to be deployed on real-world data. Accuracy relies on two sources: the model needs to represent the characteristics of the given problem accurately, and the associated optimization algorithm needs to be reliable, ideally guaranteeing that the obtained answers maintain a certain quality. Combining the joint goals of efficiency, accuracy, and reliability in understanding data is an ongoing challenge, and it fosters the confluence of statistics, mathematics, optimization, and computer science.

A productive example of this interplay of techniques are recent insights about connections between discrete mathematics and machine learning. The above introductory example tasks arise in different areas, and are phrased via different models. Yet, stripping things away to an abstract level, these tasks have surprisingly much in common: First, all of them ultimately ask to identify a "good" subset out of a larger set of candidate items. In the social network example, we seek a small, jointly influential set out of all people in the network. In sensing, we seek a small set of maximally informative measurements.

The actual notion of "good" of course varies across examples: in the social network, the measure of goodness is the influence exerted by the selected subset of people; in sensor placement, it is the information gathered via measurements in the selected locations; in other cases, it is defined via expected errors, probabilities, or costs. This measure of goodness is a "set function" that assigns scores to subsets of items.

This unifying view of subset selection problems opens ways for common computational techniques to solve these problems. Yet, as some readers may remember from a basic class in computational complexity, the problem of selecting a "good" subset can be notoriously difficult.

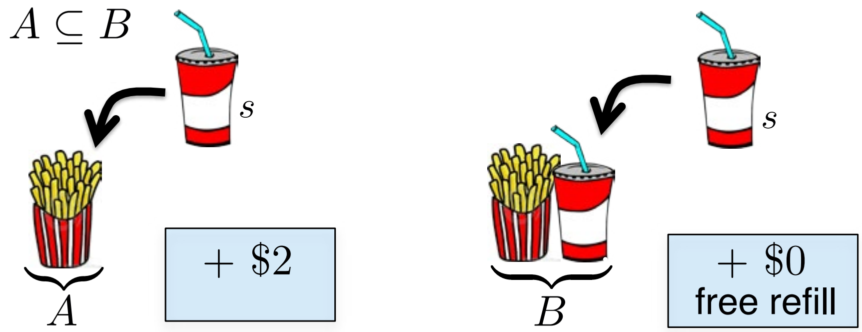
But the above examples (and many others) share another important property: the combinatorial concept of submodularity or, in simpler language, diminishing returns. This property says that the more we have, the less we gain from an additional item. **Figure 1** shows the problem of placing sensors to maximize information[1], in two situations: (a) adding a new sensor to a small set of existing sensors, or (b) adding the same sensor to a larger set of existing sensors that includes the previous ones. The additional information gained from the new sensor in (b) is never larger than in (a). The submodularity of information equally plays a role when covering news articles, summarizing videos and image collections, or identifying informative queries to pose to a human expert. Similarly, submodularity underlies our recent methods for finding objects in a collection of images, with minimal required input[2]. Submodularity is not limited to utilities: it also occurs in everyday cost functions, as the "free refill" in **Figure 2** demonstrates. Here, it expresses notions of "economies of scale."

Submodularity has long been known in combinatorial optimization, information theory, game theory, graph theory, and related fields[3]. The benefits of submodularity for machine learning have been emerging only recently. But what is special about this property, other than its perhaps surprising occurrence in a wide range of problems? This property, as simple as it may appear at first, brings along a rich mathematical structure. This structure is the foundation for computational procedures with quality guarantees for the obtained solution, one of the goals mentioned above. Phrasing machine learning problems in the language of submodularity makes it possible to exploit this beneficial structure.

If, for instance, the measure of goodness (e.g., information) that we maximize exhibits diminishing returns, then a simple greedy strategy implies guarantees on the solution. A submodular cost or loss function can be optimized by building on results in continuous (convex) optimization, achieving an optimal solution. Connecting these insights to machine learning and its application has offered a theoretical explanation for the empirical success of several "heuristics".

The properties of submodular functions do not only explain existing heuristics. Importantly, they also inspire new models and methods. **Figure 3** illustrates another example from our work in computer vision[4].

At the same time, these developments and the demands of machine learning applications pose new challenges to established theory.



$$F(A \cup \{s\}) - F(A) \quad \geq \quad F(B \cup \{s\}) - F(B)$$

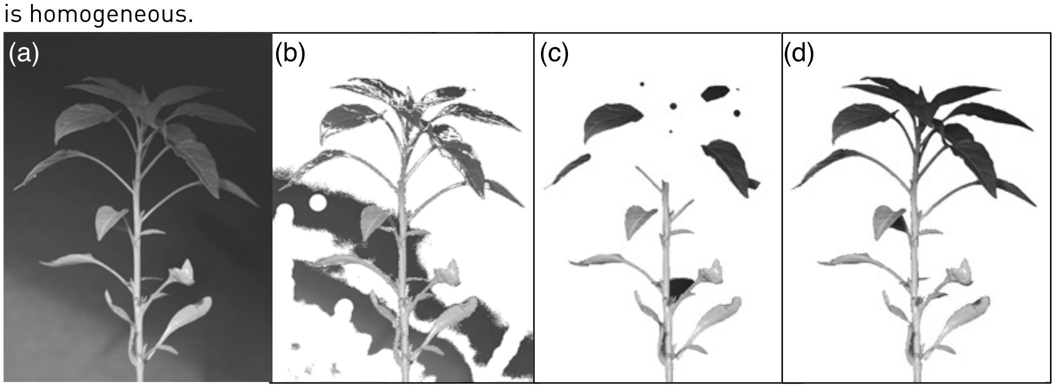
Figure 2: Submodular costs.

Are there practically efficient, scalable algorithms that retain the desired theoretical guarantees on realistic data sets? After all, diminishing returns often imply nontrivial, nonlinear dependencies between the items of interest, such as the interplay of information measured by different sensors, or correlations between different parts of a visual object. By carefully exploiting mathematical properties, we were able to devise parallel algorithms for submodular problems that indeed scale to large data, while retaining all desirable guarantees[5,6].

Moreover, new uses of submodularity, such as the example in Figure 3, give rise to new problem settings that are no longer addressed by existing methods. In recent work, we developed practically efficient algorithms for solving such problems. Besides computer vision, our algorithms have been used for tasks as diverse as the facilitation of diffusion in social networks, or aerial exploration.

While for problems like the example in Figure 3 no efficient algorithm can always guarantee an optimal solution here[4,7], empirical and initial theoretical results reveal a curious discrepancy: often, the empirical results are much better than the theory predicts. Our work helps close this apparent gap, by showing how to distinguish an "average" case from the worst case, and quantifying how often we are guaranteed to obtain much better solutions than in the worst case scenario[8].
These results indicate that identifying and exploiting submodularity in machine learning opens avenues towards more accurate mathematical models for making sense of data, and towards practically scalable algorithms with quality guarantees for a spectrum of tasks. While these observations indicate new directions of theory and applications, they are only one example of exploiting mathematical structure in combinatorial machine learning problems. We are working on exploiting such structure. Indeed, the confluence of disciplines and viewpoints often has increasing returns.

Figure 3: Example application: segmentation. (a) Input image; (b) segmenting by color; (c) classical model: neighboring pixels tend to have the same label (foreground/background); (d) new model from submodularity: diminishing marginal penalties if the boundary of the object is homogeneous.



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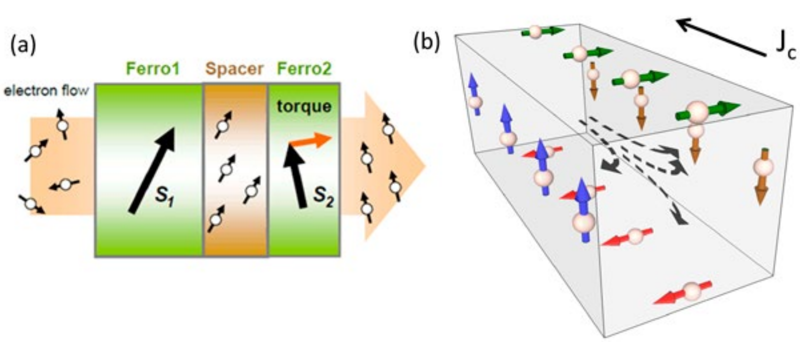
Spin orbit electronics: From heavy metals to topological insulators

By Luqiao Liu, Assistant Professor, Mircrosystems Technology Laboratories

The high power consumption of computational electronic devices has become one of the major obstacles that prevents further improvement of their performance. Conventional electronic devices utilize electron charge to represent and store information. Therefore, Joule heating related energy dissipation always exists in these operations. A potential approach to reduce the power consumption is to use a spin-based device, in which the basic operation is conducted through the flipping of electrons' spin rather than the motion of their charge. Spintronic devices also have advantages in non-volatility and scalability. Over the past decades, extensive studies have been carried out to utilize spintronic devices for memory, logic, and microwave applications.

One of the key prerequisites to create low power spintronic devices is to find a mechanism that can switch electron spins efficiently. Conventionally, in order to write the information into a bit represented by electron spins, one has to apply a magnetic field. The magnetic field can usually be generated from a current-carrying coil. The necessity of a large dissipative charge current undercuts any energy gain through the transition from charge to spin. Moreover, the nonlocality of the current-induced magnetic field also made it impossible to scale the devices into small dimensions. About fifteen years ago, it was discovered that besides magnetic field, spin polarized charge currents can also be used to switch electron spins, or more precisely, the moment orientation of a nanomagnet[1,2]. In the tri-layer structure shown in Fig. 1(a), when conduction electrons go through a ferromagnetic electrode their spins will be aligned along the direction of the local ferromagnetic moment, due to the spin-spin interaction. If the moment orientations of the two ferromagnetic electrodes are not parallel with each other, the conduction electrons will transfer their spin angular momentum onto the local ion, when they go from one electrode towards the other. The discovery of this current-induced magnetic switching effect (also known as spin-transfer torque effect) made it possible to manipulate magnetic moments locally and efficiently. Based on this mechanism, a non-volatile memory — spin-transfer torque magnetic random access memory (STT-MRAM) — is currently being developed by many computer memory manufacturers.

Figure 1: (a) Schematic illustration of the spin transfer torque mechanism in a ferromagnet/nonmagnetic spacer/ferromagnet tri-layer structure. The open circles with arrows represent the spin orientation of conduction electrons while the bold arrows illustrate the magnetic moment orientation of the two ferromagnet layer. (b) Illustration of the spin generation from spin Hall effect. Arrows with different colors represent the spin orientations at different surfaces.



While the spin-transfer torque effect provides a convenient way for controlling the magnetic moment orientation electrically, the limited conversion efficiency from a charge current into a spin current still makes it difficult to replace the existing devices (particularly memory devices) with the new ones. Recently we discovered that besides the tri-layer structure shown in Fig. 1(a), spin-transfer torque could also be realized in a much simpler system, where there are only one ferromagnetic layer and one non-magnetic layer[3,4]. Here, the generation of the spin-transfer torque is due to an effect known as "spin Hall effect," which can be understood as a spin version of the well-known "Hall effect." In the spin Hall effect, up and down spins, rather than positive and negative charges, get deflected towards different surfaces in the transverse direction as they move along the longitudinal direction (**Figure 1(b)**). More fundamentally, the deflection of different spins originates from the spin orbit interaction in solid crystals. In this non-magnetic layer, because of the spin Hall effect, excessive spins will accumulate at the interface when a longitudinal charge current is applied. Those accumulated spins will exert influence onto the ferromagnetic electrode that is in contact with them, which can further reorient the magnetic moment direction therein. With this spin Hall effect induced torque, we and other researchers have demonstrated that various types of magnetic dynamics such as magnetic switching[4-6], persistent magnetic oscillation[7,8], ferromagnetic resonance[3] and magnetic domain wall motion[9,10] could be realized. In particular, a three terminal magnetic memory device is shown in **Figure 2**, where the switching of the magnetic moment is realized through the spin Hall effect and the reading is via the tunneling magnetoresistance effect.

The biggest advantage associated with using spin orbit interaction to control the magnetic moment orientation lies in the fact that theoretically no upper limit exists for the charge current to spin current conversion efficiency. Empirically, one can use the "spin Hall angle" to quantify the efficiency, which is defined as the ratio between the spin current density $2e/\hbar \cdot J_s$ that flows vertically into the FM electrode and the charge current density J_c that is applied longitudinally. Here, *e* represents the electron charge and $\hbar$ is Plank's constant. In principle, using spin orbit interaction, the ratio between those two current densities can be far above one, while in contrast, this value can only go up to one in the spin filtering effect shown in **Figure 1(a)**. In order to fully optimize the spin orbit interaction induced torque and to reduce the power consumption, a material with a large effective spin Hall angle is highly desirable. Recently it was realized that topological insulators could provide such capabilities[11-13]. Topological insulators are a new category of materials that were discovered only a few years ago. In their bulk, they exhibit insulating behaviors while on the surface, they behave like metals. Particularly, their surface states are spin polarized, meaning that a longitudinally flowing current will naturally lead to spin accumulation at the surfaces (see **Figure 3(a)**). Roughly, the topological insulators can be viewed as a quantum limit of the spin Hall effect discussed above, similar to the relationship between the quantum Hall effect and the ordinary Hall effect. Therefore, theoretically topological insulators would have the highest charge-to-spin conversion efficiency among the spin Hall effect in other material systems. Previously, we experimentally determined the spin current generation efficiency in two typical topological insulators, Bi_2Se_3 and (Bi,Sb)2Te3, using a spin polarized tunneling technique[14,15]. As is shown in **Figure 3(b)**, it was discovered that several orders of magnitude improvement has been achieved in the effective spin Hall angle through the utilization of the topological insulators. This increase in the effective spin Hall angle indicates that the needed switching current can be lowered correspondingly. In the same figure, we also listed the corresponding resistivity of the studied materials. As the power consumption is given by $I^2 \cdot R$ (Joule's law), one can see that the decrease of the critical current in topological insulators is only partially cancelled by the increase of resistivity when calculating the power. A reduction of almost 600 times in energy dissipation is expected by going from heavy metals to topological insulators.

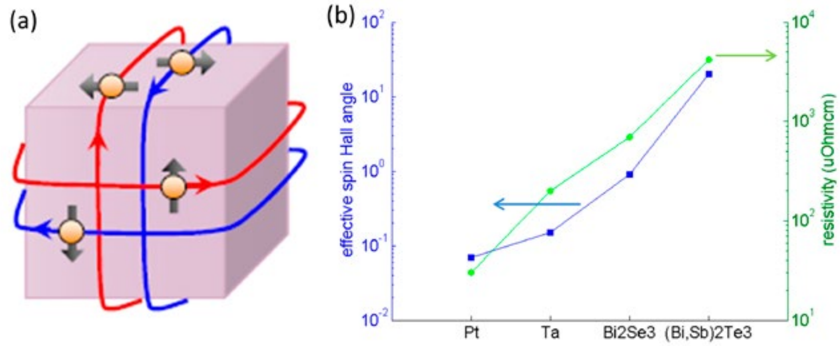
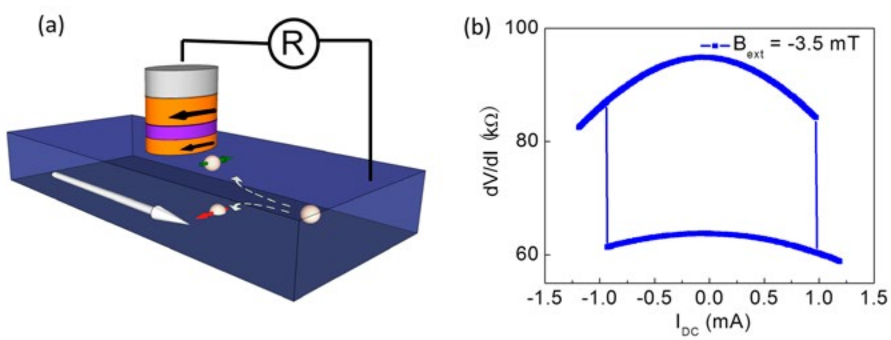


Figure 3: (a) Schematic illustration of the spin polarized surface states. (b) Effective spin Hall angle (blue square) and resistivity (green circles) of typical heavy metals and topological insulators obtained from spin polarized tunneling experiment. The data in this figure are from ref [15] and [14].

While it is possible to largely reduce the energy cost for magnetic switching by utilizing topological insulators, several difficulties still exist in directly combining topological insulators with a ferromagnetic electrode. One of the issues is the mismatch of impedance in those two materials. As one can tell from their names, topological insulators are in nature insulators or semiconductors, which have very high resistivity compared with ferromagnetic metals. Most of the current will be shunted through the ferromagnetic metal layers if an electrical voltage is applied across along the ferromagnetic metal/topological insulator bilayer film, which will dissipate large amount of energy. A ferromagnetic film which has similar impedance with topological insulator will be highly desirable to fully exploit the spin generation efficiency. Recently it was discovered that a magnetic oxide or antiferromagnetic oxide[16] could be potentially used as a buffer layer between topological insulator and ferromagnetic metal. Those oxides, while being insulating to charge flow, allow spin currents to transmit through them with little resistance. By integrating this extra layer into the device shown in Figure 2, we believe that spintronic devices with ultralow power consumptions could be finally achievable.

Figure 2: (a) Schematic of device geometry used to switch magnetic moment of ferromagnet with spin Hall effect. (b) Spin Hall effect induced magnetic switching as is detected by the change in the magnetoresistance of the magnetic tunnel junction.



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A Quantum Internet of Things

Connecting quantum memories for new applications in computing, communications, and precision measurements

By Dirk Englund, Jamieson Career Development Assistant Professor of Electrical Engineering and Computer Science, Research Laboratory of Electronics

From an engineering perspective, quantum mechanics seems like a nightmare at first sight. It's impossible to predict how a system will behave or even to measure it without changing it. But it turns out that quantum mechanics also opens up entirely new applications that would be impossible in a classical world. Over the past decades, an improved mastery of quantum phenomena has given rise to new fields of "quantum technologies."

There are two concepts underpinning these technologies **(Figure 1)**. The first is the superposition principle: a system can exist in all possible states at the same time. For example, whereas in a classical world a coin with sides labeled "0" and "1" can only be in one state at once, a "quantum coin" can be in both states simultaneously (though it is "collapsed" to one possible outcome when measured). Two quantum coins can be in four states (superpositions of 00, 01, 10, and 11) simultaneously, three coins in eight states, etc. The size of the superposition grows exponentially with the number of particles. Recording the amplitudes of an arbitrary superposition of just 60 quantum coins would require more than a million terabytes on a classical computer.

Realizing Feynman's Dream: Quantum Simulation and Computing

This exponential increase in complexity makes even small systems of interacting particles impossible to model. We have the equations, but we cannot solve them. But there is a possible solution: we could try to simulate a hard quantum problem by mapping it onto a controllable quantum system in the laboratory. This is the concept of a "quantum simulator," proposed originally in 1981 by Richard Feynman[1].

It's now possible to construct quantum systems with enough (individually controllable) quantum particles, such as trapped atoms, that they are virtually impossible to be modeled classically. In coming decades, such quantum simulators could solve important many-body quantum problems — e.g., to model high-temperature superconductivity or perform *ab-initio* design of materials or pharmaceuticals.

A more general version of a quantum simulator is a quantum computer, which has additional requirements beyond the simulator. A general-purpose quantum computer could not only simulate any classical computer efficiently, it could also perform quantum simulations and run other algorithms more efficiently than known classical-computer algorithms (including database searches, machine learning tasks, and prime number factorization).

Quantum Measurement

The second unusual idea about quantum mechanics is the so-called "No-Cloning Theorem": it is impossible to copy an unknown quantum state. Measuring any quantity comes down to reading a probe, such as a magnetometer, which is ultimately a quantum system. Measuring the quantum probe projects it into one of several possible final states, a process that has inherent uncertainty and noise. One may hope to skirt this projection noise by repeatedly measuring clones of the state, but that would violate the no-cloning theorem. Quantum mechanics places hard limits on how precisely we can measure, and we may long for a simpler classical-physics world that allows perfect measurements. But, quantum technologies are being developed that at least allow us to measure close to the physical limits. Indeed, the field of quantum metrology has produced the most precise measurement instruments devised by humankind. Atomic clocks developed by the National Institute of Standards and Technology are so precise that they wouldn't lose a second over the age of the universe. Other types of sensors are improving navigation equipment and magnetic resonance imaging.

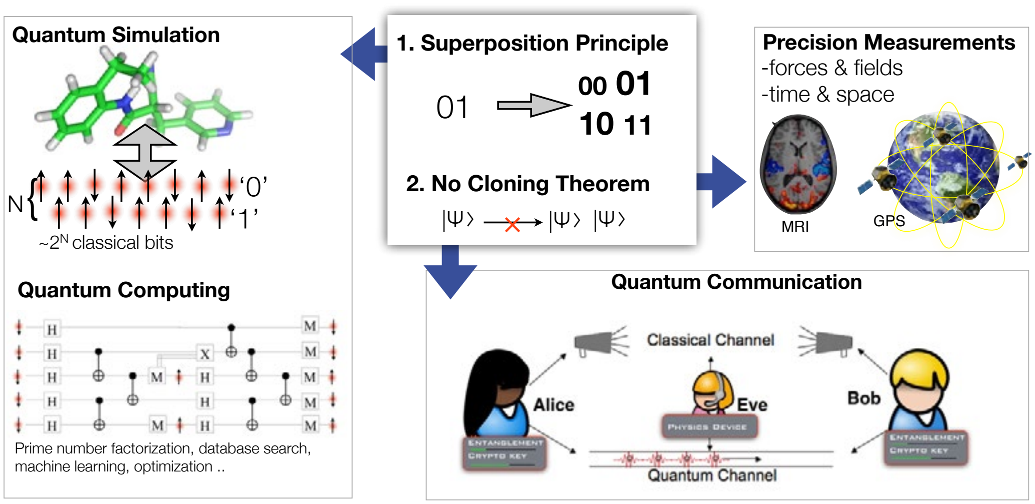

Figure 1: Quantum technologies make use of two central aspects of quantum mechanics: (1) The superposition principle — a system can be in all possible states at the same time; and (2) The No-Cloning Theorem — unknown states cannot be copied. Also shown are key quantum technologies being developed today: Quantum simulation and computing; quantum measurement; and quantum communications.

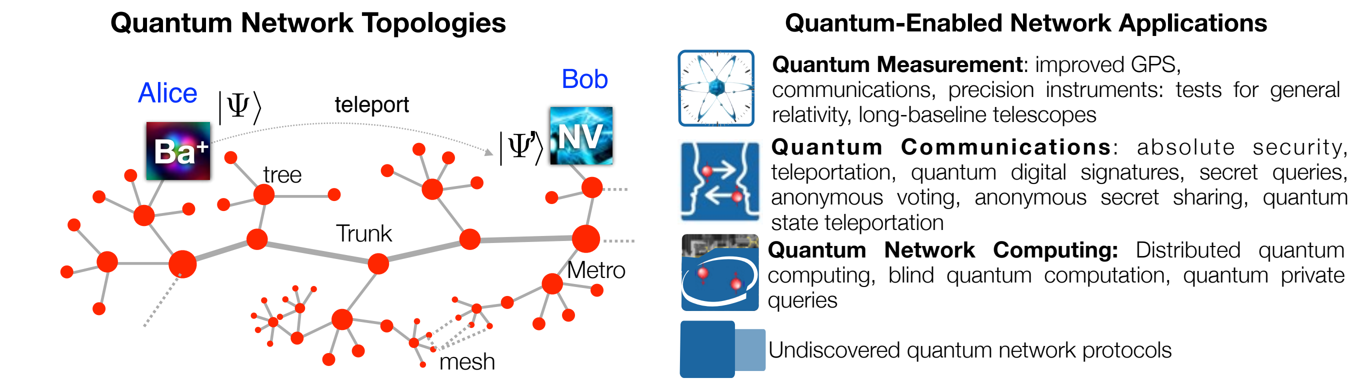

Figure 2: The quantum internet (left panel) will likely combine different network topologies, including the tree and mesh topologies shown here. It will link different types of quantum memory nodes, such as neutral atoms, trapped ions, and diamond color centers. By distributing entanglement to different users, such as Alice (with her Barium ion memories) and Bob (with his diamond spin memory), these users could, for example, teleport Alice's quantum probe |\Ψ→ to Bob. Other proposed network applications are listed on the right.

Quantum Communication

The No-Cloning Theorem also paves the way for secure communications. If two parties, Alice and Bob, send quantum states of light (photons) between them, then an eavesdropper, Eve, cannot measure these photons without also perturbing them. Alice and Bob, being paranoid cryptographers, ascribe all perturbances to Eve. If the perturbations are sparse enough, then Alice and Bob can upper-bound how much information Eve may have gleaned and erase it by classical privacy amplification codes. They end up with a cryptographic key of shared random bits, which allows for perfect encryption if used just once. This is an example of quantum key distribution (QKD). Unlike classical crypto-protocols, which rely on assumptions about the computational capabilities of an eavesdropper, QKD is secured by the laws of physics.

A Quantum Internet of Things

Today's Internet is so powerful because it combines computing, sensing, and communication. A "quantum network" — a network of stationary quantum memories (a memory for a quantum state) connected via photons — could do the same for quantum technologies, combining quantum computers/simulators, quantum communications, and quantum probes/measurements. It could combine these disparate quantum technologies as a kind of "quantum Internet of Things." A quantum network architecture is one way to build a "modular" quantum computer combining many well-controlled quantum memories. Alternatively, the memories could also be distributed between cities, connected via fiber-optic cables. The primary function of such a quantum network would be to distribute entanglement across distributed network users. Suppose Alice in Atlanta and Bob in Boston each have one quantum coin of an entangled pair. Measuring these qubits would result in random, but correlated, outcomes, which Alice and Bob could use as cryptographic key. Entangled states in a quantum network could also be used as resource for teleporting unknown quantum states. These states could encode local measurements that are optimally measured together at one location; this could be useful, for example, for long-baseline astronomical telescopes[3]. **Figure 2** lists several other applications that would be possible on a quantum network.

Building the Quantum Internet

So, how do we build the quantum internet? Many types of stationary qubit architectures are being investigated, including trapped atoms and atom-like defects in solids. Semiconductor quantum memories are particularly attractive for scaling and deployment, if Moore's Law for integrated ciruits is any guide. In particular, color centers in diamond have emerged as a leading contender for scalable and reliable qubits. Foremost is the nitrogen vacancy (NV) center in diamond, which consists of a nitrogen atom substituting for a carbon atom in the diamond lattice, adjacent to a lattice vacancy **(Figure 3)**. The NV has the desired properties of a quantum network memory: long spin coherence times in excess of one second, efficient two-qubit gates, and quantum error correction including non-destructive measurements and real-time feedback. In 2015, two NV centers were entangled over more than a kilometer[4], demonstrating an important step towards distributed quantum networks. But, challenges remain: we need to find ways to entangle qubits much faster (sub-millisecond), control tens to hundreds of NVs simultaneously, perform full error correction, and develop scalable fabrication and assembly processes.

At MIT, we are working on these problems at the intersection of physics and electrical engineering. A major goal is to develop a scalable "quantum memory node." Figure 2 lists several other applications that would be possible on a quantum network. This node requires high-quality NV quantum memories that couple efficiently to photons. We've recently taken the first steps in this direction, including efficient NV-photon interfaces in diamond optical cavities[5], techniques for scalable assembly of NV quantum memories on PICs[6], and ways to implant NV centers in diamond with nanometer scale precision[7]. Figure 3 shows an envisioned photonic integrated circuit (PIC) for controlling eight quantum memories, each consisting of several NV electron and nuclear spins. Multiple spins are needed to overcome qubit errors using quantum error correction by redundant encoding. Using our spin-photon interfaces, it should soon be possible to entangle electron spins and photons rapidly. Photons are routed on the PIC and measured jointly in a way that can entangle the respective on-chip quantum registers of on-chip quantum registers, or they are sent out into the larger quantum network

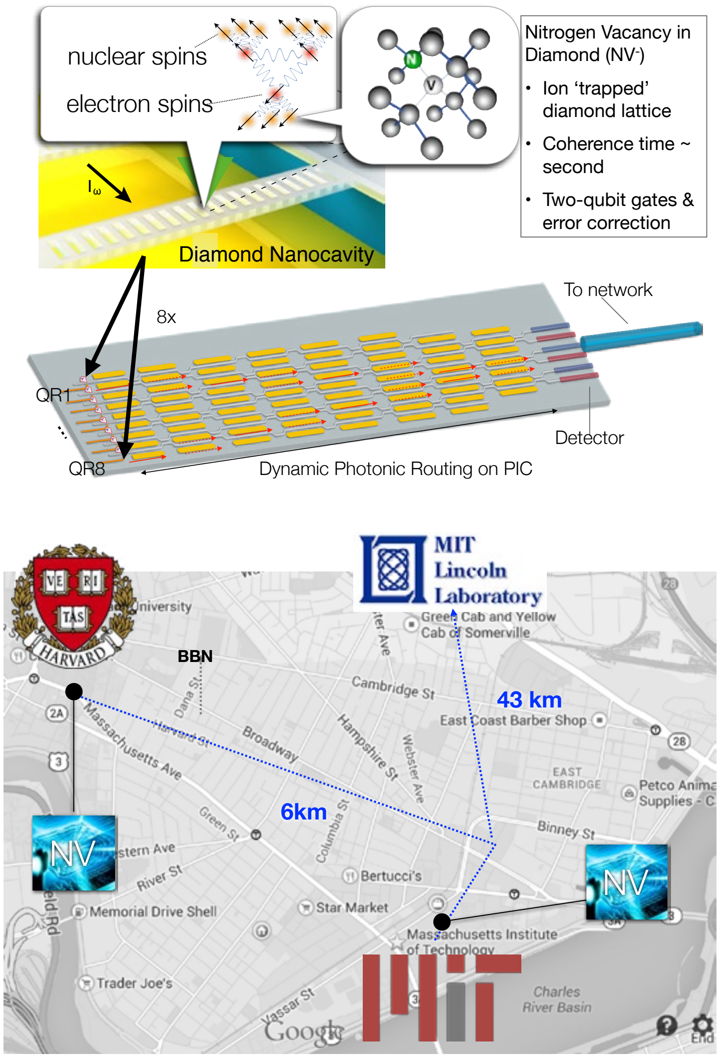

Figure 3: Top: A proposed quantum node consisting of eight diamond quantum memories, each consisting of three NV centers. Each NV has one electron spin memory coupled to multiple nuclear spins. Multiple spins are needed for error correction. The PIC routs NV photoemission for on-chip detection (and heralded entanglement) or into the network. Bottom: Installed dark fiber links in the Boston area. QKD is generating key between MIT and Lincoln Laboratory. NV-quantum memories are coming online at MIT and Harvard (Mikhail Lukin, Marko Loncar, and Hongkun Park groups).

for entanglement with remote quantum memories (up to a few tens of kilometers). Our work at MIT, together with collaborators at Harvard and Lincoln Laboratory focuses on these quantum nodes, the photonic circuits, sensors, other quantum network components, as well as the system architecture.

Many experimental and theoretical challenges still must be overcome to identify these challenges and find solutions, there's no better way than to actually build a prototype network. This is what we've started over the past years. Figure 3 (bottom panel) shows a testbed network linking MIT to Harvard University in Cambridge (6 km by buried fiber) and to MIT Lincoln Laboratory in Lexington, MA (43 km by optical fiber). The fiber optic links are "dark" — there's no regular optical traffic over them — which reduces spurious photons in our spectrum. The links are designed for light near 1.55 µm wavelength, where fiber attenuation is minimized. Because most quantum memories couple to photons at shorter wavelengths, wavelength conversion techniques are required. This step is technically challenging, but has the upside of forcing all disparate types of quantum registers to interface at a common wavelength — an important step towards standardization of quantum networks. As of 2016, this network supports QKD with a secure key rate exceeding 1 Mbit/sec between Lincoln Laboratory and MIT's main campus (not bad compared to some cable companies!). The next big step is to bring the quantum memories online.

Other teams around the globe are also beginning to build early stage quantum networks. Over the next years, it will become increasingly feasible to efficiently link qubits and to distribute entanglement across larger and larger networks, and we've just seen the first glimpses of what such networks could enable. In retrospect, engineers and scientists of the early days of quantum mechanics didn't need to be so gloomy. The aspects of quantum mechanics that seemed so upsetting at first sight actually turned out to be pretty amazing.

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IDSS conversations: Guy Bresler

By Jennifer Donovan, IDSS

Guy Bresler. Photo: Lillie Paquette.

Guy Bresler joined the MIT faculty in September 2015 as the Bonnie and Marty (1964) Tenenbaum Career Development Professor in the Department of Electrical Engineering and Computer Science (EECS). He also joined the Institute for Data, Systems, and Society (IDSS) — which addresses complex societal challenges by advancing education and research at the intersection of statistics, data science, information and decision systems, and social sciences — as a member of the Laboratory for Information and Decision Systems (LIDS). Bresler's research investigates the relationship between combinatorial structure and computational tractability of high-dimensional inference in graphical models and other statistical models. His current work focuses on learning graphical models from data, and explores how both data and computation requirements can be reduced if the model is subsequently used for a specific inference task. Bresler is also interested in applications of these methods, especially to recommendation systems and computational biology. Bresler spoke with IDSS about his work and being part of both LIDS and IDSS.

Q. You describe your research interests in largely theoretical terms — combinatorial structure, computational tractability, high-dimensional inference. How would you explain your work to those not in the field?

A. The basic question in most of machine learning and much of statistics is: How do you come up with a good model for some phenomenon you're observing? There are a lot of models out there and a lot of complicated phenomena. Learning more complicated models generally requires more data. As I get more data, can I get a better sense of what's a good model within a given class? The problem with very complex models is that learning requires too much data. The idea is that if you have some intuition about what the right model is for what you're observing, you can narrow things down. One type of model I've been interested in is graphical models. The concept of "graph" is pretty basic to a lot of the things I'm interested in. In a graphical model you have a bunch of points representing variables and some of them interact so you draw an edge, or line, between them, and some of them aren't connected. When learning the model, the goal is to understand what's influencing what. Such graphs can represent many things, among them social networks, for example, or gene regulatory networks.

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Q. Are you working on particular applications right now?

A. I'm interested in several different application domains. One application domain I'm getting more involved in now is genomics. You want to predict, for example: If I knock out this gene in your DNA sequence, what effect is that going to have on the expression of these other genes? In order to make such a prediction, one can first learn a model for how these genes are interacting, and that's done from data. Certain types of graphical models seem fairly well suited to this problem.The basic causal prediction question comes up everywhere, and the hope is to come up with statistical methodology that is as universally applicable as possible. It's useful to try and focus on one application at first, and actually validate things experimentally. Part of this genomics work we're just starting now with Caroline Uhler [EECS], Philippe Rigollet [Mathematics], Jon Kelner [Mathematics], and Aviv Regev [Biology]. Aviv Regev's lab can do single-cell experiments where we can knock out genes or change the expression of the one gene. So we can take it full cycle: learn models from a bunch of data that only she can produce for us using statistical methodology that we'll develop, and then we can then go validate to see: Did we do a good job?

Q. Why did you choose to make LIDS and IDSS your intellectual home?

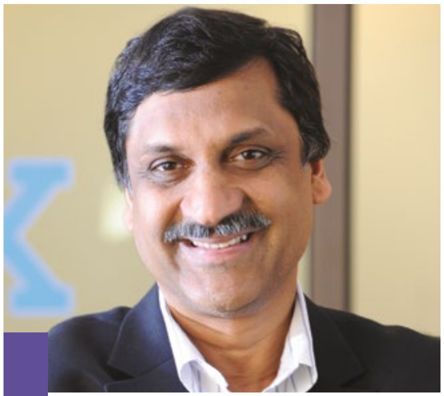
A. LIDS is a wonderful place where people have a lot of freedom to think about challenging and interesting problems. It has this great combination of scholarship coupled with drive and curiosity; a great mix of theoretical work with engineering and systems motivation. It's definitely a place where I feel really happy. And IDSS — It's super exciting what's happening. There's a steadily growing critical mass of people working on related questions, which creates a lot of energy. This builds on MIT's heritage and strength in areas such as computation and control theory. For instance, Philippe Rigollet's work has helped change the way we think about some statistical problems and how they interplay with computational questions. To me certainly that's one of the most exciting things: how much interaction there is already and I think will continue to be between statistics and other fields.

Q. Is the policy and social science aspect of IDSS of interest to you?

A. I think having social science be part of IDSS is fantastic. If everybody is a theoretician it's possible to get a bit detached from the real world, so it's crucial to have domain areas where we want to make a big impact and IDSS is doing this. But even purely from the theoretical point of view, many interesting theoretical questions are motivated by practical constraints.So I think that in terms of having impact on the world, there's a lot of potential to do that with the right mix of people at IDSS. It's something that may be more difficult within a single department; it's harder to bring together that group of people from different backgrounds. Trying to have a big positive impact on the world, it's awesome to have this as one of the driving visions of IDSS.

FACULTY FOCUS

Elfar Adalsteinsson
American Institute for Medical and Biological Engineering College of Fellows



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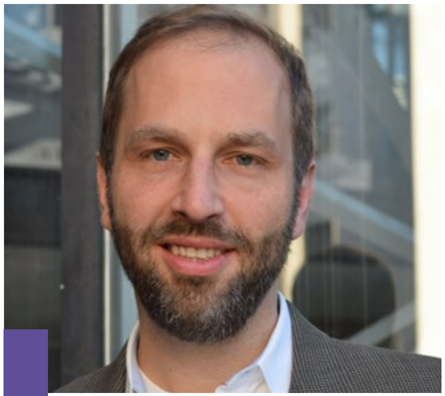
Harold W. McGraw Hill, Jr. Prize in Education

Dimitri Antoniadis
Jun-Ichi Nishizawa Medal
IEEE Electron Devices Society George E. Smith Award

Bonnie Berger
American Institute for Medical and Biological Engineering College of Fellows
Ecole Polytechnique Federale de Lausanne honorary doctorate



Karl Berggren
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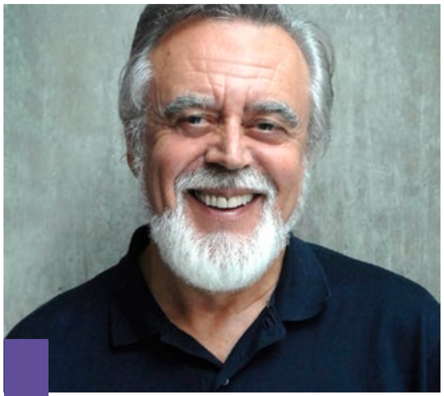
Forman Team Engineering Excellence Award



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2015 Heinz Award for Technology, the Economy, and Employment
Fellow of the National Academy of Inventors

Anantha Chandrakasan
KU Leuven honorary doctorate

Konstantinos Daskalakis
Research and Development Award by the Vatican Guiseppe Sciacca Foundation

Jesus Del Alamo
Doctor Honoris Causa at Universidad Politécnica de Madrid

Erik Demaine
Nerode Prize
U. of Waterloo Faculty of Mathematics Young Alumni Achievement Medal

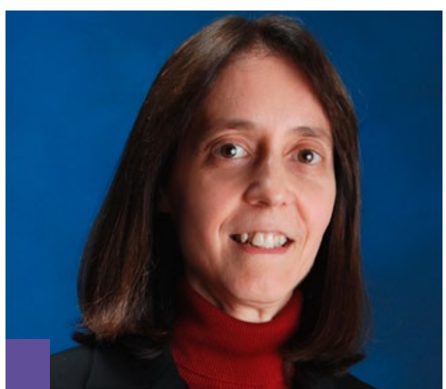
Srini Devadas
2015 A. Richard Newton Technical Impact Award in Electronic Design Automation
MacVicar Fellow

Mildred Dresselhaus
Honorary doctorate, ETH (Swiss Federal Institute or Technology) Zurich; Honorary doctorate, Tohoku University; IEEE Medal of Honor

Yoel Fink
Collier Medal

David Forney
IEEE Medal of Honor

Shafi Goldwasser
U. of Haifa honorary doctorate
Barnard College honorary doctorate
Honorary member of the London Royal Mathematics Society



Judy Hoyt
IEEE Electron Devices Society George E. Smith Award

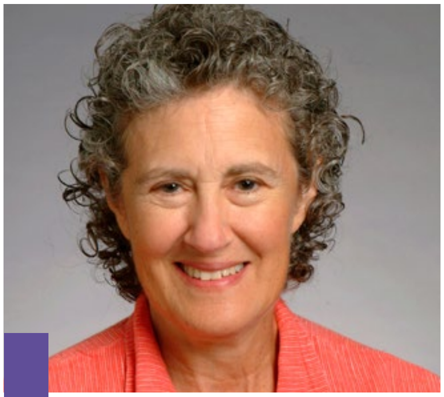
Piotr Indyk
ACM Fellow

Stefanie Jegelka

NSF Faculty Early Career Development Award
Deutscher Mustererkennungspreis
Google Research Award

Charles Leiserson

2015 SIAM Fellow
IEEE Fellow
Elected to the National Academy of Engineering



Barbara Liskov

2015 Weizmann Women & Science Award

Tim Lu

ACS Synthetic Biology Young Investigator Award; Biochemical Engineering Journal Investigator Award; Kenneth Rainin Foundation Innovator Award for Microbiome Engineering

Aleksander Madry

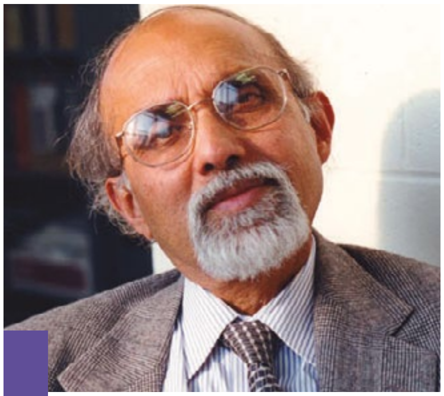
Sloan Research Fellowship
NSF Faculty Early Career Development Award

Muriel Medard

IEEE WICE Outstanding Achievement Award

Silvio Micali

Cryptography Test of Time Award



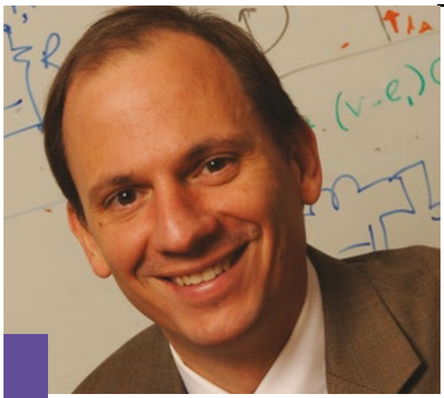
Sanjoy Mitter

Foreign Fellow of the Indian National Academy of Engineering

Pablo Parrilo

IEEE Fellow

Li-Shiuan Peh
2016 Singapore Research Professor



David Perreault
2015 IEEE Power Electronics Society R. David Middlebrook Achievement Award

Rajeev Ram
IEEE Fellow

Ron Rivest
Institute Professor

Devevrat Shah
INFORMS Revenue Management and Pricing Prize

Charles Sodini
HKUST Fellow Award

Michael Stonebraker
2014 ACM A.M. Turing Award

Vivienne Sze
2016 3M Non-Tenured Faculty Award

Russell Tedrake
Received NASA's Valkyrie robot

John Tsitsiklis
2016 ACM Sigmetrics Achievement Award

Caroline Uhler
Doherty Professor in Ocean Utilization

Matei Zaharia
2014 ACM Doctoral Dissertation Award

Lizhong Zheng
IEEE Fellow

Victor Zue
AAAS Fellow

Three faculty receive Faculty Research Innovation Fellowships

Three 2015–2016 Faculty Research Innovation Fellowships (FRIFs) have been awarded to EECS faculty members. The FRIF was established in 2011 to recognize midcareer faculty members for outstanding research contributions and international leadership in their fields. The FRIF provides tenured faculty with resources to pursue new research and development paths, and to make potentially important discoveries through early stage research.

Polina Golland, professor of electrical engineering and computer science, has been named a Frank Quick Research Innovation Fellow, a fellowship created through generosity of EECS alumnus Frank Quick '69, SM '70. Golland leads the Medical Vision Group in CSAIL where she focuses on novel techniques for biomedical image analysis and understanding. She builds computational models of the anatomical and functional variability within populations, and develops methods to detect and characterize changes in those distributions under the influence of development or disease. Her models give insight into the functional organization of the brain and into the causes of its variability. Her group releases open-source software packages for wide impact and dissemination.

Manolis Kellis, professor of computer science, has been named the EECS Research Innovation Fellow. Kellis leads the Computational Biology Group in CSAIL, and works to further our understanding of the human genome by computational integration of large-scale functional and comparative genomic data sets. He led an NIH group that created a map of the human genome, a step toward a global map that could be used in understanding fundamental processes and diseases in humans.

Jongyoon Han, professor of electrical engineering, as well as biological engineering, has been named a Frank Quick Research Innovation Fellow. Han is a principal investigator in the Research Laboratory of Electronics. His recent research focuses on molecular and cell separation/sorting technologies, as well as novel use of various types of ion selective membranes. Professor Han's ongoing research interests revolve around the application of micro and nanofabrication technology to a wide range of applications, including the molecular separation and concentration, biosensing, cell manipulation and separation, neuroscience and technology, and even desalination.

Chandrakasan named Vannevar Bush Professor

Anantha P. Chandrakasan has been appointed to the Vannevar Bush Professorship, effective November 1, 2015. The Vannevar Bush Professorship is an Institute-wide professorship established in 1982 as a memorial to one of the most outstanding scientists and engineers of the twentieth century, who was also MIT's first Dean of the School of Engineering. Previous chair holders include Gerald L. Wilson, Subra Suresh, and Ronald L. Rivest. Currently the Joseph F. and Nancy P. Keithley Professor of Electrical Engineering, Chandrakasan is widely known for his landmark 1992 IEEE Journal of Solid State Circuits (JSSC) paper entitled "Low-Power Digital CMOS Design," which brought the concept of a power-efficient chip to reality in what was to become the second-most cited paper in the history of the JSSC, the leading publication in the field.

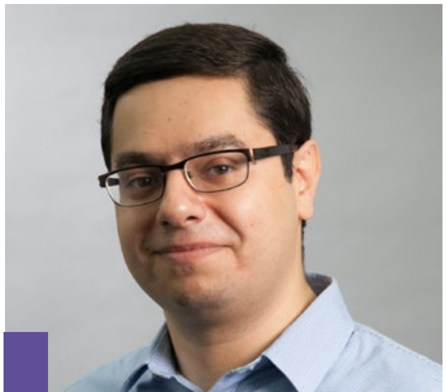
Ozdaglar named Keithley Professor

Asuman Ozdaglar, professor of electrical engineering and computer science, has been appointed to the Joseph F. and Nancy P. Keithley Professorship in Electrical Engineering. Ozdaglar and collaborators have made several key contributions to optimization theory, ranging from theoretical work in convex analysis and duality to distributed and incremental algorithms for large scale systems. Ozdaglar has focused a large part of her research on integrating analysis of social and economic interactions into the study of networks. Her work spans many dimensions of this area including learning and communication, diffusion and information propagation, and influence in social networks. Another example of her impact in this area is the framework she has developed for studying cascades and systemic risk in economic and financial networks. Ozdaglar continues to make key contributions to game theory including learning dynamics and computation of Nash equilibria in continuous games. She has been recognized by these communities as a leader in this new and emerging field and has won key awards, including the prestigious Donald P. Eckman Award. She was also recognized at MIT with the award of the inaugural Steven and Renee Finn Fellowship. She is the co-author of the book entitled "Convex Analysis and Optimization" together with Dimitri Bertsekas and Angelia Nedich.

Freeman named Perkins Professor

William T. Freeman has been appointed the Thomas and Gerd Perkins Professor of Electrical Engineering and Computer Science. Freeman co-developed a theoretical explanation of the surprising performance of the belief propagation algorithm in networks with loops, and found theoretical guarantees for the algorithm's performance with Gaussian graphical models. He brought belief propagation into the computer vision community, where it is now a common technique, used to solve inference problems in Markov random fields. He has also introduced data-driven methods for super-resolution from single images, now widely employed. In recent years, he co-developed motion magnification, a technique to visualize small motions, which has application in many engineering and science domains. For example, this has been used to visualize motions caused by sounds in the tectorial membrane, to show the vibration patterns of novel meta-materials, and to reveal complex motions of the throat during vocalization. Freeman has received several outstanding-paper awards at computer vision and machine learning conferences, and test-of-time awards for papers from 1990 and 1995. He served as the program co-chair for the International Conference on Computer Vision (ICCV) in 2005, and as the program co-chair for Computer Vision and Pattern Recognition (CVPR) in 2013.

New Career Development Chairs



Mohammad Alizadeh
TIBCO Career Development Chair

Guy Bresler
Bonnie and Marty (1964) Tenenbaum Career Development Professor

Michael Carbin
Jamieson Career Development Professor

Luqiao Liu
Robert J. Shillman Career Development Chair

Aleksander Madry
NBX Career Development Chair

Matei Zaharia
Douglas T. Ross (1954) Career Development Professor of Software Technology

Palacios is new director of 6-A Master of Engineering Thesis Program

Tomás Palacios, assistant professor of electrical engineering and computer science, became the new director of the VI-A Master of Engineering Thesis Program, effective July 1st, 2015. Palacios succeeded Markus Zahn, the Thomas and Gerd Perkins Professor of Electrical Engineering, who stepped down as director of the VI-A Program on June 30th, after more than 20 years of leadership.

New Faculty

Guy Bresler

Bresler is an assistant professor in the Department of Electrical Engineering and Computer Science at MIT, and a member of LIDS and IDSS.

Previously, he was a postdoc at MIT and before that received his PhD from the Department of EECS at UC Berkeley.

He seeks to obtain engineering insight into practically relevant problems by formulating and solving mathematical models. Concretely, he wants to understand the relationship between combinatorial structure and computational tractability of high-dimensional inference in the context of graphical models and other statistical models, recommendation systems, and biology.

Michael Carbin

Carbin joined MIT as an assistant professor in January of 2016. His research interests include the theory, design, and implementation of programming systems, including languages, program logics, static and dynamic program analyses, runtime systems, and mechanized verifiers. His recent research has focused on the design and implementation of programming systems that deliver improved performance and resilience by incorporating approximate computing and self-healing. His research on verifying the reliability of programs that execute on unreliable hardware received a best paper award at a leading programming languages conference (OOPSLA 2013). His undergraduate research at Stanford University received the Wegbreit Prize for Best Computer Science Undergraduate Honors Thesis. As a graduate student at MIT, he received the MIT Lemelson Presidential and Microsoft Research Graduate Fellowships.

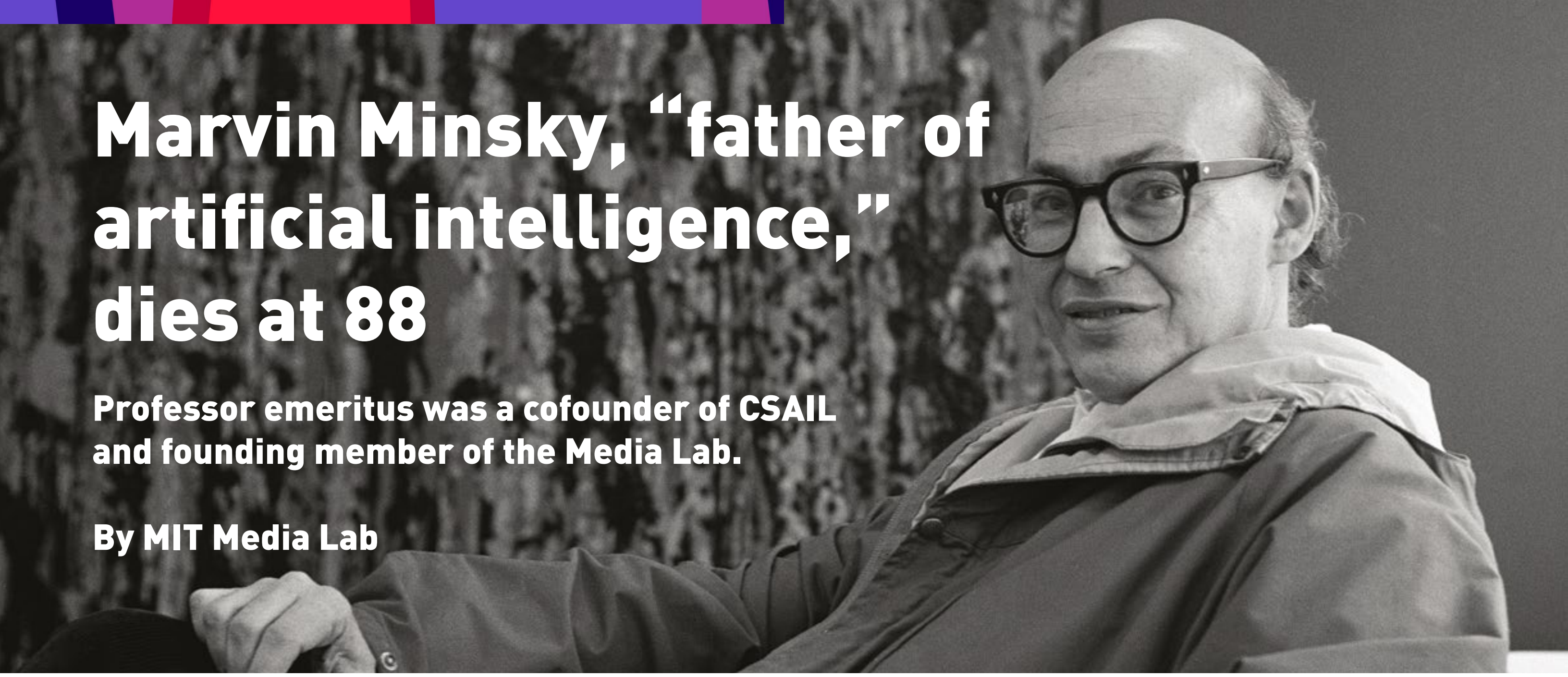
Luqiao Liu

Liu joined EECS department at MIT in July 2015 as an assistant professor. He has also joined MTL as a core member and a resident member, with his lab and office in Building 39. He received his BS in physics from Peking University, Beijing, in 2006 and his PhD in applied physics from Cornell University, Ithaca, NY, in 2012. Prior to joining MIT, he was a research staff member in the magnetic random access memory (MRAM) group of IBM T. J. Watson Research Center. Professor Liu's research focuses on exploring new materials and mechanisms that can be used as building blocks for spintronic devices, which operate at high speed with low power consumption.

Caroline Uhler

Uhler joined MIT as the Henry L. & Grace Doherty Assistant Professor, Ocean Utilization; Assistant Professor, Electrical Engineering and Computer Science in October, 2015.

After completing a master's degree in mathematics and a bachelor's degree in biology at the University of Zurich, Prof. Uhler received a PhD in statistics from UC Berkeley in 2011. After postdoctoral appointments at the Institute for mathematics and its applications in Minneapolis and at ETH Zurich, Prof. Uhler joined IST Austria in 2012. In 2013 she participated in the semester program on Big Data at the Simons Institute at UC Berkeley.



Marvin Minsky, "father of artificial intelligence," dies at 88

Professor emeritus was a cofounder of CSAIL and founding member of the Media Lab.

By MIT Media Lab

Marvin Minsky, a mathematician, computer scientist, and pioneer in the field of artificial intelligence, died at Boston's Brigham and Women's Hospital on Sunday, Jan. 24, of a cerebral hemorrhage. He was 88.

Minsky, a professor emeritus at the MIT Media Lab, was a pioneering thinker and the foremost expert on the theory of artificial intelligence. His 1985 book "The Society of Mind" is considered a seminal exploration of intellectual structure and function, advancing understanding of the diversity of mechanisms interacting in intelligence and thought. Minsky's last book, "The Emotion Machine: Commonsense Thinking, Artificial Intelligence, and the Future of the Human Mind," was published in 2006.

Minsky viewed the brain as a machine whose functioning can be studied and replicated in a computer — which would teach us, in turn, to better understand the human brain and higher-level mental functions: How might we endow machines with common sense — the knowledge humans acquire every day through experience? How, for example, do we teach a sophisticated computer that to drag an object on a string, you need to pull, not push — a concept easily mastered by a two-year-old child?

"Very few people produce seminal work in more than one field; Marvin Minksy was that caliber of genius," MIT President L. Rafael Reif says. "Subtract his contributions from MIT alone and the intellectual landscape would be unrecognizable: without CSAIL, without the Media Lab, without the study of artificial intelligence and without generations of his extraordinarily creative students and protégés. His curiosity was ravenous. His creativity was beyond measuring. We can only be grateful that he made his intellectual home at MIT."

A native New Yorker, Minsky was born on Aug. 9, 1927, and entered Harvard University after returning from service in the U.S. Navy during World War II. After graduating from Harvard with honors in 1950, he attended Princeton University, receiving his PhD in mathematics in 1954. In 1951, his first year at Princeton, he built the first neural network simulator.

Minsky joined the faculty of MIT's Department of Electrical Engineering and Computer Science in 1958, and co-founded the Artificial Intelligence Laboratory (now the Computer Science and Artificial Intelligence Laboratory) the following year. At the AI Lab, he aimed to explore how to endow machines with human-like perception and intelligence. He created robotic hands that can manipulate objects, developed new programming frameworks, and wrote extensively about philosophical issues in artificial intelligence.

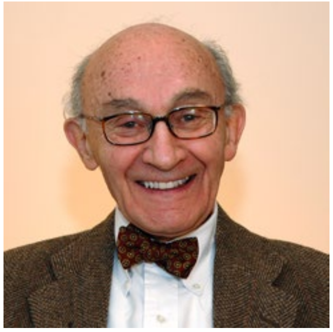
In 1985, Minsky became a founding member of the MIT Media Lab, where he was named the Toshiba Professor of Media Arts and Sciences, and where he continued to teach and mentor until recently.

In addition to his renown in artificial intelligence, Minsky was a gifted pianist — one of only a handful of people in the world who could improvise fugues, the polyphonic counterpoint that distinguish Western classical music. His influential 1981 paper "Music, Mind and Meaning" illuminated the connections between music, psychology, and the mind.

Minsky received the world's top honors for his pioneering work and mentoring role in the field of artificial intelligence, including the A.M. Turing Award — the highest honor in computer science — in 1969.

In addition to the Turing Award, Minsky received honors over the years including the Japan Prize; the Royal Society of Medicine's Rank Prize (for Optoelectronics); the Optical Society of America's R.W. Wood Prize; MIT's James R. Killian Jr. Faculty Achievement Award; the Computer Pioneer Award from IEEE Computer Society; the Benjamin Franklin Medal; and, in 2014, the Dan David Foundation Prize for the Future of Time Dimension titled "Artificial Intelligence: The Digital Mind," and the BBVA Group's BBVA Foundation Frontiers of Knowledge Lifetime Achievement Award.

Remembering EECS Faculty



Abraham (Abe) Bers ScD '59, professor emeritus of electrical engineering, died on Friday, Sept. 11, 2015 at the age of 85. Bers was known for his accomplishments in the field of plasma physics and for his contributions as an educator. A principal investigator in the Research Laboratory of Electronics (RLE) and the Plasma Science and Fusion Center, he joined the MIT faculty in 1959 after earning his BS at the University of California at Berkeley in 1953, his MS at MIT in 1955, and his ScD at MIT in 1959. At MIT, Bers collaborated with physicists, electrical engineers, and nuclear engineers studying nuclear fusion as a power source. Together with Professor Richard Briggs, Bers made the first classifications of plasma wave instabilities in the 1960s. Together with Professor Jean-Loup Delcroix of the University of Paris, he authored the two-volume "Physique des Plasmas," written in French, in which he was fluent. A longtime teacher of 6.651/8.613 (Introductory Plasma Physics I), In the final months of his life, Bers completed a textbook, "Plasma Physics and Fusion Plasma Electrodynamics," to be published by Oxford University Press this spring. Bers held numerous patents, was a fellow of the IEEE, and a member of the American Physical Society.

Frederic Richard "Rick" Morgenthaler '55 (VI-A), SM '56, PhD '60, professor emeritus of electrical engineering and computer science at MIT, died on June 21, 2015 at the age of 82. Morgenthaler was an accomplished researcher and educator, who spent his long career at MIT studying the theory and applications of electromagnetism. Born on March 12, 1933 in Cleveland, Ohio, Morgenthaler trained as an electrical engineer at MIT, completing an SB, and then an SM in 1956. He began his research in the field of nonreciprocal microwave ferrite devices while serving in the United States Air Force from 1957-1959. He joined the MIT faculty the same year. Morgenthaler led the Microwave and Quantum Magnetics Group in MIT's Research Laboratory of Electronics (RLE), where his research focused on the theory underpinning the propagation of electromagnetic waves, and its numerous practical applications. He also served as Graduate Officer from 1993-1996. Morgenthaler was a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) and the author of over 100 scientific publications. He held the Cecil H. Green Professorship for 1984-1986. After his retirement in 1996, he continued to teach as a senior lecturer until 2000.

William M. Siebert, professor emeritus, passed away Sunday, Oct. 25, 2015 at the age of 89. Siebert, the Ford Professor of Engineering emeritus, was widely known for his contributions to long-range radar. As the leader of the Radar Techniques Group at MIT Lincoln Laboratory in the early 1950s, Siebert produced the first system capable of simultaneously measuring a target's range and velocity. This would earn him the 1988 IEEE Aerospace and Electronic Systems Society Pioneer Award for "contributions to pulse-compression techniques for radar systems."Born in Pittsburgh in 1925, Siebert joined the MIT faculty after completing his BS in 1946 and his ScD in 1952, both at MIT. His 1985 textbook, "Circuits, Signals, and Systems," based on his decades of experience teaching introductory signals and systems courses, is now considered a standard in undergraduate teaching. His vision informed the creation of EECS's MEng program, and throughout the 1990s he served on the curriculum committee that designed the program. Siebert was a Fellow of the IEEE, and was the Ford Professor of Engineering from 1984-1994. He retired from MIT in 2000 after teaching as a senior lecturer for several years.

John Wyatt '68, who served as a professor of electrical engineering for 36 years, passed away at home in the company of his family on Wednesday, Feb. 3, 2016. He was 69. Wyatt was a devoted researcher who spent decades developing retinal implants to restore sight to people affected by age-related macular degeneration and retinitis pigmentosa, the two leading causes of blindness worldwide. An expert in circuits, his work focused on developing a chip that could be implanted in the retina to transmit visual information to the optic nerve. A native of Nashville, Tennessee, Wyatt received a BS from MIT in 1968, an MS from Princeton University in 1970, and a PhD from the University of California at Berkeley in 1979, all in electrical engineering. He joined the MIT Department of Electrical Engineering and Computer Science (EECS) faculty in 1979, and retired in June 2015. In 1989, he cofounded the Boston Retinal Implant Project with Joseph Rizzo of the Harvard Medical School and the Massachusetts Eye and Ear Infirmary, where he led the engineering team. In 1990, Wyatt was appointed EECS's first Adler Scholar. Named for Richard B. Adler, a professor of electrical engineering and computer science and a friend of Wyatt's, the appointment allows MIT faculty to take a class for one semester as a student.

Education News

Katherine Young (center), a sophomore enrolled in 6.S04, works with Prof. Srini Devadas on one of 6.S04's software labs. Photo credit: Audrey Resutek

A LEARN-BY-DOING APPROACH TO CODING

New class 6.S04 (Fundamentals of Programming) aims to lay a strong foundation for learning computer science.

By Eric Smalley, MIT EECS

The computer science major, a.k.a. Course 6-3, was the most heavily enrolled major in the Institute with 594 undergraduates in the 2015-2016 academic year. The major has grown rapidly over the last several years, and with this growth CS faculty noticed students were starting out with a range of programming experience.

Some students entering the major already had experience as programmers, whereas many others were underprepared for introductory classes such as 6.01 (Intro to EECS I) and 6.005 (Software Construction), says Srini Devadas, the Edwin Sibley Webster Professor of Electrical Engineering and Computer Science. CS faculty recognized that it was time to give students a solid foundation in programming. In response, they have developed 6.S04 (Fundamentals of Programming), a new course focused exclusively on programming ability.

"The teaching staff collectively saw an opportunity to improve the entire curriculum by addressing the programming ability gap early and thoroughly," said Ilia Lebedev, a CS PhD candidate and Head Teaching Assistant.

The new class was developed by Lebedev, Devadas and Associate Professor of Electrical Engineering and Computer Science Adam Chlipala. The class was piloted last semester with 42 students, and has an enrollment of 106 this semester.

"This class is about blank-slate programming. Given a specification, write an implementation. We think of it as a gym class. You jump in and you do stuff. We think of ourselves as being the trainers and the laboratories are the training exercises."

—Srini Devadas, Edwin Sibley Webster Professor of Electrical Engineering and Computer Science

6.S04 is part of a series of classes designed to step students from one level to the next in an unbroken staircase. One of the beginning classes, 6.01, is being redesigned to focus more on the basics of programming than previously, and is designed to accommodate students with arbitrary backgrounds, said Chlipala. Students with no programming background can alternately take 6.0001, an established class that teaches rudimentary programming, to prepare for 6.S04, which in turn will better prepare students for 6.005.

Introductory level computer science courses in general are under pressure to teach students skills they can use immediately, such as Java, to help them land internships. This can be at odds with the mission of laying a strong foundation for learning computer science, said Lebedev. "We compromised by teaching the class in Python, a popular language used all over, and focusing on developing the students' programming and problem-solving skills, which will help them get more out of the curriculum," he said.

Function over form

Software has many dimensions of quality: performance, algorithm and data structure choice, security, usability, clarity and maintainability, decoupling and interface design, said Rob Miller, Professor of Electrical Engineering and Computer Science and instructor for 6.005. "But the very first step is being able to write something that actually works and does what it's supposed to, functionally," he said. "That's what 6.S04 focuses on."

The defining principle of 6.S04 is write a lot of code. "This class is about blank-slate programming," said Devadas. "Given a specification, write an implementation. We think of it as a gym class," he said. "You jump in and you do stuff. We think of ourselves as being the trainers and the laboratories are training exercises."

The course teaches students good principles of design indirectly by giving them good examples. Students aren't assessed on the readability or performance of their code. Grading is based on whether the program gives the right output for particular inputs. "If your code is way too verbose and cluttered, chances are it's not going to work properly," said Devadas.

The core of the coursework in 6.S04 is weekly labs. Each assignment requires students to write a functioning program, one that does something the students might find interesting. The lab assignments this semester are:

- a Pandora-like music service
- an image filter
- a degrees-of-separation mapping
- a real-time physics simulation
- a solution to a tent packing problem
- path collecting the maximum number of coins on a grid
- a text auto completer
- a route planner that avoids left turns
- a variation of the board game Clue
- a variation of the arcade game Breakout

Students learn a particular programming concept in the once-a-week lecture and then apply the concept in that week's lab. The programming concepts include distance functions, matrix transforms, loops and control flow, recursive search, trees and linked data structures, and hybrid data structures. The labs are designed to produce programs with well-defined behavior that can be unambiguously assessed as working or not.

Lebedev built a user interface for the course based on the Chrome browser so the students can see their programs working, which helps them debug the programs. The only software required for the course is Python 2.7 and Chrome, which means the students can work off-line and with any operating system they choose.

Grading and auto grading

The 10 laboratory assignments make up 40 percent of the total grade. The remaining 60 percent of the total grade comes from three exams. The exams are reduced-scope versions of the problems the students work on in the laboratory assignments. Students are allowed to fix and resubmit their code over the weekend following each exam. They can earn additional credit in proportion to how close they came to the correct solution at the end of the timed exam.

The instructors have developed an elaborate auto grader to evaluate the student's work. The auto grader decouples evaluation from instruction. The result is the auto grader becomes a well-quantified challenge for the students to overcome and the instructors are free to be the friendly 6.S04 staff, said Lebedev. "This allows us much greater access to help them when they struggle," he said.

The EECS department expects as many as 700 students to take the class each year, once it becomes a required course. One reason for the large enrollment is the class will be required for the forthcoming Computer Science minor, slated to begin in the fall. "6.S04 is well-positioned to become the definitive 'this class makes you a programmer' course, allowing other coursework to craft a more focused, more effective syllabus," said Lebedev.

EECS Launches Graduate Communications Lab

EECS launched the Communications Lab in the Fall 2015 semester to offer writing, speaking, and visual design support for scientists by scientists.

Our Communication Advisors are EECS graduate students and post-docs who have been trained rigorously so that they are both content experts and communication coaches. The EECS Communication Advisors are available to help EECS students, staff, and researchers, with individual coaching for any scientific communication task they are working on — from to publications to conference talks.

In addition to offering coaching, the EECS Communication Lab is developing a spring semester 6-credit communication course launched in February 2016.

The Communication Lab model was first piloted in MIT's Department of Biological Engineering in 2013 and replicated successfully in the Department of Nuclear Science and Engineering in 2014.

(Left) Ariela Slutsky, sophomore enrolled in 6.S04, works with (Right) Mayuri Sridhar, junior, 6.S04 teaching assistant, in one of the class's labs.

TOWARD BUG-PROOF SOFTWARE

Class teaches students how to apply new verification technologies to systems software

By Kathryn M. O'Neill

Might it be possible one day to build software that is provably free of defects? Last spring 14 MIT students gathered to pursue this "holy grail" of computer science in a Department of Electrical Engineering and Computer Science (EECS) seminar class called 6.888 (Certified Systems Software).

The class centered on code verification, a programming technique used to mathematically ensure that a system is error-free.

"I think verification has turned a corner. In the next five to ten years, we will see more verified system software. But, it will require a lot more research," said M. Frans Kaashoek, the Charles Piper professor of EECS and one of two instructors for the course. "Over the last three to four decades, there has been tremendous progress in building new tools to state and to prove the properties of real systems. One reason we taught the class was to try to use the new technologies and apply them to systems software."

Bringing students up to speed on verification programming languages and theory was the first challenge. "To get to the point where we can verify something interesting requires quite a bit of background. It requires you take one tool and master it," Kaashoek said, noting that he and his fellow instructor—Associate Professor Nickolai Zeldovich—offered a weeklong intensive class on the theorem-proving tool Coq during the Institute's Independent Activities Period in January to help students prepare for 6.888.

Then, during the spring term, students presented case studies each week from the small body of existing research on building verified systems. "There's not a book you can read about this topic," Zeldovich said, noting that the case studies enabled students to see what tools and approaches others have used to try to create verified systems. This investigation in turn informed the students' own strategies for developing provable software using such tools such as Coq, Dafny, and Bedrock. The key deliverable for the class was a research paper highlighting findings from the students' efforts to build verified systems. Students met one-on-one with professors each week to review their projects, which were intended primarily to advance the field rather than to develop practical skills. "It's not likely you'll go to a company and in five years be doing something like this, but [certified systems software is] a cool technology that's intellectually fascinating and the holy grail is there in the back of your mind—is it really true that we might build be able to build provably correct software?" Zeldovich said.

The possibility certainly intrigues the business world. Research that emerged from this class made headlines last summer, when media outlets Forbes and ComputerWorld reported on a successful effort to develop a file system that was mathematically proved error-free. The system built by the MIT team is not optimized for practical use, but it comes with a mathematical proof that it will not lose data in a crash—which is groundbreaking.

"We were first to build a file system that proves implementation meets specifications," said Kaashoek, noting that four EECS students worked on the project—graduate students Haogang Chen and Tej Chajed and undergraduates Daniel Ziegler and Stephanie Wang. In addition, the paper was co-authored by Zeldovich and EECS Associate Professor Adam Chlipala, whose research on the forefront of verification first inspired Kaachoek and Zeldovich to develop the class. The team's paper, "Using Crash Hoare Logic for Certifying the FSCQ File System," won a best paper award at the 2015 ACM Symposium on Operating Systems Principles in October.

Other research that emerged from the class included:

An effort to ensure that packet filters downloaded into the kernel is bug-free. This project addressed a fundamental cyber-security concern, since software downloads can serve as entry points for malicious code than can damage a computer's operating system (OS). Louis Sobel '14, MEng '15 endeavored to develop a verified compiler that generates provably correct code, which can then safely downloaded in the kernel.

A framework for verifying the security of various network protocols. Undergraduate Andres Erbsen addressed the challenge of how to prove that a network is safe from deliberate attack. For his project, Erbsen built a formal model of high-level cryptographic operations such as sign and verify using Coq and successfully proved that no action by an attacker could breach the model's security.

Both professors said the 6.888 seminar was enjoyable to teach because it was a small class focused on collaboratively exploring new avenues in systems software.

"We learned a lot about this field ourselves," Zeldovich said. "[This research] changes the way you think about building software and about the properties of systems."

Both professors said they expect research into systems verification to become increasingly relevant in the years to come. "The systems verification community has made so much progress that the question is, are we at an inflection point? I think the answer is yes," Kaashoek said, though he admitted that real-world applications were likely many years down the line. "Maybe in long run they'll be an undergraduate class [on this topic] that everyone takes, but we're far away from that point."

Science on Saturday

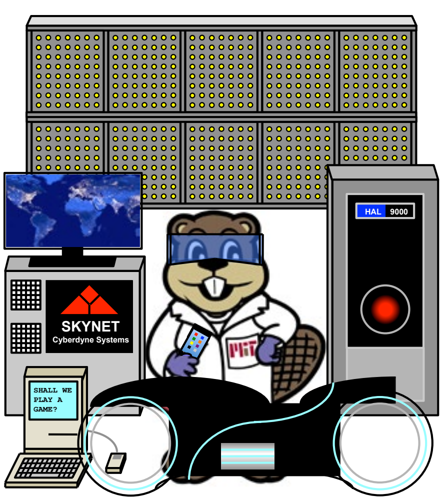
EECS faculty, staff, and students broke out their best circuits and computers demos for Science on Saturday, and event hosted by the department and the MIT Museum on Saturday, April 2.

Clockwise from top right: Vladimir Bulovic, the Fariborz Maseeh (1990) Professor of Emerging Technology and the MIT School of Engineering's Associate Dean for Innovation (center) invites a volunteer from the audience to touch an LED, which does not give off as much heat as a traditional incandescent light. Photo: MIT Museum.

William Freeman, Thomas and Gerd Perkins Professor of Electrical Engineering and Computer Science (far left) uses a tuning fork to demonstrate a "motion microscope" that can magnify tiny movements. Photo: Audrey Resutek, MIT EECS.

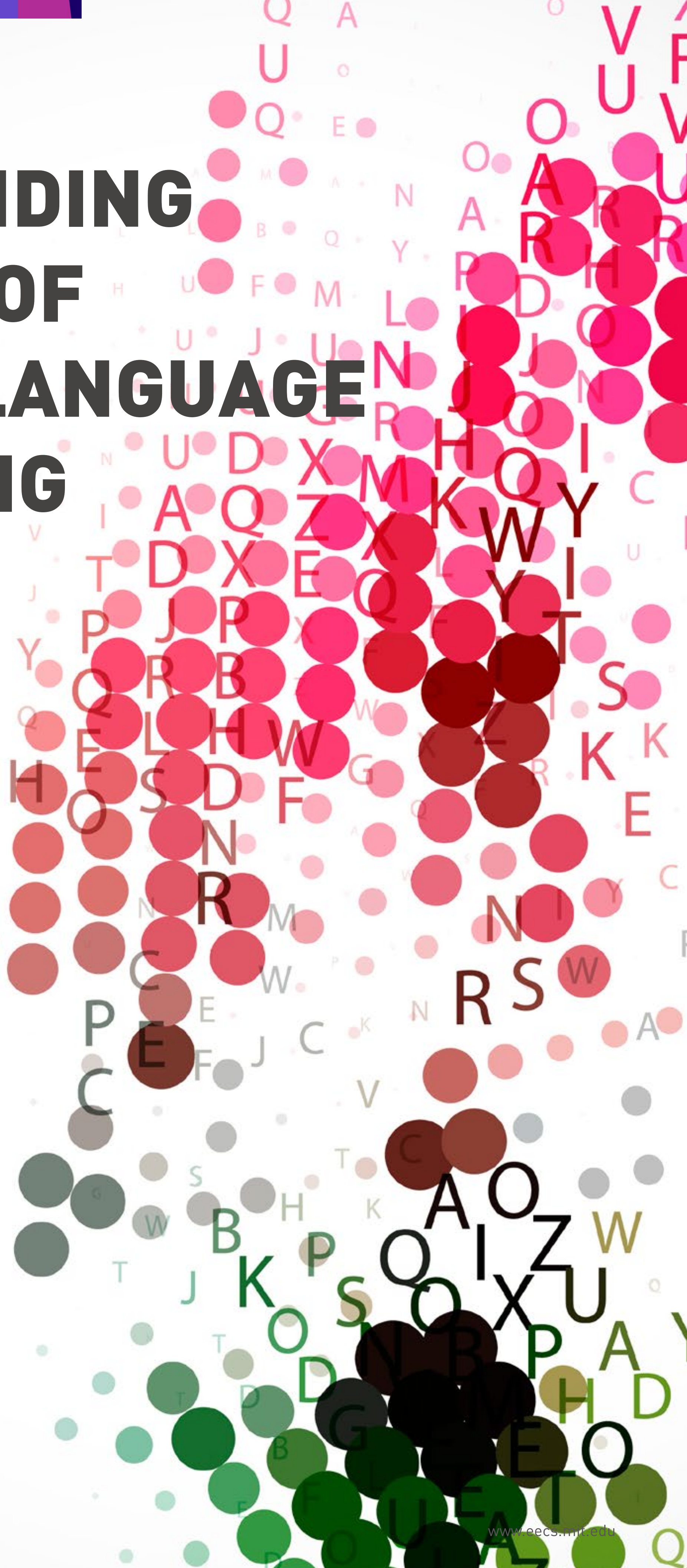
Senior Neerja Aggarwal demonstrates the MIT Edgerton Center's laser harp. The musical laser harp is an interactive music-making machine with an unusual mode of operation: more than a dozen bright red laser diodes paired with photo-resistors that act as break-beam sensors to trigger musical MIDI (Musical Instrument Digital Interface) output. Waving ones hands or an object inside the open space triggers musical notes in the melodious pentatonic scale and a fog machine enables one to see the red lasers in swirls of smoke. Photo: Audrey Resutek/MIT EECS.

Tim the beaver shows off his favorite demos.



THE EXPANDING UNIVERSE OF NATURAL LANGUAGE PROCESSING

By Stacey Resnikoff, MIT EECS



A newly revamped course, 6.806/6.864 (Advanced Natural Language Processing), is giving EECS students a deep-dive into the rapidly evolving field of natural language processing (NLP), which focuses on enabling computers to learn and understand human languages. The course, co-taught by Regina Barzilay and Tommi Jaakkola, both professors of electrical engineering and computer science, was updated last semester to include deep learning methods and a greater emphasis on student research.

"There is a paradigm shift in the field," says Barzilay, who has spearheaded 6.806/6.864 since 2004. "For the first time, we are incorporating deep learning methods in this course. Deep neural networks can actually learn representations and make semantic and linguistic connections in a very rich way."

"These are flexible machine learning tools with nearly limitless architectural variations," says Jaakkola, who lectures on deep learning. "NLP offers an exciting mixture of algorithmic questions, complex combinatorial structures, representational questions, and high-dimensional statistical estimation."

The course received a makeover in the Fall 2015 semester. Its new format puts increasing emphasis on student-driven research, with two-thirds of class time and 50 percent of the grade focused on student projects, supported by close faculty interaction. Students have flocked to the revamped course; last semester enrollment rose above 100 students, requiring Kirsch Auditorium instead of the 32-144 classroom.

Memory and Understanding

Surya Bhupatiraju, a junior in 6-3 and 18, recently decided Artificial Intelligence was his "calling" when he took 6.806/6.864. "It was a rather large milestone in my undergraduate career. Until this course, the extent of my NLP knowledge was understanding bag-of-word models and recurrent neural networks."

Bhupatiraju and fellow 6-3 junior Simanta Gautam developed their project "Non-Markovian Control Policies for Text-based Games using External Memory and Deep Reinforcement Learning," building on the 2015 work of TA Karthik Narasimhan. Like Narasimhan, they were interested in applying deep reinforcement learning framework to text-based computer games. Their goal: to teach a machine to play games not only in the present tense, but informed by past experience.

"We wanted to hook up memory networks to the model (and have it) extract certain memories that would seem most relevant or helpful (to) act," says Bhupatiraju.

For instance, the "player" might be told to go to a virtual room and repeat a previous task. Using a deep neural network, the machine could look back.

"Though game performance in explicitly non-Markovian (memory-based) policies was only barely better than the baseline model. It showed that there's a lot of potential to implement the full memory network module and use it to pick good memories," says Bhupatiraju.

Bhupatiraju says he and Gautam want to improve their model and "hopefully publish," as well as work on original NLP problems.

CRT Success

One ambitious project came at the suggestion of MGH physician Charlotta Lindvall, MD, PhD, who hoped NLP could predict the viability of invasive Cardiac Resynchronization Therapy (CRT) for heart failure patients.

Three undergraduates interested in medical data — 6-3 seniors Austin Freel, Josh Haimson, and 6-3 junior Michael Traub — worked with Lindvall on their project "Predicting the Effectiveness of

Cardiac Resynchronization Therapy Using Natural Language Processing" to harness insights behind vast quantities of data.

"I was very impressed by how quickly they grasped the extent of (the clinical) complexity and was moved by their motivation," says Lindvall.

"Most information about a patient is stored in narrative text clinical notes, which are not conducive to regression or proportional hazards models," explains Haimson. "Our n-gram bag-of-words models generated feature vectors (that) we could feed into machine learning classification models like Random Forests or Adaboost. One of the more sophisticated approaches we used, 'Paragraph Vectors,' is trained on a large unlabeled corpus of clinical text. Arbitrary length sequences of words (are mapped) to a fixed dimensional space, representing the semantic meaning of that text."

Their approach found latent clinical variables for the potential success of CRT, including symptoms (such as back pain, sleep apnea), primary diagnosis (ischemic/non-ischemic and ejection fraction readings prior to procedure), medication (beta blockers or nitroglycerin), and various social/family history features (marriage status or the father's morbidity status). The work is being prepared for publication in a clinical journal.

"I think we all hoped our work would have clinical significance, but once we started getting positive results we got very excited," says Haimson. He hopes the team's efforts will inform future CRT clinical support tools.

Exploring Expressions

Thanks to the course, Nicholas Locascio, a 6-3 senior, is now "extremely comfortable reading and evaluating the current NLP literature," as well as building on it.

He and his partner senior Eduardo DeLeon read the 2013 paper "Using Semantic Unification to Generate Regular Expressions from Natural Language" by Research Assistant Nate Kushman with Barzilay. Locascio and DeLeon and applied deep learning to machine-generate regular expressions without complex features engineering.

"Our model is a deep recurrent neural network that generates regular expressions character-by-character. It's quite 'data-hungry,'" says Locascio. "We were able to get in touch with Nate directly to ask about his code. He and Prof. Barzilay were cheering us on to try and surpass their original system's accuracy and performance."

While their model doesn't beat the Kushman/Barzilay state-of-the-art, Locascio, explains that "deep learning systems typically use hundreds of thousands (more) training examples" than they had, so the potential is there.

"I knew I wanted to do my MEng in Machine Learning and Artificial Intelligence," Locacsio says, "But I hadn't decided on working specifically in NLP until I took this class."

6.AcAd Advising Forum

EECS launched the 6.AcAd advising forum in Fall 2015 to give MEng and undergrad students quick access to authoritative answers to their questions about department curriculum, including courses, degree requirements, opportunities in the department and more. Hosted on the academic forum service Piazza, the "instructors" for the forum include the members of the Department's Academics and Advising Committee, the staff of the Undergraduate Office, peer advisors, and faculty volunteers.

A few questions recently answered on 6.Acad:

- Is it possible to substitute 2.009 for 6.UAP? (Submit a petition to do so)
- Can I work with my MEng supervisor over the summer? (Yes, as a research assistant)
- Can we stay in undergrad dorms if we have declared grad status? (Yes, if you keep your undergrad status too)

Deeply Dedicated

"Many students did projects using deep neural learning networks, and the topics were not trivial," says Barzilay, who along with Jaakkola, applauds the students' enthusiasm and ambition.

In fact, many students still come to group meetings and will continue their NLP research through UROP and UAP. Others have already submitted their papers for publication.

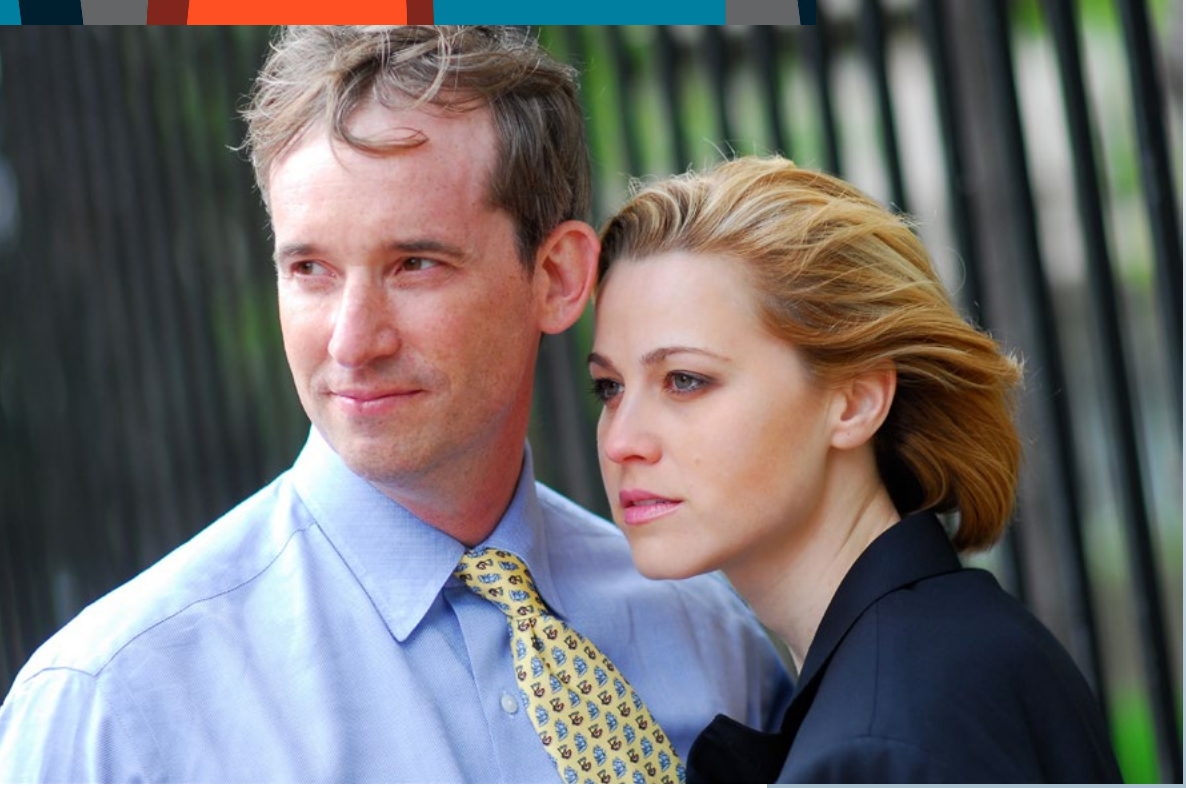
"For undergraduate students who took a three-month class to submit to our main conferences: this is remarkable," says Barzilay.

Students even volunteered in collaborative note-taking, earning a grade bonus as "scribes," capturing the immediacy of the outside-textbook content.

"The lectures and notes were incredibly well-organized considering the newness of concepts and techniques," says Haimson.

"Take the class," Barzilay tells all interested students, especially those who, like her, enjoy the thrill of the chase. "You don't know if you'll uncover the hidden puzzles in the text or not. But a model can unlock it. This is the exciting thing."

Alumni News



Colin Angle, '89, SM '91 and Erika Ebbel Angle '04 spoke with EECS about the mentors and experiences that have shaped their careers. Married since 2010, the couple is involved in a number of efforts aimed at sparking a love of science and research in the next generation of engineers, scientists, and entrepreneurs.

Colin Angle is the cofounder, CEO, and chairman of iRobot, which builds robots for home vacuuming (the Roomba), and for industrial and military uses. He studied 6-1 (electrical engineering) as an MIT undergraduate, and holds an MS in computer science from MIT.

Erika Ebbel Angle is the cofounder and CEO of Ixcela, a biotechnology startup developing diagnostic tests and natural interventions to improve gut microbiome efficacy and prevent neurodegenerative and cardiovascular diseases. Angle is also the founder and executive director of Science from Scientists. She studied chemistry as an MIT undergraduate and holds a PhD in biochemistry from the Boston University School of Medicine. In 2004 she was named Miss Massachusetts, and is the host of the Dr. Erika Show, an educational science TV show for children.

A conversation with Colin Angle and Erika Ebbel Angle

Engineer and biochemist alumni reflect on the importance of mentors, teaching entrepreneurship, and finding an intellectual home at MIT.

Q What sort of research did you do as undergraduates?

Colin: UROP played a huge role in my life. Between junior and senior year, on a bit of a whim, I interviewed for a UROP position at Rodney Brooks' robot lab. When I showed up there were 80 other students vying for the position. We were given a piece of paper and told to write down everything we had ever built. That was the interview. Ten minutes later probably a third of the people left. Twenty minutes later 80 percent of the people were gone. It might have been over an hour later I was still writing things on this piece of paper. For me it was this amazing realization that I might have found my place. I got the job, and my UROP project that summer was a small six-legged walking robot called Genghis. The creation of that robot began the partnership with Rod Brooks, which led to the formation of iRobot. I had always loved lab classes and building things, but working for Rod showed me that I could actually do this as more than a hobby. I also got access to using microprocessors for the first time. Also, I got access to different types of parts and motors that I'd only dreamed of being able to work with. This experience was my introduction to real research that I wouldn't have had until I was a graduate student.

Erika: The UROP that stands out the most for me was with Steve Tannenbaum, a professor of biological engineering studying the chemistry of nitric oxide in the body and its role in inflammation and disease. He gave me really good life advice at a time when I was trying to decide what to do. I had a variety of different skills and I was trying to choose between them and figure out how to allocate my time. He told me that to succeed you have to be able to focus your time, and put real energy into the things that you want to build and watch grow. Everything of value takes time to grow and cultivate. That was a message that stuck with me. There's still a rebellious side of me that is trying to do as much as it can possibly do, but within the context of, "if you don't spend time on something it will never work out, because all things of value take time to build." His advice also gave me good foundational knowledge. I was doing mass spectrometry work, which I then continued doing during my PhD.

Q You're supporters of EECS's SuperUROP program, which gives undergrads the opportunity to do a yearlong UROP. Why is this sort of experience important?

Colin: If all you do at MIT is show up and take classes, you've only just scratched the surface of what faculty can teach you. UROP and SuperUROP are an opportunity to interact with a professor on a different level, work with that person, do research, and find out what they have to offer. We're supportive of the SuperUROP program because it multiplies the value of going to MIT as an undergrad. There may have been other places I could have gone as an undergrad that would have given me a comparable education, but because of UROP and the opportunity it gave me to interact with Rod, my life has changed.

Erika: It's also so important for students to try different things while they're figuring out what they want to do for their careers. If you don't have any research experience, it helps you to determine if it's something that you want to do, while working with professors and getting their counsel and feedback. For me the UROP experience was an exploration of the various types of opportunities—different types of research, different types of people and personalities—that drove me to participate in it.

Q Erika, your company Science from Scientists puts scientists into classrooms to teach science to 4th to 8th graders. Why is early science education and mentorship so important?

Erika: There are countless data sets that show that children decide what they want to do, or at least what they don't want to do, by the time they've come through middle school. Those early formative years are so important because this is when self-discovery and confidence building occurs. If you don't get to that child at a very early age, you may completely lose your opportunity to strike any sort of chord with them. Science from Scientists specifically targets elementary and middle school students with the goal of improving interest and aptitude in STEM. We send real, charismatic, fun, cool scientists into classrooms every other week for the entire year to teach curriculum-relevant material that's hands-on, engaging, and exciting. We do this in collaboration with the classroom teachers, who may have limited backgrounds in STEM subject areas.

Q What inspired you to pursue science?

Erika: I had a 6th grade teacher who was in fact my English teacher. She stayed with us when there was a long field trip that I couldn't attend, and taught us everything from English to science. She had us reading books like Jurassic Park and Andromeda Strain and all sorts of other science books. Additionally we were doing basic science experiments that complemented our reading. It was because of that exposure that I became interested in science initially, and that got me involved in participating in science fairs. Once I started I was hooked. Along the way there were many others who worked with me. There was a director of a local public health laboratory who was my mentor for many years. Basically, any day I wanted to come and talk to him he was available in the late afternoons to help me and help me do my experiments. Mentorship is critical to inspiring students.

Colin: For me it was a lifelong love of building stuff. I was one of those kids where if you put me in front of a stream I would build a dam with a working gristmill. I just loved inventing. I went to MIT because I felt like it was a place where that type of attitude could find root. I would tell people, "I'm going to major in whatever lets me build the coolest stuff." At iRobot, this love of building physical things extended to a love of building companies, and everything that's required to take on even grander projects.

Q You're both founders of multiple companies. Why is entrepreneurship important, and where does it fit in an engineering education?

Colin: You actually get to build what you want to build! In all seriousness, entrepreneurship is not for everyone. It is very challenging. You have to be willing to put yourself out there, and put your finances and future at risk in a way that many people aren't excited to do. It's also a wonderfully empowering and exciting opportunity on which whole economies are built. However, we always have to remember that entrepreneurship isn't what we do if we cant get any other job; it's what we do if we truly have a deep-seated passion for it. That passion can be nurtured. That passion can be brought out in people who don't necessarily come into it with the confidence or even an understanding of what entrepreneurship is, but it can never be forced, required, or expected.

Q What advice do you have for people who are founding their own companies?

Erika: Entrepreneurship is not for everyone. I think there's a romance about being an entrepreneur that quickly fades when you become one. The challenge is that many of the skills that you need you don't necessarily learn at school. You don't take a class in people management skills, or in what to do after you've tried everything and nothing works. Mentorship and building a support network are critical to success. It's very hard starting a business alone as an undergrad. Even now, years after launching Science from Scientists and even Ixcela, I am still learning.

Colin: Don't do it alone. Whether it's a mentor group that you're hooked up with, or if you have some friends with prior experience, I think that it's critical that you have a support system where not everyone is soul-crushingly depressed on the same day.

Q If you could enroll in MIT again for a second undergrad degree, what would you study?

Erika: On the second go-around, I would try something different. I would major in music. I would study something artistically oriented.

Colin: Computer science. There is so much happening in the world of computer science with the cloud, and the Internet of things, I would love to get a 6-3 degree.

PUTTING THE PIECES TOGETHER

Alumna Katherine Yelick uses supercomputing to solve big problems.

By Audrey Resutek, MIT EECS

Katherine Yelick '82, SM '85, PhD '91 gives a guest lecture every year in an introductory computer science class at the University of California at Berkeley titled "How to Save the World with Computers."

In the talk, Yelick, a professor of electrical engineering and computer science at the university, explains how supercomputers are making it possible to answer questions that once seemed impossibly complex. These systems are used in an array of fields — from particle physics, to climate science, to biological engineering.

Researchers use the supercomputers in facilities like Lawrence Berkeley National Laboratory, where Yelick is associate laboratory director for computing sciences, to simulate complex systems or tackle massive data analysis problems. They can be used to simulate the Earth's climate, analyze the genomes of thousands of microbes living in a soil sample, or track stars in a simulation of the expansion of the universe.

An expert in the field of parallel processing, Yelick focuses on improving computing productivity and performance. She is the co-inventor of two parallel computing languages, UPC and Titanium, which are designed to let researchers take advantage of high performance computing techniques. One way they achieve this is by giving users a glimpse at features of the machine that are normally hidden.

"Programming languages are trying to give an abstraction for a machine in a way that is natural for people to think about when they're designing algorithms and writing software," Yelick says. "It's about trying to understand what details of the machine you can hide from the programmer and what characteristics you want to expose so they can get good performance out of their code by understanding that it has certain features, such as parallel processors or a hierarchy of memories."

Where a single processor performs computational tasks in order, completing the first task in a list before moving on to the next, parallel computing spreads tasks across many processors where they can be performed simultaneously. This division of labor is one the reasons, along with chip level improvements, that have dramatically enhanced performance over the last several decades. On average, supercomputers have gotten about 1000 times faster every decade.

For example, faster computers could allow climate scientists to build more detailed climate models. Currently, climate models can only approximate what is going on inside clouds; they do not resolve the processes inside them at fine scale. Having this information could allow scientists to make more accurate predictions about changes in precipitation, giving us insight into future droughts or flooding.

"The biggest question facing supercomputing today is, what are the problems we can't even anticipate that we'd be able to solve with a computer that's 1000 times faster," she says. "Over the history of computing, if you look all around us with web search and internet connectivity and applications on smartphones, it's hard to imagine what breakthroughs will come in the future if we can make computers faster and keep the cost and energy requirements in control.

Learning to love programming

As a freshman entering MIT, Yelick had been determined not to study computer science after an experience in a high school science project writing programs on paper tape soured her on the field. She grudgingly decided to take one computer science class, and to her surprise enjoyed it. She soon took another, and another.

"By the end of my freshman year I realized I really loved the process of programming," she says. "I loved thinking about algorithms and thinking about how you map problems onto computers and the abstractions of computation. Those first couple of classes really drew me into it."

Athletics also played a large role during Yelick's time at MIT. As an undergrad she was a member of the women's varsity rowing team, and spent a summer rowing on the US lightweight development team. Yelick went on to row as a graduate student as well, where she was coached by MIT Dean of Admissions Stu Schmill.

"I was not an athlete when I came to MIT. I don't think there are many schools where you can come in not an athlete and leave as one on a varsity team," she says.

Yelick went on to complete her graduate studies at MIT working with John Guttag, the Dugald C. Jackson Professor of Computer Science and Engineering. She first became interested in parallel computing as a way to make the automatic theorem proving tool that was the subject of her master's thesis run more quickly.

Parallel processing eventually became her primary research interest, and EECS awarded her the George M. Sprowls Award for best PhD Dissertation in 1991.

Finding connections

Yelick has also developed a number of applications that make use of recent computing advances.

At the University of California at Berkeley, she and her graduate student, Evangelos Georganas, are working with computational biologists on an application aimed at identifying the genomes of microbes in a soil sample. Identifying a single microbe is no easy task, since genome sequencers fragment genes and inject errors as they "read" them.

Yelick compares the problem to trying to assemble a jigsaw puzzle without any idea what the picture is supposed to look like, and with extra pieces thrown in and other pieces missing.

Instead of identifying a single organism, Yelick and her student are trying to identify all of the genomes in a soil sample, which can easily be home to thousands of microbial entities.

"Now, it's like you don't have just one puzzle, you have several puzzles mixed together, and you might have a thousand copies of one puzzle and only one copy of another puzzle, and still have the errors as well," Yelick says. "As you can imagine, the problem becomes very challenging."

The new application uses UPC, a dialect of the programming language C developed by Yelick and colleagues at multiple institutions to support high-performance computing on large-scale multiprocessors.

Yelick has been developing UPC for the last two decades. Now, she and her students are using it and related languages for data analysis and simulation problems at the front line of what computers can do.

"What excites me most has changed over the years. It used to be about the technical questions, or algorithmic questions in computing. And I still like that a lot," she says.

"Now, it's really about finding connections where you can use computing — algorithms, mathematics, computation — to solve important problems. The exciting thing is putting all of the pieces together."

Jamie Goldstein gives a talk on Startup basics at the 2015 IAP class Start6, the precursor to StartMIT. Photo: Gretchen Ertl.

BUILDING SOMETHING FROM NOTHING

Electrical engineering alum Jamie Goldstein reflects on starting companies, the entrepreneurial ecosystem, and giving back to MIT.

By Audrey Resutek, MIT EECS

For Jamie Goldstein '89, building things runs in the family. The Course 6-1 (electrical engineering) alum remembers that while he was growing up the conversation around the dinner table would invariably turn to talk of inventing.

"It was all about math and science and invention. We would always ask, 'why isn't there a product that does X' where X could be a problem big or small." says Goldstein, the founder of Pillar Companies and former Partner at North Bridge Venture Partners. "My dad even got a patent on something he prototyped with my Legos. So I knew I wanted to be involved with entrepreneurship and innovation right from the start."

Goldstein's job gives him what he describes as a front-row seat to cutting-edge shifts in technology. The entrepreneur-turned-venture-capitalist founded PureSpeech, Inc., in 1994 after getting his MBA from Harvard Graduate School of Business Administration. The company was acquired by Dallas-based Voice Control Systems Inc. in 1998 and subsequently acquired by Nuance.

Goldstein views himself as equal parts entrepreneur and investor. In addition to providing the financial backing for budding companies, Goldstein and his colleagues often help to craft and fine-tune ideas, help entrepreneurs think about what markets to pursue, and develop their value propositions.

"What I love about my job is that I get to help build something from nothing, but for a few companies at the same time. It's a great way to experience different technical areas in parallel," he says. "That is one of the things I got from MIT—a broad exposure to many domains in enough depth to understand companies whether it's a semiconductor company, or a software company, or a robotics company, which makes it really interesting."

Entrepreneurship in the air

The norms of founding a company have changed somewhat since his father, Arthur L. Goldstein, founded Ionics, Inc., in 1948, Goldstein admits. The prevailing wisdom at the time was that young engineers should try to gain deep experience in their field at an established firm before launching their own ventures.

Now, many entrepreneurs start their first company as soon as they graduate, or even as students. Goldstein reflects that technology entrepreneurship is a much more visible part of culture now—it's not uncommon for stories about technology startups to make front-page news. Furthermore, it is easier to assemble a team and find help than ever before.

"I think the ecosystem has evolved now where if you're an expert in one area it's much easier to find the other pieces to surround yourself. Whereas in the past it might have been a very lonely and unlikely path to success, now it's much more established," he says.

The trend is evident in the results of a 2014 survey of EECS alumni, which found that grads are founding their first companies at increasingly younger ages. Among those who graduated in the 1980s, only 8 percent of founders started their first companies before the age of 25. For those who graduated in the 2000s, however, 33 percent of founders started first companies before 25.

StartMIT

While starting a company is more common now, Goldstein observed that many first-time founders still have difficulty navigating the nuts-and-bolts of entrepreneurship, like developing an elevator pitch, understanding the nuances of equity, or how to market their product.

In 2014, Goldstein approached the Department of Electrical Engineering and Computer Science about creating entrepreneurship opportunities for students. The idea has developed into StartMIT, a class held during MIT's Independent Activities Period (IAP).

"Dave Husak, founder of Plexxi, (Course 6-1 '84) and I were talking about how we wanted to give students better visibility to the real world while they're students, so that they can be smarter about the process. So, I called Anantha [Chandrakasan, EECS Department Head] and I remember I was in California and Anantha said, 'Where can I call you right now?'"

Chandrakasan had just been charged by the EECS Visiting Committee with a clear mandate to give EECS students more exposure to entrepreneurship. Working together with Goldstein and Peter Levine of Andreessen Horowitz, the department set about developing a program that put aspiring entrepreneurs in contact with successful founders.

The class, formerly titled Start6, has helped students develop over 100 projects, Including Smarking (2014), now a successful company that uses big data analytics to help parking-garage managers maximize pricing and availability; GelSight (2014), which is commercializing sensors that can make 3-D maps of surfaces and could be used for more sensitive robotics fingertips; and Belleds Q (2015), which is developing a consumer product that uses streaming music to control wireless smart LED bulbs in homes.

Goldstein continues to be involved with StartMIT and the department. A member of the EECS Visiting Committee, Goldstein kicked-off the 2016 StartMIT agenda with a talk titled "Startup 101."

Each year since the launch of the program he has served as a mentor to several student teams—meeting with them over the course of two-and-a-half weeks to develop their ideas and implementation strategies. He observes that, as the program has grown, students from a broader range of backgrounds have taken an interest in the course, with experience levels running the gamut this year from MIT freshmen to entrepreneurs with 15 years of experience.

"It's great to see how students with diverse backgrounds can match up and work together," he says. "Because very often this is where you you find the most interesting ideas—at the intersection of these domains."

Next steps

Goldstein founded Pillar Companies in early 2016 to innovate on the venture capital model itself. "In meetings with many of the successful CEOs around the Boston community, many of whom have close ties to MIT, we saw an opportunity to approach the business in a different way — one that better aligned founders of young companies with capital and the resources they need to succeed."

THUAN PHAM: Engineering in Uncharted Territory

Uber's CTO on the company's astronomical growth, his management style, and love of technology

By Audrey Resutek, MIT EECS

Thuan Pham '90, SM '91, has come a long way since fleeing Vietnam in a boat with his mother and younger brother. In 1979, when he was 11 years old, the Uber Chief Technology Officer and his family were part of the wave of refugees that poured out of the country after the end of the Vietnam War, following the Chinese invasion of Vietnam and conflict with Cambodia.

Guided by a lifelong love of technology, he has gone from refugee to the head of the engineering team behind Uber, one of the fastest growing companies in history. Since its launch in San Francisco in 2011, the ride-hailing company has expanded into nearly 400 cities worldwide, and is valued by investors at over $60 billion. Known for his friendly approach to building an engineering team and dropping unnecessary formalities, Thuan prefers to go by his first name.

"The thing I love the most about my job is the endless creativity that goes into making software and building the system every day," the 6-3 (computer science) major says. "There are all kinds of challenges—technology challenges, how to build infrastructure and features faster—and I get to work with an amazing set of engineering team members here at Uber."

Thuan and his family came to the US after spending months in refugee camps in Malaysia and Indonesia, finally settling in a Maryland suburb outside of Washington, D.C. As a teenager in the early 1980s, he got his first taste of programming when a classmate's family brought home an early IBM PC. He and his friend would spend hours on the computer, at first playing games, and eventually writing their own software. Thuan quickly realized that he had an affinity for algorithmic thinking.

"I always liked to make the computer do what I wanted it to do. I don't like doing the same thing twice, and I definitely hated doing the same thing 3 or 4 times. I love to bend the computer to my will; write instructions, build a program, and make it do exactly what I want to do, only a gazillion times faster than I can do it by hand."

Despite his early talent with computers, as a freshman at MIT Thuan considered declaring a major in AeroAstro/avionics. He had always loved airplanes, and dreamed of working in the aerospace industry. To this day he still reads everything he can about planes and rockets, and is fascinated by SpaceX's Falcon 9 Rocket, which can land vertically on a launch pad.

His mother, however, sensed that the precocious programmer's true calling might be in computer science. She steered her son toward computer science, saying that he could always work on airplanes with a computer science degree.

"I said, 'ok, let me try this.' I went into computer science and I never looked back," he says. "She definitely was right. You can quote me on that. I'll send this to her. Yes mom, you were right."

Thuan especially loved coursework that gave him the opportunity to build things. His favorite course by far was 6.111 (Introductory Digital Systems Laboratory), where students build computers from the ground up. He loved the course so much that he spent several semesters as the lab TA for the course, and even served as the full TA when he was a 6-A graduate student.

Unprecedented growth at Uber

Thuan joined Uber in 2013, which he describes as a "developer's dream playground." There are many moving parts under the hood of the tech giant's front-facing mobile app and website, from the infrastructure that estimates demand and supply positioning, to dynamic pricing, and logistics modeling. All of these parts must work together seamlessly to create a reliable user experience, which is no small challenge.

Thuan is keenly aware of how many people around the world rely on Uber for transportation, and the need to prevent any would-be disruptions to service. He says the biggest challenge he faces is anticipating what kinds of problems will come up as Uber grows, and addressing them before they cause growing pains.

"At a company like Uber where growth is unprecedented and our impact is so vast, we are always in uncharted territory. So the thing we do here, not just me but everyone in the company, we have to be truth-seeking and learn on the job as fast as we possibly can. We keep our minds open, we challenge every assumption, we debate on ideas vigorously to make sure the best idea wins and that the best decision gets made."

In a recent example of this mentality, the company launched a "bug bounty" program to reward independent researchers for finding hackable bugs in its apps and websites. Researchers receive up to $10,000 for reporting bugs that could, for example, allow malicious users to take over Uber accounts. In a twist on similar programs run by other tech firms, the program is designed to encourage repeat finds in an attempt to encourage researchers to take a deep dive into Uber's code.

"What I'm most proud of at Uber is that we've managed to grow—the company, its impact—against all odds."

—Thuan Pham
CTO, Uber

"What I'm most proud of at Uber is that we've managed to grow—the company, its impact—against all odds," Thuan says. "When you do something like this, this bold, this fast, this big, lots of things can trip you up. We face lots of challenges every single day around the world and we've managed to keep doing this."

Accomplishing really big things

Thuan has a reputation as a cool boss, a style he says he learned early in his career, as a 6-A student. The 6-A program pairs EECS students with industry partners, starting as undergraduates and continuing through their 5th year Masters of Engineering thesis work.

During his internship at HP Labs, Thuan worked on developing intelligent program environments, precursors to today's software development environments (SDEs). On the weekends, his manager, Jim Ambras, would take him mountain biking and windsurfing around the Bay Area.

"Jim was a friend and mentor to me as well as a boss. That actually was one of the pivotal moments of my career, where I learned that style of management; and that has deeply influenced my management style later in my career."

Thuan says his approach to building healthy engineering teams is to adopt a structured, yet friendly, service-oriented management style rather than a mercurial or top-down approach.

He pairs this style with a bit of advice for aspiring software engineers: do what you love.

"If you look at everyone here at Uber, the work is intense. The day is sometimes very long, but if you love what you do, then work doesn't feel like work," he says. "If you go to work with a passion, with a purpose, and you get to work with amazing colleagues, then you will really enjoy the work. And as a result, you get to accomplish really really big things."

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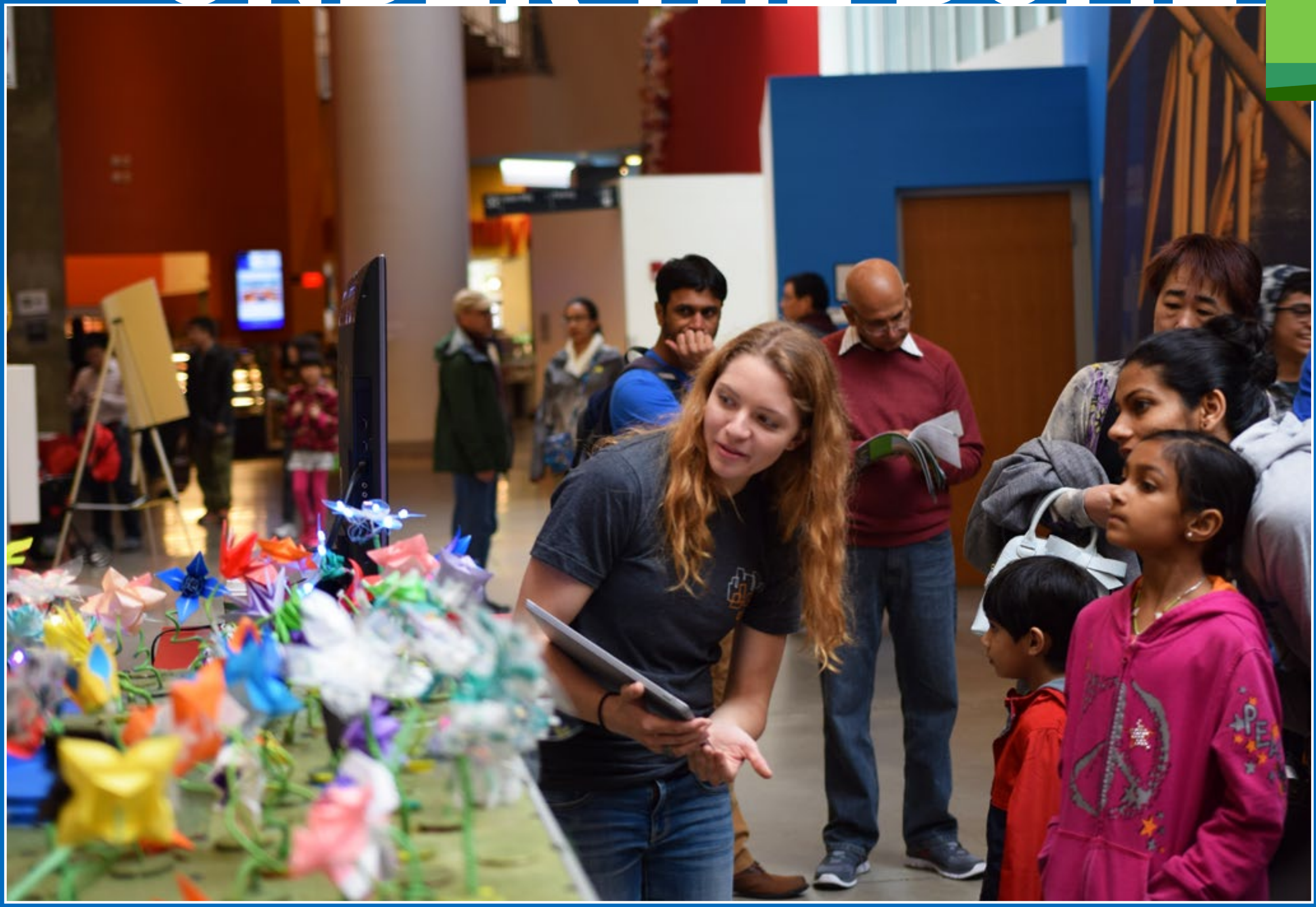
UNDER THE DOME



MIT opened its doors to the public on Saturday, April 23 for "Under the Dome," the Institute's first open house since 2011. EECS students, faculty, and staff demoed projects and gave tours to some of the estimated 40,000 people who flocked to campus for the event.

Above: Graduate student Lindsay Sanneman (center) explains the Distributed Robotic Garden, an origami-inspired garden aimed at teaching K-12 studnts the basics of programming. The origami-inspired robotic plants can change colors and orientations with the use of a tablet interface.

Bottom left: EECS senior Gerzain Mata (right) demos a self-balancing robot he developed as a project for 6.302 (Feedback Systems).

Bottom right: Technical Instructor Gavin Darcy demos a laser cutting tool in the Engineering Design Studio. Built in 2014, the studio is one of MIT's newest maker spaces.

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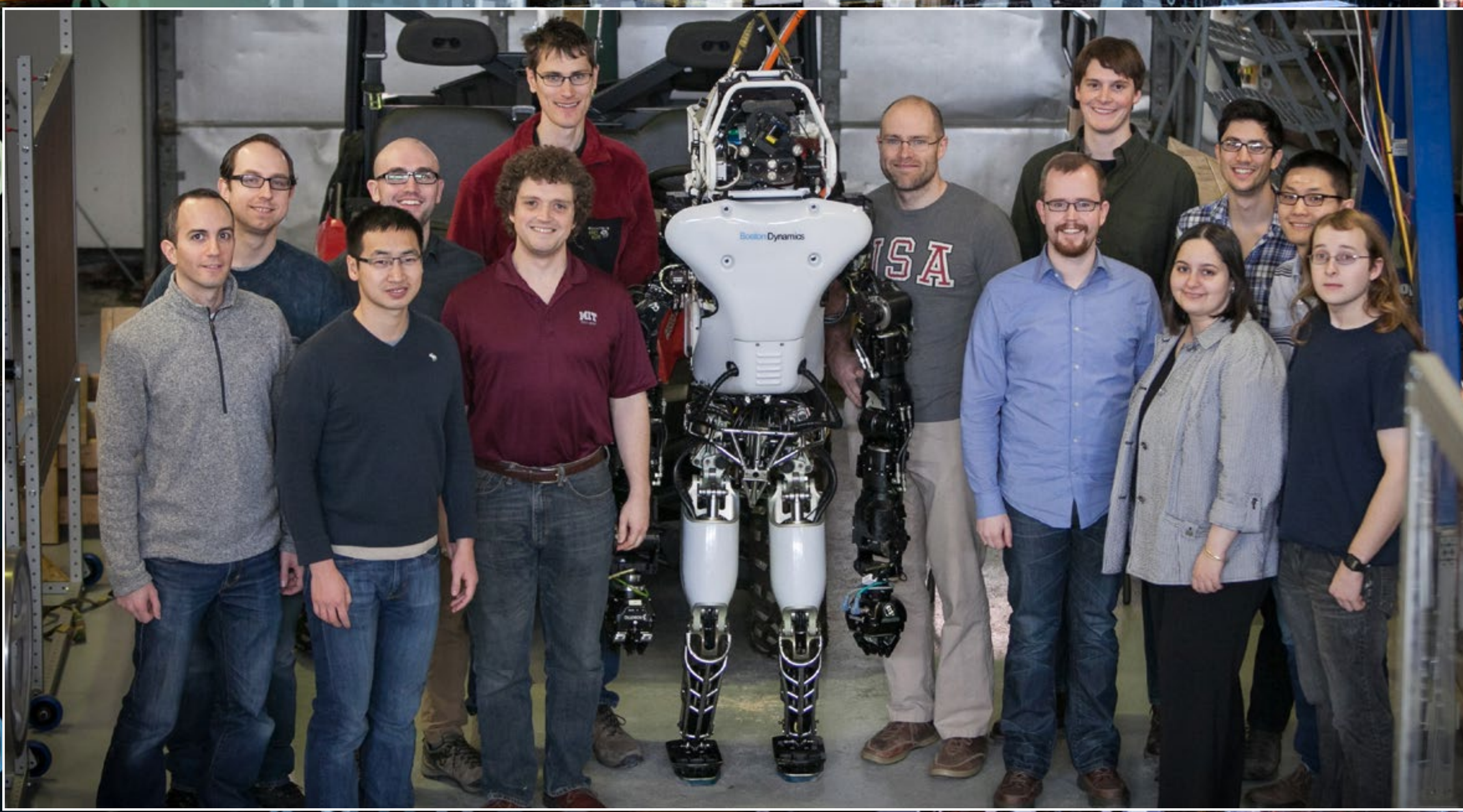

The MIT DARPA Robotics Challenge Team poses with their 6′2″, 400-pound humanoid robot, Atlas. The team came in sixth place in the June 2015 contest, which challenged robots to open a door, rotate a valve, turn on a power tool, drill a hole in a wall, climb stairs, scrable over cinder blocks, and drive a car in under an hour. Photo: Jason Dorfman/CSAIL.

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