SPRING
2014

MIT EECS CONNECTOR

Annual News from the MIT Department of Electrical Engineering and Computer Science


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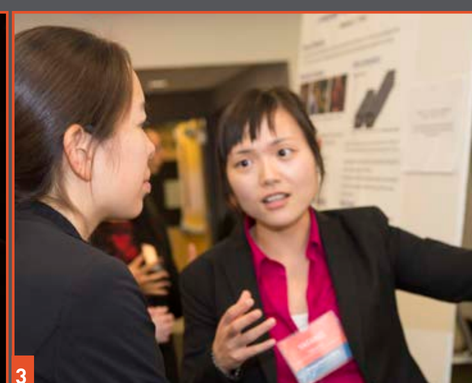
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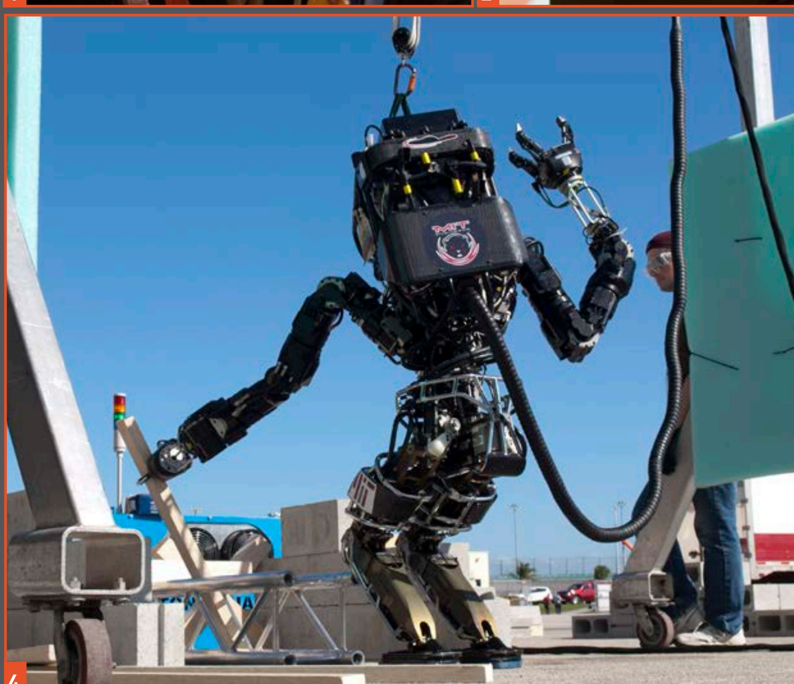
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Annual News from the MIT Department of Electrical Engineering and Computer Science

the MIT EECS Connector

SPRING 2014

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Front cover images: 1: SuperUROP students in the Department of Electrical Engineering and Computer Science talk with MIT president emerita Susan Hockfield at a reception for SuperUROP to celebrate its second year. Read more on page 62. 2: Start6, a bootcamp for EECS innovators and entrepreneurs, was launched in January to immerse students in the nuts and bolts of startups. Read more on page 5. 3: Participants including top young female PhD graduates and postdocs gathered for the Rising Stars in EECS two-day workshop to present their research and network. Read more on page 65. 4: EECS and MIT faculty, staff and students team to participate in the DARPA Robotics Challenge, placing in the top tier to compete for the final trial in mid 2015. Read more on page 14. 5: EECS alumnus and Dropbox Co-founder Drew Houston '05, talks with students in Start6 about entrepreneurship. Read more on page 7.

Perspectives from the Department Head

A Conversation with Anantha P. Chandrakasan about the latest initiatives and what lies ahead

Q: Each year since you became Department Head in July 2011, the department faculty, staff, and students have come together to create initiatives as outlined in the 2012 Strategic Plan. What are some of the initiatives that directly impact undergraduate students?

A: One of my best early decisions as department head was to form the Undergraduate Student Advisory Group in EECS (USAGE), whose members provide critical student input guiding curriculum development and enhancements. USAGE provided input crucial to the formation of the SuperUROP, which provides greater exposure to the rewards and complexities of scientific investigation and engineering development. (Read more on page 59.) In its inaugural year, 77 students completed the SuperUROP program, and around 80 students are enrolled for AY2014. USAGE members continue to provide thoughtful insight on how to enhance student life for future students. Their input this year is leading to the creation of a new space where EECS students can network with each other – to be located on the first floor of building 36. Our undergraduate and graduate students also participate in important committees such as the faculty search committee.

We have also launched a new Engineering Design Studio (EDS) — made possible through technical and financial support from Agilent Technologies Electronic Measurement Group and the Cypress University Alliance. EDS, housed on the fifth floor of Building 38 and opened on April 1, 2014, provides state-of-the-art fabrication tools for our students offering an entirely new learning and innovation dimension to our students and faculty. (Read more on page 17.)

In April this year, the Department will host its second undergraduate research conference, EECScon. This off-campus one-day event is student-organized with faculty oversight. The meeting features poster and oral presentations by undergraduate students doing UROP, SuperUROP, or other research in EECS areas. (Read more on page 64.)

Q: The EECS Department developed and launched a new entrepreneurship experience for its students. How did that work?

A: One of my key goals for AY14 was to create an opportunity to support students interested in entrepreneurship. Based on the Visiting Committee feedback, we launched an addition to our curriculum over 2014 IAP, called, "Start6: A Bootcamp for EECS Entrepreneurs and Innovators" (http://start6.mit.edu/). This initiative offered opportunities for our students and postdocs to learn more about the nuts and bolts of building a successful company. The inaugural workshop brought together roughly 60 undergraduate and graduate students and postdoctoral associates, and covered topics such as equity division, models of funding, marketing, scalability, and team building. Start6 enabled students to meet successful entrepreneurs and leaders in the VC field, provided them with resources, and inspired them to pursue their passions. Over spring break (March 2014), around 30 top Start6 students traveled to Northern California to continue exploring opportunities to move their ideas and prototypes forward. (Read more on page 5 and watch for more news on www.EECS.mit.edu).

Perspectives from the Department Head

“We’d like to give our students as much opportunity as possible to participate in shaping their futures and the future of the department.”

Q: The Department developed the Rising Stars program to strengthen the academic pipeline for top recent women graduates in electrical engineering and computer science. Could you comment on the impact of the program?

A: This fall marked the second offering of the Rising Stars in EECS workshop – an opportunity that enables women from across the country who have demonstrated the highest levels of scholarship and research in the fields encompassed by EECS to network and build their chances for academic positions. Participants in Rising Stars were also made aware of the possibilities for ongoing collaboration and professional support following the experience. We received several comments from participants such as “demystified the steps needed to be a successful applicant” and “lessened my fears about being an academic.” We are pleased that other EE and CS departments across the country are increasingly interested in promoting and collaborating on this event. (Read more on page 65.) This past fall we welcomed a new faculty member, Vivienne Sze, who was one of the Rising Stars participants in fall 2012. (Read more on page 43.)

Q: Could you comment on the plans for the newly created EECS postdoctoral association?

A: The EECS leadership group, in response to suggestions made by the 2013 Visiting Committee, created an initiative to give greater identity as a group to postdoctoral associates in the department. Postdocs have formal appointments through one of the EECS-affiliated laboratories. Following several informal gatherings to organize and gain insights on the most constructive ways to build this new group, the Postdoctoral Group in EECS was formally inaugurated with a day-long workshop held on January 30, 2014. The event featured two panels aimed at the academic career and at the startup and industry career paths most commonly followed by postdocs. The workshop featured several talks, including how to get a faculty job, developing a mission/research statement, teaching and mentoring students. (Read more on page 67.)

Q: Since the formation of edX and MITx, EECS faculty, staff and students have taken the lead in the development of this online educational initiative. What are some of the latest EECS contributions to the MOOC movement?

A: In collaboration with the Office of Digital Learning and MITx, the EECS Department has led the development of a new certificate-granting sequence of MITx modules titled “Foundations of Computer Science,” inaugurating the XSeries program on edX. We are looking forward to building this new integrated approach to online learning while exploring new approaches to effective residential education. (Read more on page 8.)

We are also excited to offer 6.041x (Introduction to Probability) this spring and 6.341x (Discrete-Time Signal Processing) in fall 2014. (Read more on page 9.)

Q: What are some of the faculty highlights from this past year that you want to share?

A: Over the years, members of our faculty and alumni have made notable advances in the fields of artificial intelligence and robotics. Under the leadership of two of our faculty (Seth Teller and Russ Tedrake) a multi-department team from MIT took part in the first of two major rounds for the DARPA Robotics Challenge — an opportunity sponsored by the Department of Defense to raise the potential for robotics assistance in major disasters. Competing with sixteen of the top robotics teams worldwide, MIT made DARPA’s "cut" to the top eight teams and will move on to the final round, anticipated for summer 2015. We are inspired by the strong commitment of this group of faculty, research staff and students, and look forward to the final trial in 2015. (Read more on page 14.)

The scope of research and innovation coming out of the department is also reflected in the notable awards that are presented to our faculty each year. Marvin Minsky, who started out in 1958 in the Electrical Engineering Department and formed the Artificial Intelligence Lab, has been recognized as one of the early founders of the field of artificial intelligence by the BBVA Foundation’s Frontiers of Knowledge Award in Information and Communication Technologies, and by the Dan David Foundation Prize.

We are pleased to cite the many recognitions and awards that our faculty have received this year — and note with deep appreciation for their legacies and a profound sense of loss, the passing of three luminaries: former faculty member Amar Bose, Prof. Emeritus Kenneth Stevens and Prof. James Roberge. (Read more about our faculty starting on page 33.)

Q: As department head, you are in touch with many of the department’s twenty thousand alumni. What message do you want to share with them?

A: It is a tradition in our department to invite several of our alumni to share their “stories” through our newsletter. This year our featured alumni include Limor Fried, who carried her delight in making electronic gadgets at MIT into her startup, Adafruit Industries, regarded as a pioneer in the maker movement; Conor Madigan, whose graduate work and postdoc at MIT provided the inspiration, knowledge and team with which to launch his startup Kateeva, aimed at low-cost OLED manufacturing; Bill Irving, a trained PhD electrical engineer who transitioned to a highly successful financial career with Fidelity (during the economic downturn); Andrea Wong, who turned her abilities as an engineer to her passion for television entertainment, becoming a leader in the industry; Shyam Gollakota, now an assistant professor at the University of Washington and making waves in developing new ways for using wireless signals; and Bill Thies, a gifted computer scientist who is living his passion developing technology to impact global disparities in health, education and livelihood in India. (Read more on page 76.)

We are interested in featuring our alumni not only in this annual newsletter but also on our website. In that effort, we have included a small number of the many awards given to our graduates that we have learned about over the past year (on page 88). We are also eager to engage you in a number of departmental initiatives, and we look forward to hearing from you.

Anantha P. Chandrakasan
Joseph F. and Nancy P. Keithley Professor of Electrical Engineering and Computer Science
Department Head, MIT Electrical Engineering and Computer Science

"Regardless of the SuperUROP students’ goals — for graduate school, career in industry or launching a startup — the program has demonstrated a new way to innovate how students, faculty and industry work together to generate ideas while building new leaders.”

Features

Start6 inspires student engineers to become entrepreneurs

by Lauren J. Clark

In Start6, a new entrepreneurship program for MIT engineering students during IAP, participants have received advice from such guest speakers as Paul English, co-founder of Kayak; Mike Evans '99, MEng '00, COO and co-founder of GrubHub; Marina Hatsopoulos '92, serial entrepreneur, director and angel investor; and Max Krohn '08 , co-founder of OkCupid. And that was just on the first day.

The three-week workshop, which began January 13, also featured visits from Drew Houston '05, CEO and co-founder of Dropbox; Google vice president Jeremy Wertheimer '89, formerly CEO of ITA Software; Nanxi Liu, a 23-year-old who has already founded two successful startups; Rodney Brooks, founder, chairman and CTO of Rethink Robotics and Panasonic Professor of Robotics (emeritus) at MIT; Ray Stata '57, cofounder of Analog Devices; and Robert Langer, prolific inventor and entrepreneur and the David H. Koch Institute Professor at MIT. In addition, venture capitalists such as Peter Levine of Andreessen Horowitz and Jamie Goldstein '89 of North Bridge Venture Partners walked the Start6 students through various phases of a startup.

Learning from the Pro's

"It's awesome to be able to hear insightful things from people who have done this before and know what they're talking about," says Ari Weinstein, a freshman from Philadelphia who plans to major in electrical engineering and computer science (EECS) and already has some entrepreneurial experience. He created DeskConnect, an app that allows users to share files between devices with one button. It already has more than 100,000 users.

"MIT has excellent resources for aspiring entrepreneurs. Our students, faculty, staff, and alumni have an exceptional track record of producing successful new ventures. However, increasingly our students see the acquisition of entrepreneurial knowledge, skills, and attitudes—whether for use in starting a new venture or in an existing organization—as an essential part of their education," says Ian A. Waitz, dean of the MIT School of Engineering. Start6 is one of several exciting new initiatives that will provide even greater opportunities for our students to develop these essential abilities."

The 50-plus students participating in the workshop are primarily from, but not limited to, EECS.

Building the EECS Entrepreneurship Connection

Anantha Chandrakasan, the EECS department head and Joseph F. and Nancy P. Keithley Professor of Electrical Engineering, says that Start6 is a new opportunity for MIT's engineering students and postdoctoral candidates to dive into "everything entrepreneurship—particularly as it relates to EECS." He told the workshop attendees, "Our ultimate goal is to create a community of entrepreneurs, not just at MIT but when you go out into the world."

Evans of the online food-ordering company GrubHub gave a talk in which he chronicled how he went from a young corporate employee paying off student debt in 2003 to the COO of a company that did $1 billion in sales last year. GrubHub, which recently merged with competitor Seamless, covers 20,000 restaurants in about 500 cities.

"In the past, you needed a massive amount of capital to start a company," Evans says. "The people in this room have the capital in their minds—in their ability to write software. You can go create businesses with very little capital."

Follow your passion, but learn the nuts and bolts

Start6 has practical sessions that help students with the nuts and bolts of a startup: perfecting a product pitch, types of funding from bootstrapping (relying on support from yourself, family and friends) to venture capital, and how to split equity among company founders, for example. Students appreciate the how-to aspect of the workshop but say it's just as important to hear the stories of successful entrepreneurs. In those stories, several themes come up again and again: passion, focus, persistence, resilience, team-building.

Start6 inspires student engineers to become entrepreneurs, *continued*

"Be passionate about your idea," says Dave Gifford, EECS professor and founder of three successful companies. "A startup has to be meaningful to you as a creative act. Money is secondary."

Hatsopoulos, former CEO and director of 3D printing leader Z Corporation, stresses the importance of building the right team to lead a start-up. "Each member should bring something very unique to the table. Then this team can do magic—it can create something that's so much bigger than any one of you."

Persistence to ride out the tough times is key, says Rob May, CEO and co-founder of Backupify, which securely backs up data in the cloud. "Do you have the stomach for a start-up? In the early days, it's often only the will of the founder that keeps people there."

English urged the students to boil their idea for a startup down to a simple idea or a narrow market. When he started the travel website Kayak a decade ago, he pitched it simply as "the anti-Expedia." He learned to avoid explaining all of the site's features, or the algorithms that made it work, to potential funders or buyers. Its success has been such that Priceline purchased it for nearly $2 billion last year.

"Engineers tend to be pretty cerebral," English says. "For every problem presented to us, we try to come up with solutions that solve 10 additional problems. We need to be more decisive."

That message resonated with Sam Prentice, an EECS graduate student. "It's very easy here at MIT to get focused on the technology instead of building something that someone wants," he says. He has several ideas for startups, including one based on a technology that augments human perception.

"What I've learned has already transformed my project," says EECS senior Danielle Gordon. Her software, called Mode, would enable users to link together disparate data, such as social media accounts and files stored on one's computer. Before Start6, she had been describing the technology as a "way to link objects together for organization purposes. Now I'm calling it a content management system for life."

Start now!

One topic that came up frequently in Start6 panel discussions is when to start a company. Liu answers unequivocally: "I recommend students start a company as soon as they can and especially while they are still students. They've got tons of student organizations that they can send beta codes out to for testing their product."

Liu, a graduate of the University of California-Berkeley, is CEO of the year-old startup Enplug, which has placed its interactive digital billboards—on which advertising and social media blend in real time—in more than 30 cities. Before that, she founded Nanoly Bioscience, which is developing a chemical that allows vaccines to survive without refrigeration.

She told the students that starting a company early means that "by the time you graduate, you'll be able to hit the ground running on a full-time startup without making any rookie mistakes."

Just as Evans reminded Start6 participants that they have the capital "in their minds" to start a company, Liu pointed out another readily available resource: fellow students. "In the 'real world,'" she says, "companies pay tens of thousands of dollars to recruiting firms to help them get connected with students at MIT. So, for students at MIT, getting classmates and acquaintances to be teammates is a recruiting jackpot."

Start6 speakers.
See: http://start6.mit.edu

Drew Houston and Bob Langer encourage Start6 students at completion of workshop

Start6 wrapped up its third week with sendoffs from two icons in the world of startups: Drew Houston, '05, Co-founder and CEO of Dropbox, and Institute Professor Bob Langer.

Joining Anantha Chandrakasan, EECS Department Head and creator of Start6, for a fireside chat on Monday, January 27, Houston related his experiences as an MIT EECS student with a strong interest in startups. When asked about the place of computer science as an Institute requirement, he responded positively noting, "Now all kinds of major industries are being turned upside-down by software, which is rocking all industry," Houston told the large crowd gathered in 34-101. "So absolutely, people are massively underestimating the shift. It's now not only possible but it's ordinary that a couple of kids in a dorm room can build something that reaches millions of people, completely changing the way [people] do something."

He also encouraged the students saying that picking up the business side on the fly was within reach of any MIT engineering student. And, he suggested that as MIT seeks to foster entrepreneurship, more students should be encouraged to take up to 6-month internships with top-tier, venture-backed startups. (He was personally involved in five other startups before Dropbox.)

Photos: page 6 top: Jeremy Wertheimer, VP at Google, formerly CEO at ITA Software, discusses startups with Start6 students. page 7 top: Drew Houston speaks with Dept. Head Anantha Chandrakasan and Start6 and other MIT engineering students. Immediately above: Institute Prof. Robert Langer ends Start6 with encouraging and salient advice. All Start6 photos by Rahul Rithe, EECS grad student

Robert S. Langer, the David H. Koch Institute Professor, the most cited engineer in history, and founder of 26 companies, gave the final Start6 sendoff on January 28. He shared his formula with a receptive group.

Langer recommended starting with platform-building technologies for long-term successful manufacturing of products that are covered by a broad, blocking patent, and established by publication in a top journal. He encouraged what he called the 'champion effect.' "You want people who will walk through walls to to be at the company and make things work," he said. "You care a lot more for [their] passion than experience." He cited Steve Job's starting Apple, the company's subsequent decline when Jobs was forced to leave, and its historic rise to the top on his return.

Langer told the stories of six companies that he founded with his students, starting in the late 1970s. He noted that in five of the six, the idea of starting a company followed the publication and broad patent of the original discovery. He said that although MIT was not actively encouraging startups in those days, his experiences were all successful. Not one of his companies has gone under.

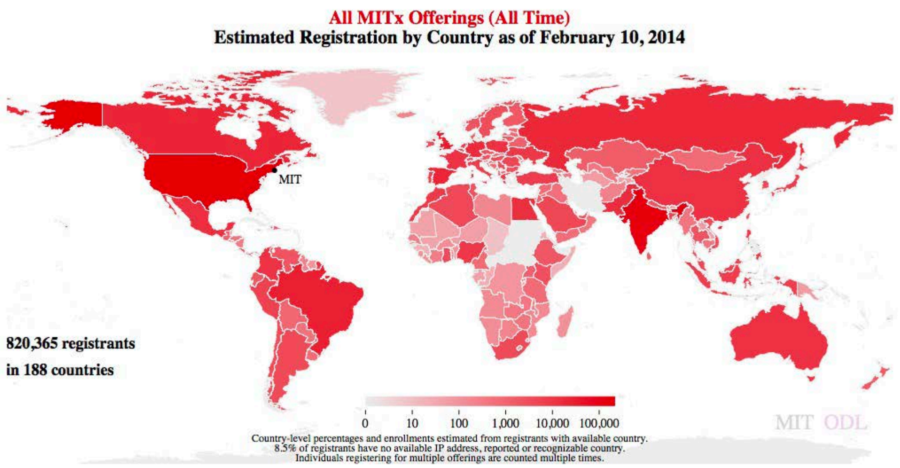
Prof. Langer advised that the biggest reason for success or failure is the CEO. He also urged that younger inventors do due diligence to determine how to deal with venture capitalists and investors. "The pie is only so big. Dig deep in your heart about what you want to do."

In answer to a question about Drew Houston's lack of emphasis on patents, Bob Langer agreed with Houston's advice, noting the importance of patents in the life sciences compared with the information and computer sciences where marketing takes a bigger role. From their own perspectives, Langer and Houston each encouraged the Start6 students. As Drew Houston put it, "Do it [launch a startup] now!"

http:start6.mit.edu

XSeries: a new phase in online education for MIT

by Lauren J. Clark



MOOC datasets from the first 17 edX offerings, along with accompanying visualization tools, were released by MITx and HarvardX, and provide an intuitive interface for accessing enrollment and demographic data. See: Office of Digital Learning: http://odl.mit.edu/insights/

"It's providing a great opportunity for people to learn about computer science and to launch themselves into the field,"

says John Guttag,
Dugald C. Jackson Professor of Computer Science and Electrical Engineering

Online education has entered an exciting new phase, and MIT's Department of Electrical Engineering and Computer Science (EECS) is leading the way.

EECS has developed "Foundations of Computer Science," one of the first two certificate-granting courses for MITx, the Institute's massive open online course (MOOC) effort. It consists of a sequence of related modules on the edX platform, which MIT launched with Harvard University in 2012. The Institute laid the foundation for edX a decade earlier, when it began making all of its course materials available online, for free as part of the OpenCourseWare initiative.

The sequences, called XSeries, represent a new approach to MOOC instruction and certification across integrated offerings more expansive than the individual courses that have thus far defined the MOOC landscape.

"These sequences are an opportunity for MIT to both explore how subjects can be addressed in depth through the MOOC format and to better understand student interest in various types of certification," says Anantha Chandrakasan, the Joseph F. and Nancy P. Keithley Professor of Electrical Engineering at MIT and head of the EECS Department. "XSeries sequences allow our departments to reimagine the building blocks that structure teaching in our disciplines for the digital environment."

Just like on-campus EECS courses, "Foundations of Computer Science" introduces key concepts of computer science and computational thinking. After viewing video lectures by MIT faculty, XSeries students apply these concepts and build their engineering skills by completing software and hardware design problems. Additionally, they test their understanding by taking a series of exams.

To create the XSeries, EECS faculty divided three undergraduate courses into seven shorter modules that are more accessible to online learners—most of whom are studying during time off from jobs or school. The faculty estimate that the XSeries, whose post-introductory modules are still under development, will take two years to complete.

"It's providing a great opportunity for people to learn about computer science and to launch themselves into the field," says John Guttag, the Dugald C. Jackson Professor of Computer Science and Electrical Engineering, who oversees the first two XSeries modules, "Introduction to Computer Science and Programming in Python" and "Introduction to Computational Thinking and Data Science." He adds, "The feedback is almost all highly positive. It is very gratifying."

The XSeries format allows EECS instructors to experiment, says Ana Bell, a lecturer who has taken a lead role in transforming EECS residential coursework to the digital world. For example, in one of the initial modules, "We added an extra section and problem set on clustering algorithms," Bell says. "These algorithms can be applied to many real-world problems that are associated with 'big data.' We want students to understand how to make sense of such data—be it from social networks, biology, the financial industry—rather than to think of it as a popular buzzword."

Importantly, MITx users include MIT students. By making use of online courses that mirror their residential offerings, they can learn at their own pace. EECS senior lecturer Chris Terman says that when he helped adapt "Circuits and Electronics" for MITx in 2012, he and his fellow instructors also used it to teach their on-campus students that semester.

"The students cited a number of advantages," he says. "They liked the online lectures, because they could play through the things they didn't need to think heavily about, but replayed a number of times the things they hadn't quite gotten. We ended up doing a sort-of flipped classroom, because we held office hours for questions [the students] had."

"Flipping the classroom" means that students first encounter new material outside of class, usually via reading or video lectures, and then use class time to do the more challenging work of assimilating that knowledge, through problem-solving and discussion, for instance.

Terman and his fellow EECS instructors tend to look beyond this concept, which, like "big data," has become somewhat of a buzzword. "The most interesting outcome will be when we get to a place that's really different than packaging up what we do now," he says.

That's where research comes in. MITx is, after all, a quintessential Institute endeavor in that it blends technology, teaching and research.

Rob Miller, an EECS professor who heads the User Interface Design Group at the Computer Science and Artificial Intelligence Laboratory, estimates that about 80 percent of his researchers' projects focus on online education, including edX and MITx. "Part of the larger idea behind edX is about both teaching the world and studying how to teach better," he says.

PhD students, postdoctoral candidates and SuperUROP students in Miller's group are studying, for example, how to make video lectures more effective at teaching, how to develop self-generating tutoring systems based on students' trial-and-error problem solving, and how to improve in-class activities that will be key to the future of flipped classrooms.

Miller is also developing upcoming modules for the XSeries based on a residential class he teaches called "The Elements of Software Construction."

"It's just as useful," he says, "to actually be teaching courses ourselves" as it is to mine their data for research.

EECS and physics professor Isaac Chuang shares Miller's views about the significance that the XSeries and edX hold for "teaching the teacher." Last year, he co-led a joint MIT-Harvard study of courses on edX that offered new findings on how students engage with MOOCs.

"The story hidden underneath this series of reports may be this," Chuang concludes. "Institutions like ours are coming to appreciate how cross-institutional educational collaborations involving many students and many courses can open new routes to understand and improve student learning—making a difference around the world and back here on campus."

Further reading from the Office of Digital Learning, the MITx Working Papers: http://odl.mit.edu/mitx-working-papers/

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Isaac Chuang,
Professor of Electrical Engineering and Comptuer Science

The tale of 6.041 and 6.341 and their respective "x's"

The world is full of uncertainty: accidents, storms, unruly financial markets, noisy communications. The world is also full of data. Probabilistic modeling and the related field of statistical inference are the keys to analyzing data and making scientifically sound predictions.

Over the 50 years that "Probabilistic Systems Analysis and Applied Probability" (6.041) has been taught in MIT's Electrical Engineering and Computer Science Department, the course has evolved. Recently, it became an offering on MITx, attracting roughly 20,000 online learners from around the world.

Called "Introduction to Probability - The Science of Uncertainty" online, 6.041x equips students with the models, skills, and tools that enable them to analyze data and think probabilistically.

EECS professors John Tsitsiklis and Patrick Jaillet teach both the residential and online versions of the course. Tsitsiklis, the Clarence J. Lebel Professor of Electrical Engineering and associate director of the Laboratory for Information and Decision Systems, says it is relevant to a much wider audience: "The class is targeted not just to EE (Electrical Engineering) students. For example, biologists need probability tools more and more."

The tale of 6.041 and 6.341 and their respective "x's"

The online class offers the same content and is just as challenging as the residential class. Tsitsiklis and Jaillet, the Dugald C. Jackson Professor of EECS, videotape their lectures in the form of a sequence of short clips interspersed with concept questions and simple exercises. Students have to solve the problems on the spot, which provides them immediate feedback. In addition, they have access to problem-solving videos, mostly recorded by EECS graduate students that correspond to the recitations and tutorials in the residential course.

"We're more ambitious than the typical undergraduate probability class," Tsitsiklis says. "We're different from a class that gives an overview of problems and ideas. We aim to provide the crispest way of explaining the concepts."

He is intrigued by teaching through a new medium, which can appeal to students with various learning styles. "Some people prefer to learn by reading a textbook. Some want the encouragement of chatting with an instructor. We hope this medium (MITx) will be perfect for some people."

Those who complete 6.041x will be able to successfully apply the tools of probability theory to real-world applications or their research.

This article was adapted from a Jan. 29, 2014 MIT News story written by Sara Sezun and Steve Carson, MIT Office of Digital Learning.

6.341x Flips the Classroom

New MITx course could transfer innovation to other online classes

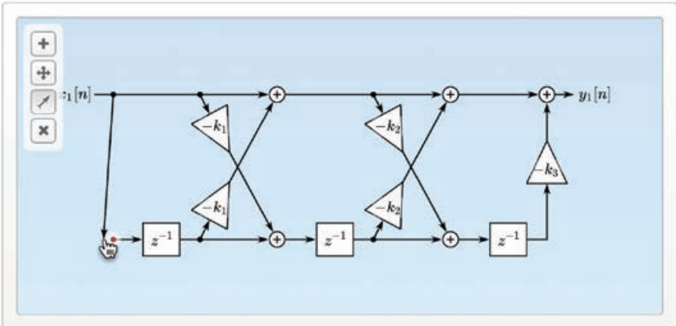
This fall, the first EECS graduate course will launch on MITx. "Discrete-Time Signal Processing" (6.341x). This course, based on the residential offering of the same name, teaches the digital signal-processing technologies on which modern computation and communication systems depend.

Ford Professor of Engineering Alan Oppenheim and Dr. Thomas Baran developed the course after successfully using the MITx online learning platform to innovate the way that 6.341 is taught residentially. While they structured the residential course in the traditional style—two weekly lectures, weekly recitation and problem sets, plus projects and exams—they introduced new features that turned out to be highly effective. A number of enhancements to the online platform were also developed. These new features were highly effective and will be incorporated into MITx for use by the 6.341x development team and potentially by others for a variety of online classes.

During lectures in the residential course this past Fall semester, students used hand-held clickers, i.e. polling technology, to answer in-class questions anonymously. For example, Oppenheim frequently put a problem up on the screen and ask the students to choose the correct answer or indicate that they could only guess. A histogram of the class results would then immediately be projected on screen.

"That's instantaneous feedback to me and to them," Oppenheim says. "My teaching style has always been very highly interactive. I need feedback from the class as to how they're relating to the material. [The students] loved the in-class questions which provided both a short pause to digest a concept, and immediate feedback. They felt it was a tremendous enhancement to the teaching."

EECS graduate student Anuran Makur commented that "The in-class questions gave students an opportunity to gauge in real time to what extent they had understood the material presented in the lecture." He adds, "The anonymity of using the clickers encouraged the majority of the class to provide an answer without fear of being singled out." All of the in-class questions plus many additional ones were typically posted for the class ahead of time but without autograding. Following the lecture the MITx autograding was activated for those problems so that the students could then revisit them with the autograding feedback, says Oppenheim.



Screen capture of a 6.341x student inputting a signal processing system into the platform for auto-grading. Courtesy Tom Baran

The class also used MITx for online evaluation of both the weekly problem sets and the course projects in order to provide immediate feedback to the students as they were working on the assignments. The MITx autograding platform was augmented with an online text box in which students could provide explanations of how they arrived at their answers. "Utilizing the MITx platform for enhanced autograding of the online questions, homework and projects was universally applauded by the students. The students also made use of an online discussion forum that was very actively managed by a teaching assistant.

"This experience has radically changed the way I think about teaching," Oppenheim says. "It will be an exciting educational adventure as we explore the many new ways of leveraging online resources for enhancement of residential teaching."

The VLSI revolution at MIT *by Paul Penfield, Jr.*

Remember the VLSI revolution?

If you are over 50, you might. If not, you have probably heard about it. In the late 1970s the VLSI (Very Large Scale Integration) revolution opened up the design of integrated circuits to people who did not know anything about device physics or semiconductor processing.

This was first demonstrated here at MIT. Below is the story of the two people, Lynn Conway (photo lower right) and Professor Jonathan Allen (photo right), who made it happen. Ideally, these two should tell the story, and Conway has written a compelling account from her perspective, "MIT Reminiscences: Student years to VLSI revolution", http://ai.eecs.umich.edu/people/conway/Memoirs/MIT/MIT_Reminiscences.pdf. Sadly, Allen died in 2000 but I will try to tell the story from the MIT EECS perspective here. Please read both accounts.

Although in the 1950s and 1960s our department (named EE at the time) was innovative in using physical device models to teach electronics, we consciously decided not to expand research in silicon devices and circuits because we thought industry could do it better.

The rise of computer science made us rethink that decision. In the early 1970s we decided not to split into separate EE and CS departments but stay united, under the new name EECS. Then we realized that our research in computer architecture and digital systems was hindered: testing new ideas in the form of hardware required LSI (large-scale integration) that was available only in industry. Allen knew this both from his own research in speech technology and through serving as Associate Director of the Research Laboratory of Electronics. He wanted fabrication as a service, not something he and other digital hardware designers would have to know how to do.

Meanwhile a revolution was brewing in California. Professor Carver Mead at Caltech had used industry connections to get student projects fabricated and the students loved it. A group centered around Lynn Conway at Xerox PARC (Palo Alto Research Center) set out to make designing integrated systems so simple that lots more people could do it. Both Stanford and Berkeley (who had continued their research in silicon devices) were interested.

In 1977 we decided we had to get on board. Several decisions followed. To keep true to our decision to stay as one department, we needed relevant research in both EE and CS. That meant: a silicon fabrication facility where research on devices and processes was informed by the needs of digital systems; research in digital systems that could use novel processes; and research on design tools to connect the two. This would address the three central questions about integrated systems: how do you make them, how do you design them, and what should they do.

Professor Jonathan Allen was the sixth Director of the Research Laboratory of Electronics, RLE, and a member of the EECS faculty since 1968. Photo courtesy of RLE.

Lynn Conway (left) in her office at Xerox PARC (1983). On Lynn's desk are the Alto computer she used to write the VLSI textbook, and the TI terminal she used to interact with PARC while at MIT. Photo by Margaret Moulton, courtesy Lynn Conway.

Carver A. Mead (right). Photo taken by Emilio Segre in 1985 on the occasion of the Franklin Institute's John Price Wetherhill Medal presentation to Prof. Mead. Courtesy AIP Emilio Segre Visual Archives, *Physics Today* Collection.

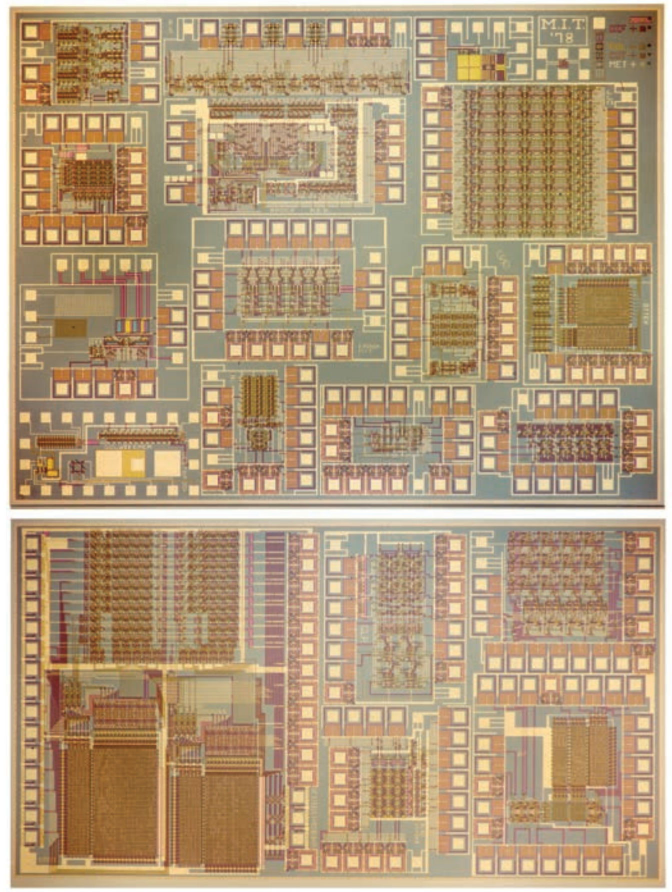
First we wanted to learn what industry was doing. In January 1978 we invited Chuck Botchek to teach to EECS faculty and researchers in many areas (devices, circuits, computer architecture, and AI) a two-week intensive course he had designed for industry. Allen and both EECS Associate Department Heads (Professors Fernando Corbató and Paul Penfield) set the example by attending and doing all the assignments. This was exciting.

But what Conway was doing was even more exciting. She worked intensely with Mead and others to simplify the design process. They recognized that designing a research chip to test out a system idea is not the same as designing a successful chip for an industrial product. You don't have to use an advanced process; on the contrary you are better served by a mature, more reliable, process. You don't have to tweak the layout to minimize space; instead make the layout reflect the logical design of your system so it's easier to debug. You don't need to minimize power usage or maximize speed; instead focus on your innovative ideas. Rapid prototyping is the point, not flawless operation, best performance, or minimum production cost.

Understanding complicated digital systems is helped by abstract modeling, using modules with well defined interfaces. Conway and her colleagues realized that the same is true of the design process itself. They defined standard notations to support designs. One was a language for layouts, CIF (Caltech Intermediate Form) that could be used for the output from layout software programs. Another was simple design rules that had a single length parameter (lambda) that could fit the rules to many processes; this allowed last year's design to be run with next year's process, and also let carefully designed utility circuits be scaled and reused year after year. They even supplied some, including wiring-pad circuits. They knew that modularity and standard interfaces in the design process would stimulate design of VLSI CAD (Computer Aided Design) tools.

They needed to test and refine their simplified design methodology by teaching it. MIT needed to learn the new ideas and contribute to them. So Conway came to MIT and taught a graduate subject in Fall 1978. It was a match made in heaven.

The MIT end of this bargain was handled by Professor Allen. The TA for the course was graduate student Glen Miranker. There were 32 students; several faculty and staff sat in. The course covered the relevant ideas from circuits, devices, switching theory, computer architecture, and digital logic. It also introduced the design abstractions and offered some primitive CAD tools. Students designed projects of their choice and submitted the layout, expressed in CIF. These layouts were combined to form two chips and all this data was sent to Conway's colleagues at PARC who got lithography masks made and delivered to Hewlett-Packard for fabrication. Students got working chips back in the middle of January for testing.

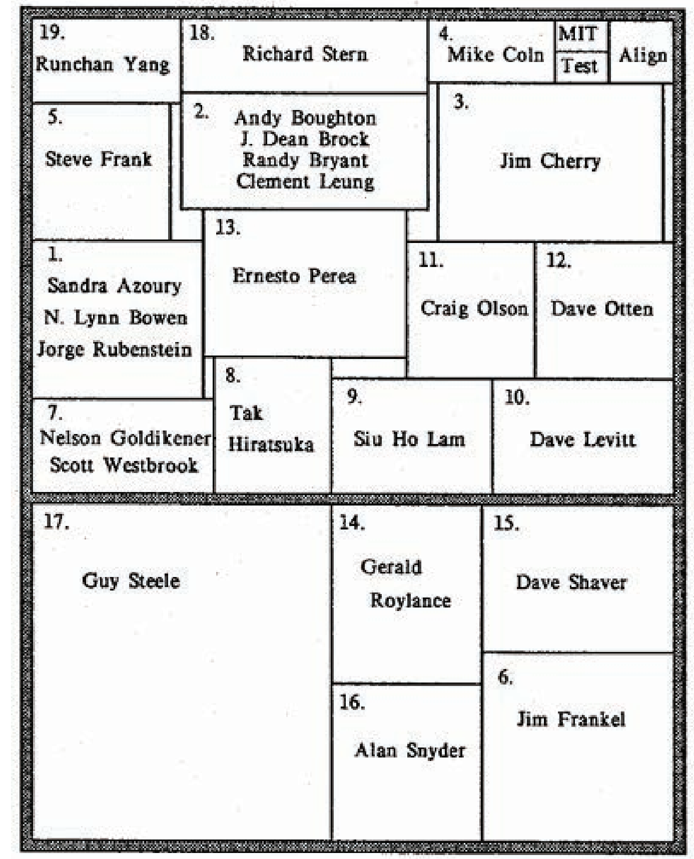


MIT 1978 chip set. Courtesy Lynn Conway

It really worked. This course demonstrated that a person who is not an expert in device physics or semiconductor processes can design an integrated circuit that implements some digital system. This was revolutionary. It was followed by a multi-university multi-project chip in 1979. The Mead-Conway book "Introduction to VLSI Systems" was rapidly published and Conway produced a much-appreciated teacher's guide. Twelve universities offered similar courses in 1979, and 113 as early as 1983. At MIT 6.371 was taught until 2002 by several people, including Professor Allen as recently as 1996.

The VLSI revolution was not just for students. It led to many advances in industrial VLSI design tools, and many custom commercial designs. Eventually the structure of the industry evolved to include large for-profit "foundries" to process custom designs.

The VLSI revolution impacted other areas of manufacturing, not just integrated circuits. Today 3D printing (or additive manufacturing) is becoming very popular. An object is represented by a three-dimensional digital model, created by someone who is not an expert in materials. Then a 3D printer, guided by this model, produces the object. Design and fabrication are separated, just as with VLSI.



VLSI project map. Courtesy Lynn Conway

At MIT, the new VLSI research program flourished, with the hiring of several new faculty. The new fabrication facility had flexibility that proved ideal for constructing things other than integrated circuits. This has included several innovative MEMS (Micro-Electro-Mechanical Systems) chips with sensors and actuators. Some of these have used variations of CIF to specify layout. There was also a CAF (Computer Aided Fabrication) language developed for specification of processes.

A more general question, which Conway has started to think about, is how the VLSI revolution itself can be repeated in other domains. Perhaps a methodology (with computer tools, of course) can be established for launching other technology revolutions.

EECS should be proud of MIT's contributions to the VLSI revolution. Many of the people with the early ideas were MIT graduates. Many EECS students who took the 1978 course went on to teach similar courses elsewhere, or designed chips using the new methodology at various places.

And, we discovered some 20 years later that even Lynn Conway had an MIT connection we had been unaware of. She had in fact been an undergraduate physics major in the late 1950s, drawing inspiration from the likes of Norbert Weiner and Dudley Buck. (Buck, an EECS faculty member, died in 1959 at age 32).

She did not reveal this connection for a personal reason: although labeled a 'boy' at birth, she had always felt compelled to become a girl. She left MIT while a senior because of the stress of living with this issue. Nine years later she successfully completed her gender-transition, changed her name, and started her career all over again in a new identity. However, she kept her gender history as secret as possible, even after joining the University of Michigan faculty, until about 1999 when reports about her early research work began to circulate. In recent years Lynn has taken a more public position, serving as a role model and advocate for transgender people. She also recently encouraged the IEEE to include anti-discrimination protections for gender identity and gender expression in the IEEE Code of Ethics.

Well done, Lynn.

Thirty years later, Lynn Conway returned to visit the scene of her successful MIT course. Photo, October 6, 2008, courtesy Lynn Conway

Read Lynn Conway's VLSI story: "MIT Reminiscences: Student years to VLSI revolution"

http://ai.eecs.umich.edu/people/conway/Memoirs/MIT/MIT_Reminiscences.pdf

Making 330 lbs of electronics, metal and hydraulics move like an athlete —

The goal is for greater speed and more fluid motion — the answer is to build more autonomy

Team MIT takes on the DARPA Robotics Challenge

"Our dream is to build machines that go where they're told and do what they're told."

Professor Seth Teller and co-lead Professor Russ Tedrake are developing machines in pursuit of this dream, as part of the MIT team they are leading in the DARPA Robotics Challenge (DRC). Teller is enthusiastic about the progress that Team MIT has made in the first two major rounds of this Department of Defense-sponsored competition, in which researchers from around the world strive to develop and operate robots that could save lives and prevent or mitigate devastation in future disasters.

Since March 2012, Teller, Tedrake and about 20 others from across MIT including faculty, staff, postdocs, PhD students, Masters students, and UROPs from EECS and the Department of Mechanical Engineering, the Center for Ocean Engineering, and the Department of Aeronautics and Astronautics, have focused their talents and drive on developing a humanoid robot that will meet (and, they hope, surpass) DARPA's requirements.

Like many other competing teams, Team MIT members chose to program a DARPA-supplied humanoid robot called Atlas, rather than build their own hardware. The team wanted to capitalize on its relative strength in algorithms and software systems, rather than expend significant effort on hardware design and development. This choice made particular sense for MIT, as the Atlas robot is manufactured by the local firm Boston Dynamics, co-founded by former EECS Professor and Artificial Intelligence Laboratory member Marc Raibert. After qualifying in June, MIT received its Atlas robot, with a listed value of $2 million, in August 2013.

Why humanoid?

Teller says: "For many task domains, humanoid robots are the future. If they are to work in a world of humans, negotiate our stairs, fit through our doors, and use our tools and appliances, a roughly human form will serve them well."

Atlas cuts an impressive figure, standing six feet two inches tall and weighing more than 330 pounds. Its black metal frame includes chrome caging surrounding its flexible torso, to which are attached two arms, two legs and a head. Its backpack compressor, driving 28 hydraulically-actuated joints, creates a loud droning sound, and multiple lights including a yellow beacon on its head signal bystanders to pay attention. Despite its connection by a flexible tether to electric power, cooling fluid, and external computers, Atlas looks relatively independent.

After successful completion of DARPA's Virtual Robotics Competition, held in simulation in June 2013, sixteen teams from various universities, industries and institutes competed in December 2013 in the first of two "Trials" to be held over the multi-year DRC competition. Teams demonstrated robots with both humanoid and non-humanoid forms attempting a series of tasks set by DARPA that include walking on uneven terrain, turning valves, handling and operating tools, dragging and hooking up firehoses, opening doors, climbing ladders and driving cars – with minimal input from remote human operators. MIT was one of the top eight finishers in December, earning a competition berth in the DRC Finals, expected to occur in mid-2015. The single top-scoring team at the Finals will take home a $2 million prize.

Teller and Tedrake anticipate that their approach, which combines high-level perception and decision-making by the human operators with low-level motion planning and controlled execution by the robot, will do well in the final stage of the competition. This confidence stems in part from the experi-

ence and infrastructure the team developed as part of the 2007-8 DARPA Urban Challenge, the goal of which was the development of a vehicle that could drive unoccupied, with no remote assistance, through an urban-like road network. Teller notes that "work from the labs of Professors John Leonard, Jon How, and Emilio Frazzoli not only paved the way for the current effort, but continues to help other robotics groups all over the world through their use of software tools that came out of MIT."

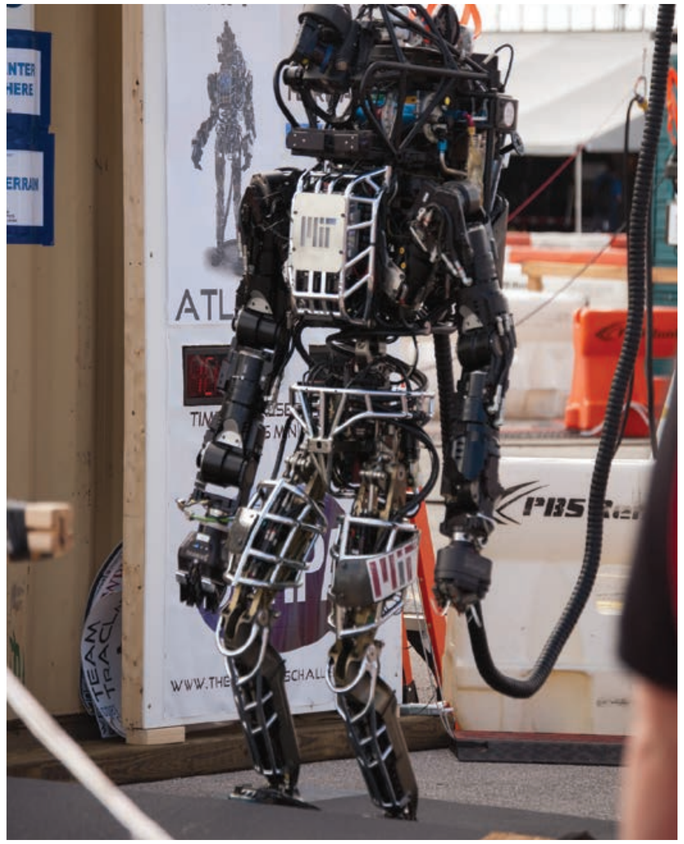
Nevertheless, there were challenging moments at the December trials.

EECS PhD graduate student Robin Deits, a student in Tedrake's Robot Locomotion Group says that the lowest and highest points of the December trial happened during the rough terrain-walking task. Besides glitches in the DARPA-supplied network infrastructure the day before competition began – for which DARPA asked MIT Team member and networking expert Toby Schneider to troubleshoot, later awarding him a medal for doing so – strong winds brought other challenges. After months of developing software and piloting the robot through the walking task, Team MIT members were dismayed when the robot fell over due to either sudden winds, or problems with the robot's tether. DARPA allowed the team to continue the run (after sacrificing one point, of the maximum four possible, due to the need for human intervention), and the MIT team piloted its Atlas over the finish line – something only two other teams managed to do.

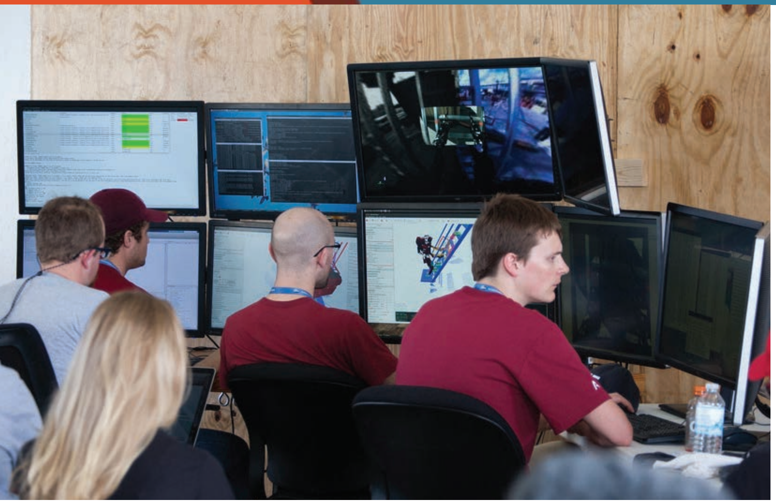
Tedrake notes that the robot's third-party hands and head are clearly things to avoid breaking in a robot fall. But Teller notes, "One of the big lessons we learned in December was that we can give up on perfection, and still get a really useful robot. What we care most about is not autonomy, but real-world utility." He agrees with Tedrake's metaphor about the robots' current slow speeds – "though our robot moves like a statue now, it is moving more like a dancer or an athlete every day."

The DRC goal is for greater speed and more fluid motion, and the answer to that challenge is to build more independence into the robot's behavior. MIT Research Scientist Maurice Fallon, who is the perception and infrastructure lead on the team, says that as the robot embodies greater autonomy, it will be more responsive in unexpected situations. "It's almost a philosophical thing," he suggests. "Can the robot make a decision? If the robot pulls on a door, and it doesn't open, will the robot figure that out – and adjust its behavior accordingly – or will it try to walk through anyway?"

Using the data collected by Atlas's cameras, laser range scanners, joint encoders, and inertial sensor, the operators can monitor the status of the machine and its surroundings as they command it to walk, climb and handle objects. While Fallon works on figuring out exactly where the robot is and how it's moving through space, Pat Marion, robotics software engineer and soon a first-year PhD candidate in the EECS Department at



Team MIT takes on the DARPA Robotics Challenge, *continued*



MIT, has taken the lead on using the data to semi-automatically fit object models, transmit the data and convert it to height maps used to help the robot place its feet.

Atlas interprets its surroundings through its perception system, but it truly engages the world as it is operated under a planning and control system that can be applied from the lowest levels – commanding each of the 28 joints – to the more basic but wider control of the upper body. Scott Kuindersma, postdoctoral associate working with Prof. Tedrake, is the planning and control lead for the MIT DRC team.

"Once the human operator has interpreted the robot's surroundings from available sensor data," Kuindersma, says, "the planning software works with the operations goal – such as walking to a door, for example. From there the controller, which runs on the robot, is responsible for actually carrying out the motions produced by the planner." If it sounds like he is overworked, part of Kuindersma's job is to organize the efforts of the large group of graduate students working on the planning and control aspects of the system. He notes, "That part is easy, because the students are all extremely talented and self-motivated."

Overall, Teller notes that the DRC has motivated Team MIT to incorporate their research advances into the DARPA tasks to achieve real-world utility. He is pleased that he and his students, whose previous focus had not been on human-like motion, are engaging in an intensive collaboration: "It's wonderful to work with and learn from Russ and his group."

Equally impressed with the power of collaboration, Russ Tedrake notes about the DRC experience: "It's a big commitment; the people who really contribute are giving their lives for this. It's a big deal." The dedication of the MIT team is highlighted by the fact that it was competing with teams from NASA and Lockheed Martin – while many of MIT's members were taking final exams!

Teller and Tedrake agree that the DRC has been a fantastic driver for robotics research. Tedrake says: "We are getting a really good litmus test of what we can and can't do in order to compare ourselves with the rest of the world. It's good for [upcoming] research and it's good for communicating our research to others." In the meantime, students from both of their labs end up working for or starting robotics companies that are in the news.

As robotics plays a bigger role in manufacturing, medicine and as yet only fantasized roles in society, Teller and Tedrake hope that the strides the MIT DRC players have made will lead to large scale alliances to sustain longer-term collaborations. Teller says, "The capabilities that we and other DRC teams are developing are bringing us closer to the day when these machines will do useful work in our public spaces, our workplaces, and our homes."

Visit: http://drc.mit.edu/
Meet the team:
http://drc.mit.edu/team.php

Engineering Design Studio brings 'mind and hand' to EECS *by Lauren J. Clark*

Students build their own electronics with help from Cypress Semiconductor and Agilent Technologies

Electrical engineering and computer science students at MIT are accustomed to designing the circuitry or control algorithms for, say, a robot. But they have largely been left out of building the robot itself. Now, a teaching laboratory called the Engineering Design Studio enables them to fabricate entire electronics-based systems.

"I had never soldered before I came [to MIT], I had never used a drill," says Lizi George '12 MEng'14, who worked as a teaching assistant in the new fabrication facility. "The majority of EECS students don't have that experience. But that's one of the goals of MIT—the 'mind and hand' motto, getting the hands-on experience."

George had a revelation when, as an undergraduate, she took machining and power electronics classes with Steven Leeb '87, a professor of EECS, and member of the Research Laboratory of Electronics. "I was totally struck—I had never built anything before," she says.

Leeb lent his own laboratory space to undergraduates. But the equipment wasn't up to date, and ongoing research projects took precedence over class assignments. He decided that MIT needed an advanced prototyping facility dedicated to EECS.

"If you think about MIT after World War II or during the sixties and seventies, that's when the students who were coming to us fixed cars or were ham radio operators," says Leeb, who earned his bachelor's, master's and PhD in EECS at MIT.

"The nature of how to connect engineering science with practical applications has changed. [With EDS], we want to convey some of the excitement of modern manufacturing." With laser cutting tools, a soldering station and other fabrication equipment, Leeb says, "students can easily create all the mechanical assembly required for an iPod dock and two speakers. They learn first-hand how two resistors are going to lower a voltage. It's not just an abstract problem."

Prof. Steve Leeb, third from left, instructs students on the basics of soldering circuit boards in 6.115, Microcomputer Project Laboratory in the new Engineering Design Studio.

Brian Sennett '13, an EECS graduate student and teaching assistant in EDS, says he knew in high school that he wanted to be an engineer. "When I came to MIT I was undecided between EECS and mechanical engineering," he says. "I liked computers, so I gravitated to computer science. But I realized I'd rather do more hands-on building." EDS enables students like him to experience "how electrical things work with mechanical things," Sennett says. For his thesis, he is building a sensor system that will be able to detect whether and how many people are in a room based on their electrical properties.

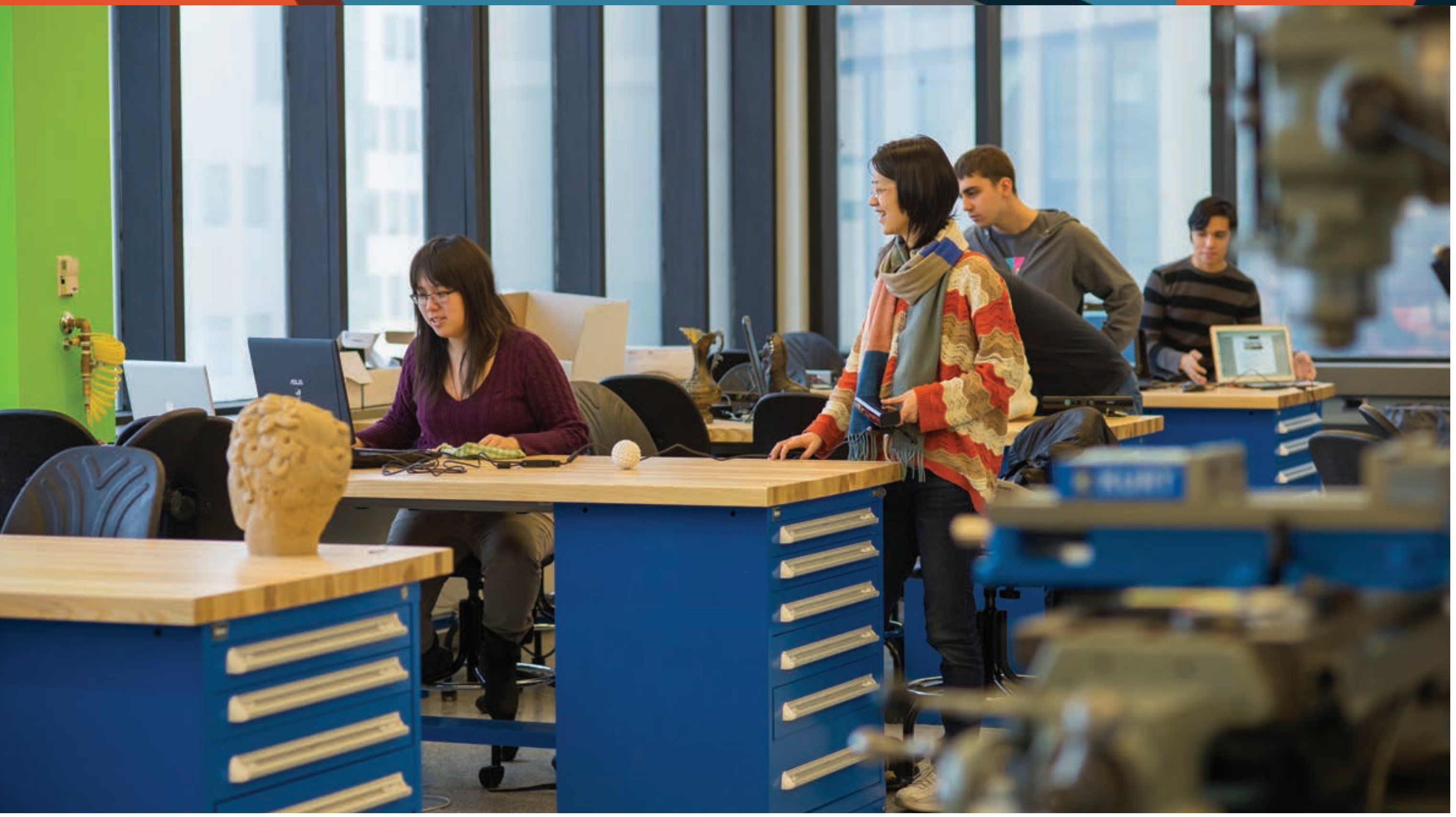
The students in EDS are making use of a game-changing technology called PSoC, or programmable system on a chip. Provided by Cypress Semiconductor, which sponsored the creation of EDS in Building 38, the chips combine the capability to receive analog input—from human touch or a temperature sensor, for example—and process that input digitally for the desired application. Previously, these different capabilities required separate components, such as amplifiers, an analog-digital converter, and a computer.

PSoC, says Leeb, "is like having a whole parts store on a chip. You can program it to be what you want." Currently, these chips are in use in everything from smart phones to automobile control consoles to computer-network servers.

Cypress CEO T. J. Rodgers, who created the Cypress University Alliance in 2006 as a way to engage with engineering students and educators, says that his company's alignment with MIT is strong.

"MIT students grasp what our design tools do for them, and we're trying to enable them to be the great engineers that we know they're going to be," Rodgers says. "We believe in getting the best minds and enabling them to develop the really cool things of the future. It's a fun and exciting process."

Engineering Design Studio brings 'mind and hand' to EECS, *continued*



Students in 6.S079, the new Computational Fabrication class taught by Prof. Wojciech Matusik, use the Microsoft Kinect to scan and acquire object geometry in the new Engineering Design Studio space, spring 2014.

As the head of the Cypress University Alliance, Patrick Kane works directly with MIT faculty and students. Providing educational tools, he says, is key. "Students should learn as many technologies as they can when they're in school."

Agilent Technologies Electronic Measurement Group (soon to be Keysight Technologies), a manufacturer of testing and measurement instruments, has partnered with the Cypress University Alliance in supporting EDS. It donated state-of-the-art mixed-signal oscilloscopes, which allow the precise observation and generation of electrical signals.

"Agilent is excited to support the EECS Department at MIT," says Jay Alexander, vice president and general manager of the company's Oscilloscope and Protocol Division. "It's an excellent opportunity to give back and to help enable the education of future engineers at such a prestigious research and teaching institution."

Anantha Chandrakasan, EECS department head and Joseph F. and Nancy P. Keithley Professor of Electrical Engineering, acknowledges Cypress's and Agilent's support. "Their involvement in EDS not only provides students with the most sophisticated equipment, but also the know-how to design and build their own systems. We are thrilled at their technical engagement with MIT."

Research Lab News

Practical Foundations for Software Correctness and Security

by Adam Chlipala, Assistant Professor, Computer Science and Artificial Intelligence Lab

Software is taking over the world, finding its way into devices within everyday objects, even in places that would have seemed like jokes 20 years ago if someone had predicted them. Software bugs can have dramatic costs in human safety and happiness. The software development methods applied broadly today seem to have hit a sort of complexity wall, where it is just too hard to get substantial software systems sufficiently right in the first place. Especially in the domain of computer security, we see important software systems "debugged" by releasing them and waiting for hackers, well-intentioned and otherwise, to expose serious security vulnerabilities that leak user data, cause physical infrastructure to malfunction, or worse.

A holy grail of software engineering is the development of systematic methods to build software that by construction is free of certain important kinds of defects. We could hope someday that the first release of a new, substantial software system can be trusted to be as reliable as a newly built bridge in the physical world. Formal logic is a popular starting point for efforts of this kind, and my group has been developing such a system called Bedrock. This work is joint with my students and postdocs Thomas Braibant, Santiago Cuellar, Patrick Hulin, Gregory Malecha, Duckki Oe, Peng Wang, and Edward Z. Yang.

The heart of trustworthiness in Bedrock is machine-checked mathematical proofs. Here one formalizes the rules of valid logical deduction, so that any proof of a theorem is a sequence of inferences of facts from previously proven facts, using only a small number of built-in inference rules, like modus ponens, which from the known facts "P" and "P implies Q" allows one to conclude "Q". A relatively small software program implements all of the rules, which can be chosen to be sufficient for encoding practically any convincing mathematical argument. Such technology (like in the Coq proof assistant system, which we use in Bedrock) can be applied to pure mathematics, as in a recent machine-checked proof of the four color theorem, but our interest is in checking proofs that establish good behavior of specific software programs.

Complex software systems are hard to get right because no one person can keep all of their details straight. Proof-checking software can be made simple enough that an expert can audit it effectively in a day of work. With such software in hand, we ask authors of software packages to tell us the **theorems** that characterize proper behavior and give us **proofs** that the theorems are true. Savvy end users can read the theorems, to make sure they correspond with expectations; but there is no need to read the proofs, because the small proof-checking software will validate that those proofs establish the claimed theorems.

It is quite a lot of work to write formal derivations at the level of detail that the small proof-checker understands. If we are ever to arrive at a world where software producers routinely provide proofs that their code operates securely, it is important to reduce the costs of constructing derivations.

One key technology here is **automated theorem proving**, which can fill in the tedious reasoning steps within high-level arguments written by humans. We have spent a good deal of effort implementing such automation in Bedrock, to understand the complex combinations of features in modern software systems, including pointer-based data structures and function pointers.

Just as in classic software engineering, an important path to reducing the effort of proof construction is choosing the right **modular decomposition** of a software system. Some kinds of decomposition work through defining new programming languages that in the end compile to the assembly languages of real processors, which is the setting for the final theorems that we check in Bedrock. We have implemented **proved-correct compilers** for several higher-level programming languages, allowing programmers to think and prove at that level, while still in the end receiving theorems about the assembly code that actually runs.

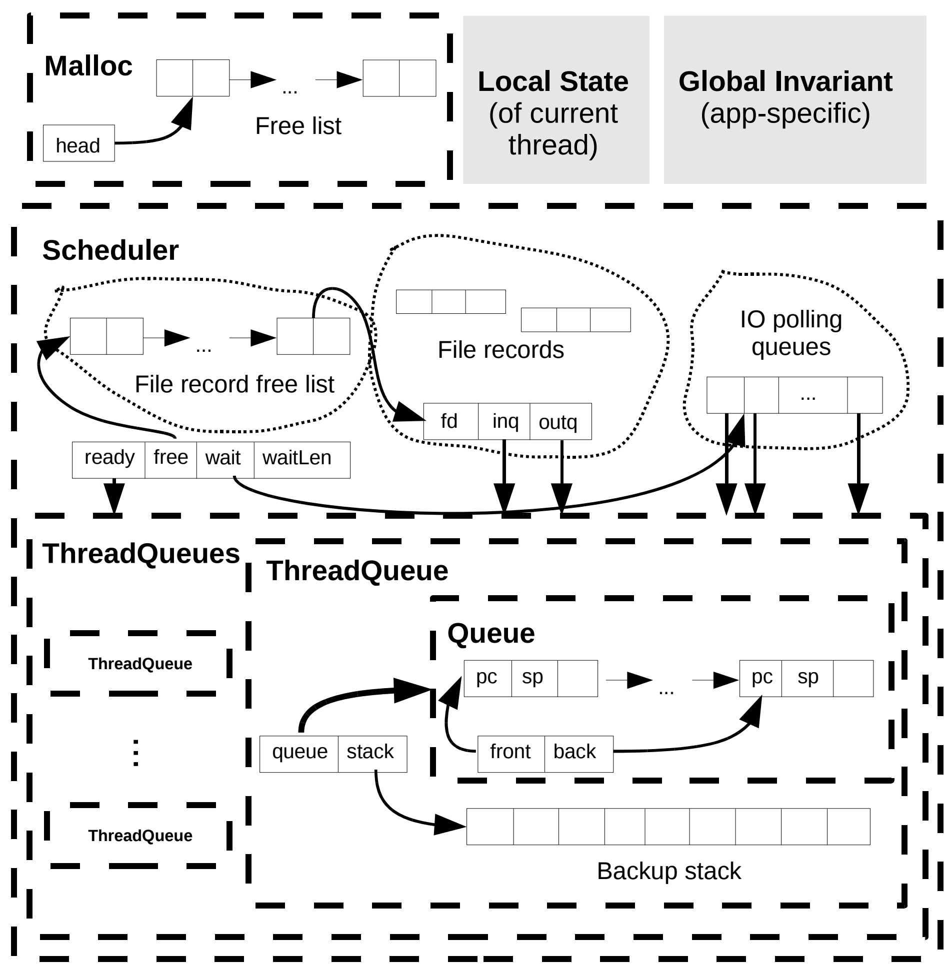
We also depend critically on more standard kinds of program decomposition into modules. It would be untenable to implement efficient dictionaries mapping keys to values for each new program. Instead, one wants reusable modules implementing dictionaries in different ways, employing **data abstraction** to hide implementation choices from client code. This kind of abstraction may also be used to hide proof details from programmers responsible for proving other modules, and the win in decreased complexity of arguments is even greater here than for traditional programming.

It is possible to structure traditional computer system software components in ways that support modular coding and proof of correctness. For instance, below is a schematic diagram of the modules in a verified multithreading library in Bedrock. Dashed rectangles indicate encapsulated modules that may only be accessed by other modules through narrow, well-defined interfaces.

Each module has a correctness proof, as do each of a number of applications that use this library, like a simple Web server.

The proofs of all modules may be linked together to produce a proof that the full set of software leads to the behavior that end users expect. Our current final correctness theorems make only relatively weak claims about systems accessing just the hardware resources that have been assigned to them. Our final goal is to prove stronger properties characterizing user expectations of observable program behavior.

Bedrock is available as open source software at:
http://plv.csail.mit.edu/bedrock/



Processing Queries over Encrypted Databases

by Nickolai Zeldovich, Associate Professor, Computer Science and Artificial Intelligence Lab

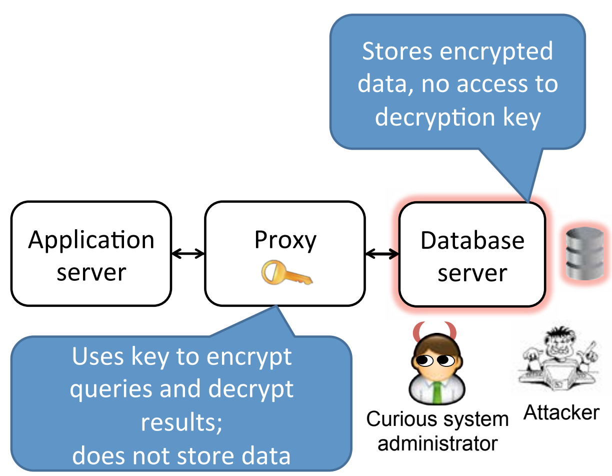
Theft of confidential information, such as credit card and social security numbers from computer systems, is a signicant problem. Unfortunately, experience suggests that the traditional approach to security—preventing all compromises in the first place—is not working. Compromises are inevitable in any real, complex system. Programmers make mistakes when writing code, and many security vulnerabilities arise due to coding mistakes. Even if there were no software bugs, administrators would still make mistakes in setting up security policies, and users would still choose passwords that can be guessed by adversaries. Instead of trying to prevent all compromises, a better plan would be to build systems that provide security despite compromises.

One promising approach for providing security despite compromises is encryption: an adversary that breaks into a server storing encrypted data will not get access to confidential information, unless they have access to the decryption key. The challenge is that, in order to do anything useful with the data, this same server must typically decrypt the data, requiring access to the decryption key. But if the server has access to the decryption key, so would an adversary that breaks into that server, defeating the point of encryption.

A recent theoretical breakthrough by Craig Gentry, reasearcher at IBM, demonstrated the existence of fully homomorphic encryption (FHE): given encrypted data, FHE enables an untrusted server to compute any function of that data, and produce an encrypted result, all without decrypting the data [1]. In principle, if servers stored only FHE-encrypted data, they could process it without access to decryption keys, and adversaries would get no sensitive data from a compromised server. However, FHE is too inefficient in practice, with overheads on the order of 10^9.

In our recent research, Raluca Ada Popa, Hari Balakrishnan, and I have shown that there are important classes of computations that can nonetheless be made to run efficiently over encrypted data. Consider a database server, which often stores all data in an application, and which executes queries issued by the application over that data. These database queries, written in SQL, are constructed using a small number of primitive operations, such as checking if some field in a record is equal to a given value, sorting records, or performing keyword search.

Our insight was that, for many of these query operations, we can construct efficient encryption schemes that enable a server to perform that operation over encrypted data. The simplest example is equality: if data is encrypted with a deterministic encryption scheme, a server can check if two data items are equal simply by checking if their encryptions are equal. Other schemes have been developed for keyword search over encrypted data [4], and we have also developed a secure order-preserving encryption scheme [2], which ensures that the ciphertexts preserve the sort order of the plaintext data, and allows a server to sort or compare encrypted data values.



Using a collection of such encryption schemes, we built CryptDB [3], the first practical system that can execute most SQL database queries over encrypted data, without revealing plaintext data or decryption keys to the database server. CryptDB works as a proxy, intercepting SQL queries from the application and rewriting them before forwarding the queries to a database server storing encrypted data. When the database server sends encrypted results back, the proxy decrypts them before forwarding them to the application. Using a trace of queries from a popular database server at MIT used by many web applications, we found that CryptDB's approach can execute queries on encrypted data for over 99% of columns. In terms of performance, one surprising result is that processing queries on encrypted data with CryptDB costs only 27% in throughput for the popular TPC-C database benchmark.

One challenge that faced CryptDB is that different encryption schemes can reveal different information about the data. To avoid revealing too much information about confidential data, we came up with a technique called onions of encryption that allows CryptDB to adjust encryption schemes for each data item at runtime, thereby revealing only the encryptions necessary to execute the given queries, and enabling CryptDB to provide provable, well-defined confidentiality guarantees.

A limitation of CryptDB's approach is that it can execute only queries that match its set of efficient encryption schemes. This works well for certain workloads, such as web applications, but for a more complex workload like the TPC-H database benchmark that models complex analytical queries processing large data sets, CryptDB can handle just 4 out of 22 queries. However, in collaboration with Stephen Tu, Sam Madden, and Frans Kaashoek, we showed that it is possible to efficiently run more complex computations on encrypted data as well.

The insight lies in running most parts of the query on the server over encrypted data, and running the rest of the query on the client on decrypted data, since the client has access to decryption keys. Specically, we built a system called Monomi [5] that can execute arbitrarily complex queries over an encrypted database. By precisely modeling the cost of server-side and client-side computation and the cost of transferring and decrypting data, and taking into account past query and data patterns, Monomi can determine the best encryption schemes to store on the server, and can choose an optimal strategy for executing a given query across the client and the server. Using these techniques, Monomi can execute arbitrary SQL queries on an encrypted database, and it achieves a surprisingly low 24% overhead for the TPC-H benchmark.

There are a number of important questions that remain in this area. What can an adversary learn from the different encryption schemes employed by CryptDB, and how damaging would this be to an overall application? How can we verify if the results returned by a database server are correct? Can similar techniques be applied to systems outside of databases? For instance, can this approach be pushed further in the context of web applications, so that all encryption and decryption happens in the user's web browser, and no plaintext data is ever sent out of the user's computer? What additional encryption schemes might be required in practice to compute over encrypted data? We hope to answer some of these questions in our future work.

Our papers and software are available at:
http://css.csail.mit.edu/cryptdb/.

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[2] R. A. Popa, F. H. Li, and N. Zeldovich. An ideal-security protocol for order-preserving encoding. In *Proceedings of the 34th IEEE Symposium on Security and Privacy*, pages 463-477, San Francisco, CA, May 2013.

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Selfish and Competitive Routing in a Network under Uncertainty

by Patrick Jaillet, Professor, Laboratory for Information and Decision Systems

Imagine . . . It is 7am, you are home sipping your favorite coffee, the sky is grey, and you have just looked at what you have to do before your business meeting in downtown Boston at 8:30am. All in all, you have about 90 minutes, in order to drop your daughter at school in Cambridge sometime before 8am, buy this special loaf of bread for tonight at your favorite bakery not far from the school (if street parking is available), and who knows, time permitting, for picking up your forgotten laptop at your office at MIT. If no-one else would be on the street during that time, barring some unforeseen technical problem with the car (life is uncertain!), all of this could easily be done, with enough time to arrive early at the 8:30am meeting, including the luxury of getting that extra latte at the nearby coffee shop.

But, for some reason, other people will probably be driving on the streets as well (how could you pay them to stay off the streets, or take the subway?). And it looks like it is about to rain, and other people (but not you, of course) drive erratically under such conditions.

Aren't you glad that at least you have access to your smartphone with no less than three competing apps giving you advice on how to go from A to B, with color coded choices (avoid red, pick green, choose orange at your own risk). You are even a member of a social network with "real-time" alerts on traffic jams, accidents, etc. (you sometimes post, but rarely; you aren't even sure that you want to be associated with some of the members who clearly have nothing else to do but flood the site with dubious warnings; you even wonder if they don't do it just to divert the traffic, and get the road to themselves).

Sounds familiar?

Well, trying to develop tools (mainly algorithmic ones) to meet such typical individual (selfish-optimizer) behaviors and do it in a way that is 1) robust against exogenous uncertainties (e.g., weather) or endogenous ones (individual user behaviors), 2) scalable (time, space, number of users), and 3) avoids chaos at the aggregate level (with tens of thousand of users) are some of the challenges that our research group is trying to address within the Singapore-MIT (SMART) future mobility research program[1].

[1]A large five-year research program involving 10 MIT PIs, several of whom are also in EECS and/or in LIDS (Profs Emilio Frazzoli, Li-Shuan Peh, Daniela Rus, and Dina Katabi).

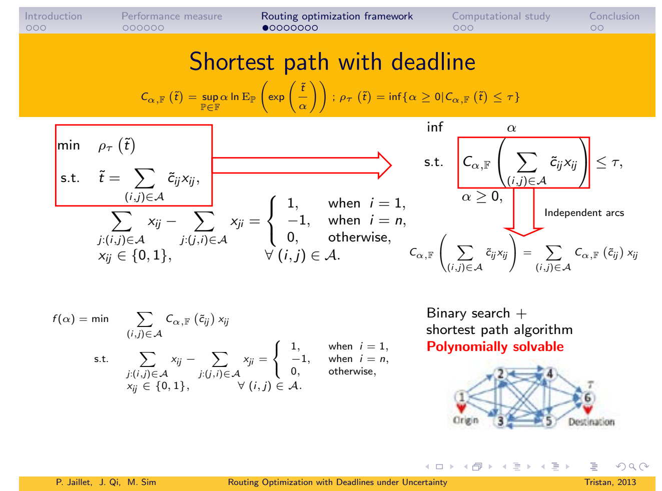
This line of work is part of our goup's long-term research focus on methodologies for online, stochastic, and/or data driven optimization. Other applications within our research group include Internet auctions and advertising, health-care applications (dynamic matching in the kidney donor market), container port optimization, and other dynamic matching in social networks (e.g., job market exchanges).

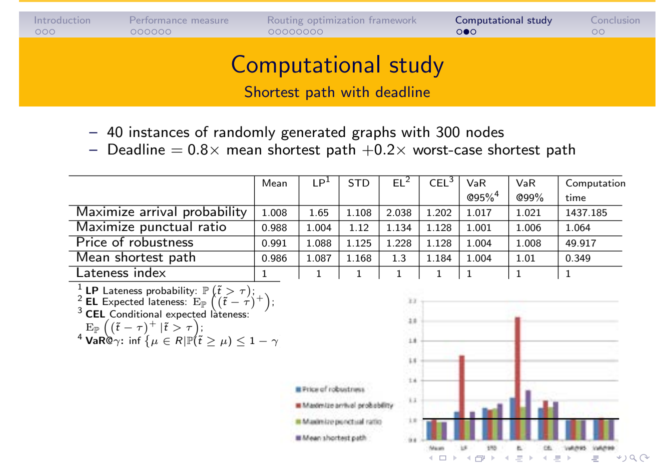
Illustration 1: Routing Optimization with Deadlines under Uncertainty

We consider here a class of routing optimization problems on networks with deadlines imposed at a subset of nodes, and with uncertain arc travel times. Routing decisions are made prior to the realization of uncertain travel times. The goal is to find routing policies such that arrival times at nodes respect deadlines "as much as possible".

We propose a precise mathematical framework for defining and solving such routing problems. We first introduce a performance measure, called lateness index, to evaluate the deadline violation level of a given policy for the network with multiple deadlines. The criterion can handle risk, where probability distributions of the travel times are considered known, and ambiguity, where these distributions are partially characterized through descriptive statistics, such as means and bounded supports.

We show that for the special case in which there is only one node with a deadline requirement, the corresponding shortest path problem with deadline can be solved in polynomial time under the assumption of stochastic independence between arc travel times. This is in contrast to all previous stochastic versions of shortest path problems.





For the general case, we provide two mathematical programming formulations: a linear decision rule formulation, and a multi-commodity flow formulation. We develop practically "efficient" algorithms involving Lagrangian relaxation and Benders decomposition to find the exact optimal routing policy, and give numerical results from several computational studies, showing the attractive performance of lateness index policies, and the practicality associated with the computation time of the solution methodology.

With the proposed optimization criterion and distributional ambiguity formulation of uncertainty, our model can be applied to transportation networks, e.g., for delivery service providers to route their vehicles, where multiple vehicles and uncertain service time could be incorporated, or for an individual to make his/her travel plan. Furthermore, it can be employed to solve routing problems in other applications such as those arising from telephone networks or electronic data networks.

In this project, we are interested in designing robust decision supports for taxi drivers in a large fleet (say 10,000 taxis) operating in a given urban environment (subdivided in many, say hundreds, of zones), in order to improve the overall availability (time and space) of taxis within the overall urban area (customer demand satisfaction) and increase the total revenue obtained by taxi drivers (acting individually with their own revenue maximization).

As opposed to some other routing problems in the context of large-scale dynamic networks, a key distinguishing feature of the problem involves some involuntary movements on the part of the individual agents (taxi drivers); when a taxi is hired by a customer, its next movement (destination) is uncontrolled and depends on the customer's requirement.

Initially, collaborators in Singapore had developed a stochastic selfish routing model, a variant of a congestion game, which accounts for involuntary movement of agents. By employing game theoretic models and extending adaptive learning approaches, the research demonstrated a significant improvement in performance of taxi drivers (15-40% increase in average revenue) and the overall system (5-10% reduction in starvation). Furthermore, the research was extended to situations with limited adoption (from taxi drivers) of the suggested decisions.

We have recently extended this research along several different dimensions. One of these corresponds to the analysis of robustness of computed strategies to changes in customer flow information. The current strategies for decision support are computed based on aggregate values of customer flow between various zones. While such an approach works well in expectation, we would like to understand and improve its performance in best and worst-case settings of customer flow.

As a first and critical step, one has to consider an adequate model for representing the robust decision of one selfish agent. In a recent Neural Information Processing Systems (NIPS'13) paper, we have proposed such a possible framework by seeking robust policies for uncertain Markov Decision Processes (MDPs). Most robust optimization approaches for these problems have focused on the computation of max-min policies, which maximize the value corresponding to the worst realization of the uncertainty. Recent work had proposed min-max regret as a suitable alternative to the max-min objective for robust optimization, but only with uncertainty over rewards only. We provide sampling-based algorithms that (a) handle uncertainties over both

Selfish and Competitive Routing in a Network under Uncertainty

Continued

transition and reward models; (b) incorporate dependence of model uncertainties across state, action pairs and decision epochs; and (c) allow scalability and quality bounds. Finally, we demonstrate the empirical effectiveness of our sampling approaches, providing comparisons against benchmark algorithms on two domains from the literature.

In very recent work, we have focused on the problem of optimizing social welfare in the context of selfish routing with involuntary movements. Building on classic selfish routing and stochastic game models, we have introduced a new model to accommodate these involuntary movements.

In the most general case of reward and transition functions in a non-atomic stochastic selfish routing game, we have proved that the policy optimizing social welfare will be the same for all agents. We have also provided efficient formulations for optimizing the social welfare for important and practical categories of reward and transition functions.

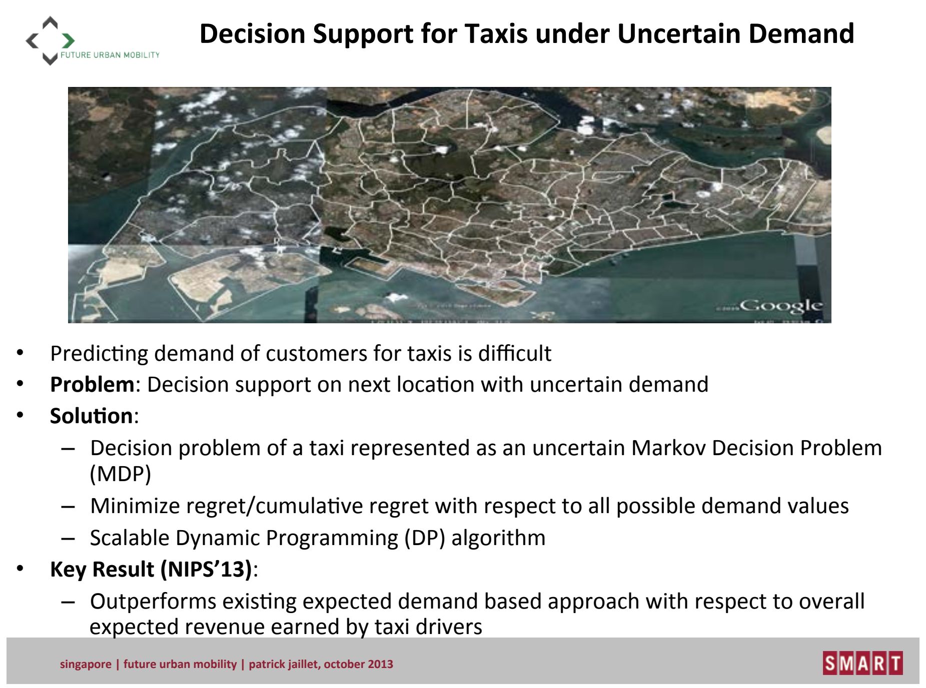


Illustration 2: Decentralized Optimization for Multi-Agent Stochastic Routing.

Quantum Photonic Technologies for Information Processing and Sensing

by Dirk Englund, Jamieson Career Development Professor, Microsystems Technology Laboratories and Research Laboratory of Electronics

In recent decades, researchers have recognized that the world of quantum mechanics holds enormous potential for new technologies that address unsolved problems in communications, computation, and high-precision measurements. Quantum key distribution now makes it possible to transmit information with unconditional security; quantum simulation protocols could solve intractable many-body problems such as high-temperature superconductivity, which in turn could revolutionize the way we produce and transmit energy; and quantum metrology techniques push the boundaries of precision measurements.

Efforts are underway across the globe to develop such technologies in a range of physical systems, including atoms, superconductors, and exotic topological quantum states in solids. As a specific example of, say, quantum simulation, suppose that we wanted to calculate the energy states of a small quantum system consisting of N spin-1/2 particles, such as electrons. Just to describe this state on a classical computer would require 2^N coefficients — a task that's practically impossible when N exceeds 60 or so, as it would require more than one million terabytes of classical memory. On the other hand, on a quantum simulator, the state could be represented with just 60 quantum bits, or qubits. Thus, the physical resources can be exponentially smaller than on a classical computer.

With my group, I'm focusing on developing quantum technologies in semiconductors, combining techniques from atomic physics and modern nanofabrication. In this approach, we encode information in light and matter — specifically, in quantum states of photons and electrons.

Quantum Photonic Processor

Among the various physical systems that are being studied to implement quantum memories, photons are particularly attractive. They can encode quantum states in several degrees of freedom, such as polarization or the photon's location in time and space.

For many quantum technologies, we need to control large numbers of photonic quantum states with high precision. This becomes difficult very quickly if we want to do so using traditional table-top optics. Fortunately, we can leverage new types of integrated photonic circuits to guide and control tens or hundreds of optical channels in waveguides, which are thin wires of semiconductors that can guide infrared photons with very low loss on a chip. Such photonic integrated circuits (PICs) offer a robust and scalable platform for implementing a number of proposed quantum technologies, including linear optics quantum computation, quantum simulation, and quantum communication systems.

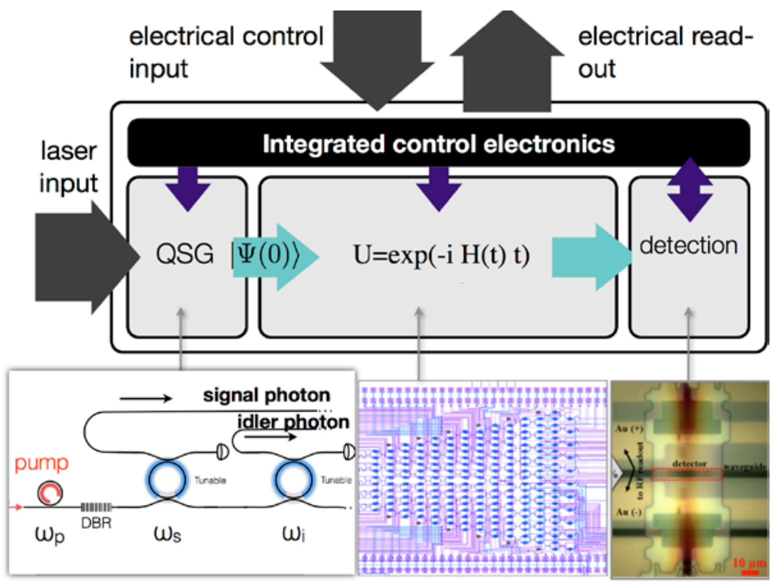


Figure 1. Process flow: A user-provided algorithm is converted to a machine executable using a compiler for the classical central processing unit (CPU) and the quantum photonic processor (QPP). The classical processor executes 'experiments' on the QPP for a specified number of repetitions or until an output with sufficient certainty is produced. The QPP consists of quantum state generator (QSG), the quantum photonic unitary (QPU), and the SNSPD detector array. Bottom row: Examples of QSG, QPU, and waveguide-integrated SNSPD (with the Karl Berggren group at MIT).

However, experiments in photon-based quantum information processing to date have been limited by three major obstacles: inefficient production of single and entangled photons; the difficulty of fabricating the potentially very complex PICs; and the measurement of quantum states of many photons across tens to hundreds of channels.

Continued

One of the major goals in my group and our collaborators' is to solve these problems by developing a silicon-based PIC that includes sources of photonic quantum states, a programmable network of waveguide channels to implement a particular quantum algorithm, and efficient detectors.

In recent theoretical work, we have shown that such a 'quantum photonic processor' (QPP) would enable the implementation of many proposed quantum algorithms based on linear optics. After initial trials with these kinds of chips, we hope to scale to larger and more powerful systems with more than ten photonic qubits; since each waveguide is just 500 nanometers in cross section, one can fit hundreds on a chip just a few millimeters across (allowing for some space between them). In addition to implementing known algorithms, we hope that this kind of programmable quantum processor will enable us and other researchers to prototype new algorithms rapidly and possibly to discover entirely new applications of small quantum systems.

Figure 1 (upper right previous page) shows the major components of the QPP. These chips are fabricated in silicon-on-insulator technology in collaboration with two leaders in the silicon photonics field, IBM and the OPSIS foundry. The initial optical state is generated using entangled photon sources based on nonlinear processes. This state then passes through the programmable optical network — basically a large array of waveguides with programmable couplings to implement a chosen transformation — followed by measurement using single-photon detectors, which are developed together with the group of Professor Karl Berggren at MIT. The transformation and detection realize the logic between the qubits. Each preparation, state evolution, and measurement represents one experiment, which is then repeated to build up statistics.

Quantum memories in diamond

Many applications require long-lived stationary quantum memories in addition to flying photonic qubits, which have a rather short life of at most a few hundred microseconds. One of the most promising quantum memories in semiconductors is the nitrogen vacancy (NV) color center in diamond, which consists of a substitutional nitrogen atom adjacent to a vacancy in the carbon lattice. The electron spin of the NV center is well isolated from the environment and represents an excellent quantum memory. To connect these NV memories to photons — our information transmitters — it is necessary to amplify the photon-electron interaction using optical resonators, or 'cavities'.

Figure 2 (above) shows a photonic crystal cavity in diamond

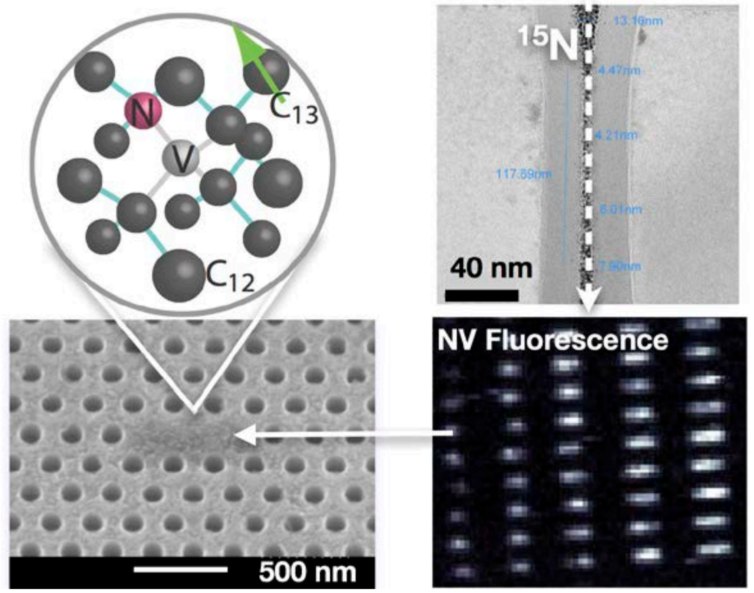


Figure 2. Interfacing quantum states between photons and electrons. Clockwise from top right: The nitrogen vacancy (NV) center in diamond; cross-section of silicon-based implantation mask for targeted implantation of nitrogen atoms into diamond; fluorescence of NV centers produced by nitrogen implantation and binding to crystal vacancies by annealing; single-crystal diamond photonic crystal nanocavity with implanted NV center.

that allows us to pass a photon about 10,000 times past an NV located in the cavity, while squeezing the photon into a small volume on the scale of a cubic wavelength. A strong interaction results between the NV spin state (our stationary qubit) and the photon (or flying qubit), which enables the transfer of quantum states between them. Recently, we developed a technique to position the NV with high precision inside the cavity by implanting nitrogen atoms through narrow masks, as shown on the top right of Figure 2. This advance in fabrication provides a way to produce hundreds of such NV-cavity systems with high yield. The goal, then, is to integrate these optically coupled NV quantum memories on photonic waveguide chips, much like the ones shown in Figure 1. The resulting chip would have the properties we desire in a general-purpose quantum information processor: many individually addressable quantum memories, efficiently interconnected via photons.

Quantum-enhanced sensing and imaging

The spin states of the NV are not only great memories, but also very sensitive probes of the NV's local environment. Pioneering work by groups at Harvard, the University of Stuttgart, Berkeley, U.C. Santa Barbara, and elsewhere, have already

demonstrated the NV as an excellent magnetometer, sensitive enough to detect single electron spins — and recently even nuclear spins. This could enable nuclear magnetic resonance imaging at the scale of single atoms, e.g., for visualizing the structure of individual proteins in solution.

Working with researchers in chemistry and neuroscience, we are now trying to use the NV to solve another problem, to optically image action potentials over thousands of live neurons at once. The ultimate goal is to observe real-time messaging in the mammalian brain. To this end, we have developed high-purity diamond nanocrystals — about 10-20 nm in diameter — containing NV centers with long-lived electron spin states and coated with molecules to selectively attach them to the cell membrane. *In vitro* proof-of-principle experiments already show that these NVs can report local electric fields with a time resolution similar to the duration of single-cell neuronal action potentials.

Now, we hope to translate these results into living tissue. Figure 3 (below) shows neurons in the hippocampal region of a mouse stained with diamond nanocrystals, seen as the bright spots under an optical microscope.

Rather than working with single NVs, one can amplify the read-out signal using NV ensembles in larger diamond crystals. For instance, we are developing a new type of clock based on the collective motion of about 100 million NV electron spins in a millimeter-scale diamond crystal resonator. This solid-state analog of an atomic clock could be very compact and integrated right with the electronics on a standard circuit board.

Looking forward to 'down there'

Richard Feynman's talk "There's plenty of room at the bottom" at the 1959 American Physical Society meeting famously helped inspire the development of nanotechnologies; but he also suggested the possibility for entirely new applications exploiting the rules of quantum mechanics: "When we get to the very, very small world we have a lot of new things that would happen that represent completely new opportunities for design. Atoms on a small scale behave like nothing on the large scale, for they satisfy the laws of quantum mechanics. So, as we go down there and fiddle around with the atoms down there, we are working with different laws, and we can expect to do different things."

Indeed, we now know that computers could be built to exploit these different laws to perform computations that are impossible with even the most powerful classical computers — whether today or fifty years from now. The emerging field of quantum information science has also shown us how to communicate with absolute security and how to measure at the limits allowed by physics. Over the next decades, we will be able to create new kinds of quantum states of nature, including states of many particles that are highly entangled. It is impossible to predict all the consequences, in part because we don't have the imagination or computing power to describe such systems. What we can predict is that there will be many exciting discoveries.

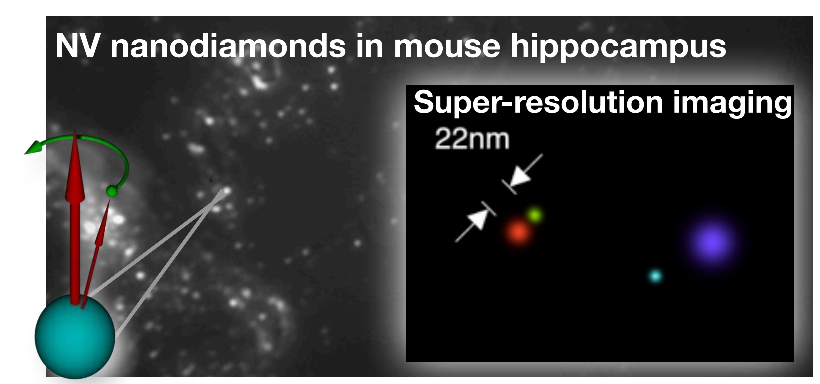


Figure 3. Diamond nanocrystals containing NV centers embedded on mouse hippocampal cells, in collaboration with the group of Rafael Yuste at Columbia University. Inset: super-resolution imaging using NV centers. (E. Chen et al, Nano Lett. 13, 2013)

Exploration in Flatland

by Jing Kong, Professor, Research Laboratory of Electronics and Microsystems Technology Laboratories

Graphene, a single layer of carbon atoms arranged in a honeycomb lattice, has attracted tremendous attention during the past decade. Historically it was called "monolayer graphite", and has been mostly studied on metallic substrates. The explosion of graphene research started in 2004 when Geim and Novoselov demonstrated that such a single atomic layer can be isolated on an insulating substrate, and exhibit remarkable properties. Since then, many further unique properties and great potential have been demonstrated with this fascinating material. More recently, the rapid advance in graphene has also inspired the investigations of other two-dimensional (2D) materials with many distinct and useful properties. Such possibilities have opened our eyes to an entire world of 2D crystals.

In fact, materials with confined dimensions (such as quantum dots, nanowires or nanotubes) have been a main focus of scientific investigations for several decades. The restrained dimensionalities bring many interesting properties to these systems that their bulk counterpart cannot offer. Among them, 2D materials bear the unique characteristic that they can be considered both macroscopic (in-plane dimension, thus easier for integration) and microscopic (out-of-plane dimension). Although a wealth of knowledge has been accumulated for thin film systems, the science of a truly 2D system has been a relatively unexplored topic.

With the enormous interest and need for these 2D materials, it is highly desirable to obtain them with high quality and in a controlled manner. The research focus of the nano-materials and electronics group led by Prof. Jing Kong has been on the synthesis and characterization of graphene and related 2D materials, using a chemical vapor deposition (CVD) method.

Figure 1, above, illustrates the CVD synthesis of graphene using metallic substrates. In a typical CVD synthesis, the metal substrate is placed inside a (quartz) tube furnace, which is heated up to high temperature (e.g. 1000°C). Hydrocarbon gas is introduced into the growth chamber and catalytically decomposed on the metal surface, leading to the growth of graphene. In order to isolate the graphene from the metallic substrate, a transfer technique has been developed and widely used: a polymer (Poly(methyl methacrylate), PMMA) layer is coated on the graphene first as a protective layer, followed by removal of the metal substrate via wet chemical etching. After thorough rinsing, the graphene/PMMA layer is transferred onto the target substrate, and lastly the PMMA is removed either by using acetone or via thermal annealing.

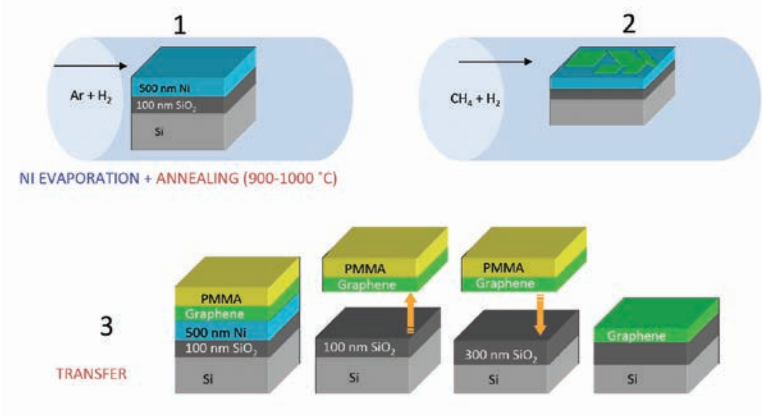


Figure 1. Illustration of the CVD synthesis of graphene using metallic substrates.

Figure 2a on the next page shows graphene that is transferred onto an Si substrate (with SiO_2) (left) and optical absorption of graphene in the UV-vis regime (right). This was among the very early samples taken when the synthesis and transfer techniques were developed in 2008. At present, roll-to-roll processing and production of much larger areas (~100 cm^2) have been demonstrated.

Monolayer hexagonal Boron Nitride (hBN) is the second member of the 2D family that entered the scene. It has a very similar honeycomb structure as graphene, but each hexagon is composed of alternating Boron and Nitrogen atoms. It has been called "white graphene" because apart from structure, in many aspects it has similarly remarkable properties as those of graphene, such as high mechanical strength and chemical stability. But "white graphene" is a direct bandgap (~6eV) semiconductor while graphene has no bandgap. It also has a wide range of applications based on its extraordinary properties, such as being a deep ultraviolet emitter, acting as a transparent membrane or dielectric layer, and able to be used for protective coatings. Particularly, it has been demonstrated as a superior substrate for graphene based devices — the on-substrate mobility of graphene on exfoliated single crystalline hBN is comparable to that of suspended graphene due to its ultra-flat and impurity-free charge surface. A giant flexoelectric effect was also predicted for monolayer hBN, suggesting its potential for ambient agitation energy harvesting. The CVD synthesis of hBN has also been under investigation. Compared to graphene, hBN is more challenging to grow. Nevertheless, there have already been some encouraging results.

Figure 2b (right, middle panel) shows the optical image of monolayer hBN transferred on Si substrate (with SiO_2) and on quartz substrate (inset). The right panel shows transmission electron microscope images of the hBN layer on the edge. Both monolayer and bilayer hBN can be seen here. The synthesis of hBN is also very similar to graphene — a metallic substrate is used and the synthesis is at high (~1000°C) temperature — except that a different precursor (containing both B and N) is used. Afterwards hBN can be transferred to desired substrates using the same method as shown in Figure 1 (step 3).

Although graphene has many outstanding characteristics, it lacks a bandgap, making it very challenging for a graphene transistor to be turned off. Ways to overcome this problem have been proposed and are under investigation, such as applying an electric field across the two layers of AB-stacked bilayer graphene to open up a bandgap. In the meantime, layered transition metal dichalcogenides (LTMD) (such as MoS_2, WSe_2) in the 2D material family have attracted extensive attention as atomically thin semiconductors.

More interestingly, due to quantum confinement, the bandgaps of these semiconductors depends on their layer number, and they change from indirect bandgap to direct bandgap in the transition to monolayer. Thus the LTMD monolayers, being considered as the thinnest semiconductor, exhibit great potential both for advanced short-channel devices and optoelectronic devices. Furthermore, the broken inversion symmetry of the monolayer and the strong spin-orbit coupling lead to a fascinating interplay between spin and "valley" (i.e., valley in the electronic band structure) physics, enable simultaneous control over the spin and valley degrees of freedom, and create an avenue toward the integration of spintronics and valleytronics applications.

The CVD method has also been applied to the synthesis of the LTMD materials. Interestingly, it was found that it is easier to directly use insulating substrates, while most metallic substrates will have a severe sulfurization problem. By using organic aromatic-based small molecules as "seeds", mm^2 to cm^2 sized monolayer MoS_2 has been grown on Si substrates with SiO_2. Figure 2c, bottom right, shows the optical image of individual triangular MoS_2 flakes grown on Si (with SiO_2) substrates, and the photoluminescence spectrum on the right shows a peak at ~1.8 eV from monolayer MoS_2.

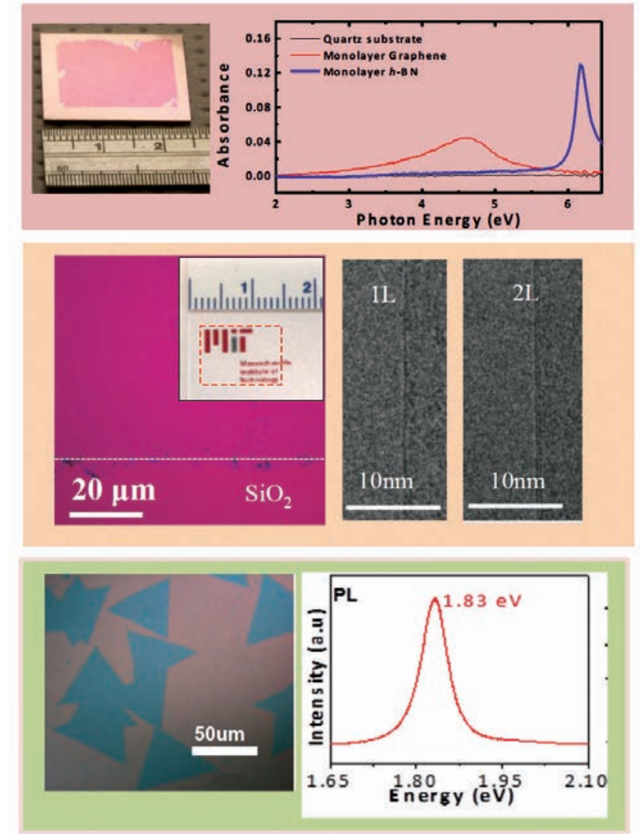


Figure 2: (a top) Photograph of 2 x 2cm^2 graphene trasferred onto a Si/SiO_2 substrate (left) and optical absorption of graphene, monolayer hBN. (b middle) Optical image of monolayer hBN transferred onto a Si/SiO_2 substrate (left) with hBN transferred to a quartz substrate (left inset) and transmission microscope image of monolayer (1L, middle) and bilayer (2L) hBN. (c bottom) optical image of triangular monolayer MoS_2 flakes directly grown on Si/SiO_2 substrates (left) and photoluminescence spectrum from monolayer MoS_2(right).

The investigative efforts on 2D materials have seen rapid growth in the past few years. Many exciting possibilities with new phenomena remain to be discovered and novel devices are yet to be seen. There has been constant need for the development of better synthesis methods and processes in order to provide high quality materials. Better capabilities will greatly facilitate the explorations in this Flatland.

Faculty Features

Faculty Awards

Anant Agarwal
Elected to American Academy of Arts and Sciences
Distinguished Alumnus, IIT Madras, 2014

Saman Amarasinghe
2013 IEEE/ACM CGO for most influential paper

Tim Berners-Lee
2013 inaugural Queen Elizabeth Prize for Engineering in the creation (25 years ago) of the World Wide Web

Srini Devadas
2014 ASPLOS Most Influential Paper Award; IEEE Computer Society's 2014 Technical Achievement Award
50th Design Automation Conference (DAC) Top 10 Cited Author, Best-Paper Hat Trick Award

Mildred S. Dresselhaus
Materials Research Society 2013 von Hippel Award

William T. Freeman
Test-of-time awards from the 2013 International Conference on Computer Vision and the 2013 IEEE Automatic Face and Gesture Recognition Conference

James Fujimoto
2014 IEEE Photonics Award

Shafi Goldwasser, Silvio Micali
Association of Computing Machinery's (ACM) A.M. Turing Award for pioneering work in cryptography and complexity theory

Qing Hu
Boston Museum of Science and Boston Patent Law Association honor 2013 Inventions & Inventors for Terahertz Quantum Cascade Lasers and Real Time Terahertz Imaging

Faculty Awards, *continued*

Piotr Indyk
2013 Simons Investigator
2012 ACM Paris Kanellakis Theory and Practice Award

Dina Katabi
2013-14 MacArthur Fellow
2013 Association of Computing Machinery (ACM) Fellow
2012 ACM Grace Murray Hopper Award

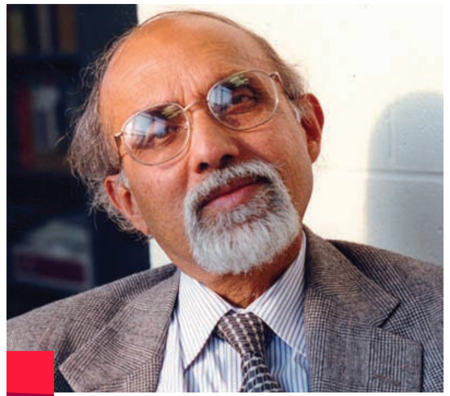
Charles E. Leiserson
IEEE Computer Society 2014 Taylor L. Booth Education Award
2013 ACM Paris Kanellakis Theory and Practice Award

Andrew W. Lo
Elected to American Academy of Arts and Sciences

Tomás Lozano-Pérez
2014 MacVicar Faculty Fellow

Timothy K. Lu
2013 ONR Young Investigator Prize

Marvin Minsky
BBVA Foundation Frontiers of Knowledge Award
Dan David Prize 2014 Future: Artificial Intelligence, The Digital Mind



Sanjoy Mitter
2013 Fellow of the International Federation of Automatic Control

Alan V. Oppenheim
2013 Capers & Marion McDonald Award for Excellence in Mentoring and Advising

Tomás Palacios
2013 Royal Spanish Academy of Engineering Agustin de Betancourt Award

Pablo Parrilo
2013 INFORMS Optimization Society Farkas Prize

Jeffrey S. Shapiro
2013 Fellow of SPIE, the International Society for Optics and Photonics

Nir Shavit
2013 Association of Computing Machinery (ACM) Fellow

Henry I. Smith
2014 National Academy of Inventors Fellow

Vivienne Sze
2013 RLE Jonathan Allen Junior Faculty Award

Peter Szolovits
2013 American College of Medical Informatics (ACMI) Morris F. Collen Award of Excellence

Jacob White
2013 50th DAC ACM/IEEE A. Richard Newton Technical Impact Award in Electronic Design Automation

Alan S. Willsky
2013 IEEE Signal Processing Society Award

Faculty Research and Innovation Fellowships for 2013-2014

Marc Baldo

Regina Barzilay

Samuel Madden

David Perreault

The recipients of the Faculty Research and Innovation Fellowship (FRIF) for 2013 - 2014 are Marc Baldo, Regina Barzilay, Samuel Madden and David Perreault. The FRIF, in its third year, is given to recognize senior EECS faculty members for outstanding research contributions and international leadership in their fields. Winners of the FRIF receive three years of gift funding as discretionary support of new or ongoing research projects.

Marc Baldo's research focuses on building inexpensive and highly efficient organic light emitting devices and solar cells. His seminal contributions hinge on engineering the spin of excitons, which are quasiparticles of energy that mediate the emission and absorption of light within organic semiconductors. He has mixed excitons to quadruple the efficiency of LEDs, and split excitons to obtain more than one electron per photon in solar cells. Marc is currently the director of the Center for Excitonics at MIT. He is a member of the Research Laboratory of Electronics (RLE) at MIT.

Regina Barzilay studies how computers can understand and generate human language. She develops models of natural language, and uses those models to solve real-world language processing tasks. Her research enables the automated summarization of documents, machine interpretation of natural language instructions, and the deciphering of ancient languages. She is acknowledged to be a world leader in computational linguistics. She is a wonderful mentor to her students, who have received recognition within MIT and internationally for their doctoral theses and their research. She is a member of the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL).

Samuel Madden works on databases and computer systems. His research ranges over data management, live sensing, and networking, and he is broadly known for his contributions in sensor data management (TinyDB and CarTel) and database storage (C-Store and H-Store). Professor Madden is a leader in the data management community, with a number of award papers in top conferences over the past few years. His recent research efforts include crowd-sourced database, data management for the cloud, and interactive data visualization. He leads the BigData@CSAIL initiative and directs the Intel Science and Technology Center (ISTC) in Big Data. He is a member of CSAIL.

David Perreault's research focuses on the design, manufacturing, control and application of power electronics. He has made outstanding contributions to the development of power converters operating at very high frequencies and in their use to benefit efficiency and performance in renewable energy, lighting, communications, computation and transportation. He is co-founder of Eta Devices, a startup company focusing on high-efficiency RF power amplifiers. Professor Perreault is a Fellow of the IEEE and co-author of six IEEE prize papers. He is a member of both the Microsystems Technology Laboratories (MTL) and RLE at MIT. Prof. Perreault was appointed EECS Associate Department Head in November 2013. (Read more on page 43).

Erik Demaine is the 2013 Steven and Renée Finn Innovation Fellow

Professor Erik Demaine was selected as the Steven and Renée Finn Innovation Fellow for 2013-2014. In announcing this honor, Department Head Anantha Chandrakasan said that MIT EECS alumnus Steven Finn and his wife Renée established the fund to provide tenured, mid-career faculty in the department with resources to pursue new research and development paths, and to make potentially important discoveries through early stage research. The Steven and Renée Finn Innovation Fund provides a funding of $75,000 to the recipient. Professor Asu Ozdaglar was selected in 2012 as the inaugural Steven and Renée Finn Innovation Fellow.

Erik Demaine has been a faculty member in the EECS Department and Principal Investigator in the Computer Science and Artificial Intelligence Lab since 2001. His research interests range throughout algorithms — from data structures for improving web searches to the geometry of games, puzzles and magic tricks.

As a recipient of a MacArthur Fellowship in 2003, he was described as a "computational geometer, tackling and solving difficult problems related to folding and bending — moving readily between the theoretical and the playful, with a keen eye to revealing the former in the latter."

Erik co-wrote a book about the theory of folding, together with Joseph O'Rourke (Geometric Folding Algorithms, 2007), and a book about the computational complexity of games, together with Robert Hearn (Games, Puzzles, and Computation, 2009). With his father Martin, Erik's interests embrace the connections betwen algorithms and art. This father-son collaboration has resulted in the creation and display of their curved origami sculptures in the permanent collections of the Museum of Modern Art in New York, and the Renwick Gallery in the Smithsonian. Erik is also featured in the origami documentary "Between The Folds" (2008).

Erik Demaine has received numerous awards including the Ruth and Joel Spira Award for Distinguished Teaching (2004), the NSF CAREER award (2004), the Esther and Harold E. Edgerton career development chair (2005), the Alfred P. Sloan Fellowship (2006), an honorary Doctor of Laws degree (2007), the International Francqui Chair of Belgium and Francqui Gold Medal (2007), the Katayanagi Emerging Leadership Prize (2008), the Presburger Award (2013), and a Guggenheim Fellowship (2013).

Jeffrey H. Lang appointed to the Vitesse Professorship in EECS

Professor Jeffrey H. Lang was appointed to the Vitesse Professorship in Electrical Engineering and Computer Science, effective July 1, 2013 as announced to members of the EECS Department by Department Head Anantha Chandrakasan in late spring 2013. The Vitesse Chair was established in 2000 to honor the Vitesse Semiconductor Corporation, a company co-founded in 1984 by former MIT students. The first chair holder was Prof. Clifton G. Fonstad Jr.

The selection of Prof. Lang as the new Vitesse Chair holder recognizes an EECS faculty member who has demonstrated exceptional commitment to teaching, research, mentoring and service in the Department. Upon completion of three Course 6 degrees at MIT (SB '75, SM '77 and PhD '80 with a doctoral thesis on electrostatically-shaped reflecting antennas co-supervised by former professors David Staelin and James Melcher), Prof. Lang joined the MIT faculty in 1980, becoming full professor in 1992. He is a member of the Research Laboratory of Electronics and the Microsystems Technology Laboratories.

Prof. Lang has devoted himself to developing and teaching a wide range of classes in the areas of circuits and electromagnetics. He began teaching 6.002 (Circuits and Electronics) in 1992; together with Prof. Anant Agarwal he modernized that subject in 2000. That effort led them to co-author the now widely used 6.002 textbook, Foundations of Analog and Digital Electronic Circuits. Beginning in the early 1980s, Prof. Lang taught 6.601 (Fields, Forces and Motion), and the core electromagnetics subjects 6.013 and 6.014. He took part in their collective reorganization in 2003. Prof. Lang also led the creation of the digital control systems lab 6.142, and in collaboration with Prof. George Verghese, he created the graduate class 6.238 on the control of electric machines. Prof. Lang received MIT's Harold E. Edgerton Award in 1986 and the Graduate Student Council Teaching Award in 1987. More recently, he was appointed as the EE Graduate Admissions Chair in Fall 2012, and played an important role in the implementation of guaranteed support for all incoming students.

An IEEE Fellow (1998), Prof. Lang has written over 250 papers on the design, analysis, estimation, and control of high-performance electromechanical energy conversion and motion control systems, with applications ranging from novel micro/nano-electromechanical systems (MEMS/NEMS) to energy

harvesters, robots, white goods and electric vehicles.

His current research focuses primarily on power MEMS/NEMS, including motors, generators, relays, switches, pumps, and valves, some of which have demonstrated record power and/or torque densities. He has also worked to develop various MEMS sensors. Prof. Lang has often collaborated on cross-disciplinary projects, such as his recent development of high-torque-density motors for use in the MIT Cheetah Robot, which should allow the machine to reach speeds of up to 35 mph.

Ron Rivest is appointed to the Vannevar Bush Professorship in EECS

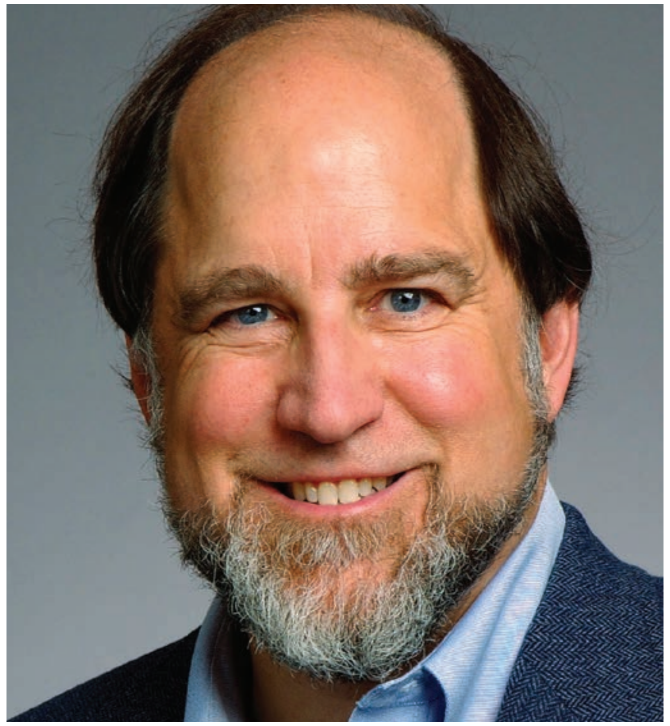
Ron Rivest was appointed the new holder of the Vannevar Bush Professorship — announced by EECS Department Anantha Chandrakasan in October 2013. The Bush Chair is an Institute-wide professorship established in 1982 as a memorial to one of the outstanding scientists and engineers of the twentieth century.

As one of the founding fathers of modern cryptography, Ron Rivest worked with colleagues Len Adleman and Adi Shamir to create the public key system, known worldwide as the RSA system – one which has resisted sophisticated attack (in the more than four decades since its invention) and which is based on the first known algorithm that supports both digital signing (authenticating the sender) and encryption. Besides playing a critical role in the success of today's Internet commerce, the RSA code on which the system is based represents an example of elegant and abstract theory that has ultimately had immense practical impact.

Prof. Rivest is also a dedicated teacher, mentor and educator. Professors Rivest and Leiserson co-developed 6.046, Introduction to Algorithms – a course which Rivest has taught over a dozen times. Professor Rivest co-authored the text (by the same name) with colleagues Professors Cormen, Leiserson and Stein. This text, also dubbed the "CLRS book", has been listed as the best selling textbook in all of Computer Science – over 500,000 copies of this text have been sold. Generations of computer programmers, world-wide, have learned their craft from the CLRS book, considered the standard reference on the subject.

Prof. Rivest, formerly the Viterbi Professor of Computer Science in the EECS Department at MIT, is a member of the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL), a member of CSAIL's Theory of Computation Group and is a leader of the CSAIL Cryptography and Information Security Group. Prof. Rivest has made significant contributions in many other areas of computer science including computer-aided design of integrated circuits, data structures, computer algorithms and systems for electronic voting. In the past he has also worked extensively in the area of machine learning.

Prof. Rivest has served as a Director of the International Association for Cryptologic Research, the organizing body for the Eurocrypt and Crypto conferences, and as a Director of the Financial Cryptography Association. He is a founder of RSA Data Security,



which was bought by Security Dynamics. The combined company was renamed to RSA Security and later purchased by EMC. He is also co-founder of Verisign and of Peppercoin.

As a member of the CalTech/MIT Voting Technology Project, Prof. Rivest served on the Technical Guidelines Development Committee (TGDC), advisory to the Election Assistance Commission. In this role, he developed recommendations for voting system certification standards. He was chair of the TGDC's Computer Security and Transparence Subcommittee and serves on the Advisory Board of the Verified Voting Foundation. He was a member of the 'Scantegrity' team developing and testing voting systems that are verifiable "end-to-end".

Daniela Rus is appointed as Andrew (1956) and Erna Viterbi Professor in EECS

Professor Daniela Rus was appointed as the Andrew (1956) and Erna Viterbi Professor of Electrical Engineering and Computer Science. Department head Anantha Chandrakasan announced the appointment in October, 2013, noting that the Viterbi Chair was established in 1999 by Andrew and Erna to recognize significant contributions in the field of communications and signal processing. Prof. Ronald Rivest was the first chair holder of the Viterbi Professorship.

Professor Rus, the Director of MIT's Computer Science and Artificial Intelligence Laboratory, has made seminal contributions to motion planning, controlling, and fielding autonomous robots. Her research covers a broad spectrum of technical problems related to self-organizing networks of robots, including robot design, control, locomotion, manipulation, and high-level planning and control for groups of robots. Her work on shape shifting robots is foundational for the field of modular self-reconfiguring robot systems, where the objective is to design robot modules and planning and control algorithms that enable the resulting robot systems to self-organize as the shape best suited for the sensing, navigation, or manipulation needs of a task. Her work has contributed several new robot platforms with novel capabilities and algorithms for controlling networks of robots. (See the back cover for photos of Prof. Rus's robots.)

In his announcement, Prof. Chandrakasan noted Prof. Rus's dedication as an educator, saying, "She is also an outstanding educator and a wonderful mentor to her students." Prof. Rus developed, in collaboration with Professor Seth Teller, two very popular courses for the Robotics Science and Systems sequence (6.141 and 6.142). Two offerings of the advanced course (6.142) resulted in refereed conference publications authored with the class that were nominated as best papers at the premier conferences in robotics, ICRA and IROS. The first paper described a class project on an autonomous greenhouse and the second paper described a class project of assembling Ikea furniture with robots. More recently, Professor Rus has worked with Professor Erik Demaine and Chuck Hoberman to create an innovative course that explores the role of computation in mechanical innovation.

Professor Rus has also devoted significant time to robotics education outside of MIT. As education co-chair of the Robotics and Automation Society, she spearheaded an effort to create an electronic repository of robotics teaching materials with the goal of enabling non-experts in the field to offer undergraduate robotics courses.

She has also played a leadership role in the field, serving on the Long Range Planning Committee of IEEE's Robotics and Automation Society, as general chair for several robotics conferences including the International Symposium on Experimental Robotics and Algorithmic Foundations of Robotics, and in the roles of program committee member, associate editor, and technical contributor for all the premier robotics journals and conferences. Her contributions have been recognized with a MacArthur fellowship in 2002 while she was an associate professor at Dartmouth College, where she directed the Dartmouth Robotics Laboratory, which she founded in 1994.

Dina Katabi is appointed as Andrew (1956) and Erna Viterbi Professor in EECS

In announcing the appointment of Dina Katabi as the second Viterbi Professor in the EECS Department, Department Head Anantha Chandrakasan said: "It is my pleasure to announce the appointment of Prof. Dina Katabi as the Andrew (1956) and Erna Viterbi Professor of Electrical Engineering and Computer Science. Professor Katabi is an ideal candidate for this professorship, given her outstanding technical contributions and leadership in wired and wireless networks. The honor of being the Andrew (1956) and Erna Viterbi Professor of Electrical Engineering and Computer Science is also held by Prof. Daniela Rus. Both appointments reflect the exceptional leadership set by Dr. Viterbi as a pioneer in the communications field."

Professor Katabi's research covers a broad range of topics related to wireless systems, and her work is characterized by a rare combination of building and deploying practical systems, coupled to rigorous formal analysis. She has authored or co-authored many award-winning and highly cited papers in top networking and telecommunications conferences, and is widely recognized both nationally and internationally as a star among networking researchers.

Katabi's research toolkit is very broad, as she frequently adapts methods from various fields of applied mathematics such as control theory, queuing theory, and machine learning to solve problems in computer networks. She breaks boundaries separating CS and EE disciplines, and optimizes systems across network abstraction layer boundaries. Dina Katabi has been recognized by several awards, including recently the 2012 Grace Murray Hopper Award for advances in network efficiency, a 2013 MacArthur award, and as a 2013 ACM Fellow.

In collaboration with Prof. Muriel Medard, Prof. Katabi is known for early demonstrations of practical wireless systems exploiting network coding, a method to increase network capacity that was promising but primarily of theoretical interest at that time. She also came up with an innovative solution to the classic "hidden terminal problem." Katabi's approach allows two colliding 802.11 packets to be decoded correctly, without loss of efficiency, and without any requirement for power control or special coding. The paper describing this idea, in an implementation called ZigZag, and an evaluation on a wireless network testbed, received the Best Paper Award at SIGCOMM 2008, the premier conference in computer communications. She has also developed an efficient security approach for implanted wireless medical devices. In such devices, wireless transmissions are typically insecure, allowing eavesdropping, or even intentional device sabotage. Katabi and her group devised a solution: a wearable device that acts as a firewall and sets up a secure channel with the base station. This work also received a best paper prize at SIGCOMM, in 2011.

In addition to being an outstanding researcher, Dina Katabi has demonstrated exceptional leadership. In collaboration with Prof. Hari Balakrishnan, she started the new Wireless@MIT Center hosted in CSAIL. The center includes roughly 40 MIT professors and graduate students and has several major industry partners. She has also served as the Program Co-Chair of ACM Mobicom 2010 and Usenix NSDI 2012.

Katabi is a dedicated educator and a wonderful mentor to her students. She has been involved with a number of courses, including 6.02, 6.033, 6.263, 6.829, and 6.888. Most recently, she has been involved as a lecturer in 6.033, one of the largest undergraduate classes. She developed a new graduate level class, 6.888, that focuses on labs and hands-on experience with wireless networks, where students develop the full baseband of OFDM systems. Her graduate students have taken faculty positions in top universities. (Read the Alumni feature on Shyam Gollakota on page 78.)

Muriel Médard is appointed as Cecil H. Green Professor in EECS

Muriel Médard has been appointed the Cecil H. Green Professor of Electrical Engineering and Computer Science. The Green Chair is a fitting memorial to Cecil Green, who passed away on April 11, 2003 at age 102. Sir Cecil Green earned the SB and SM in Electrical Engineering at MIT. In addition to founding Texas Instruments, he partnered with his wife Ida in extraordinary philanthropic activity. On announcing this appointment, Department Head Chandrakasan noted: "Professor Médard is an ideal candidate for this professorship, given her outstanding technical contributions and leadership in communications, signal processing and information theory. The honor of being a Cecil H. Green Professor of Electrical Engineering and Computer Science is also held by Prof. Jacob White."

Professor Médard leads the Network Coding and Reliable Networking Group at RLE. The primary applications of her research are in the area of wireless communications, in which she won an IEEE-wide paper award in 2002. She and her students and other coauthors went on to demonstrate outstanding results in network coding, which bridges coding, information theory and networking. Network coding borrows from linear algebra, transmitting linear combinations of packets rather than the originals, acknowledging on the degrees of freedom of the set of linear combinations received rather than on receipt of individual packets. The flexibility afforded by coding in the network, without the need to reconstruct the original data, provides significant gains in throughput, reliability and security. This work was recognized with an NAE Gilbreth Lectureship in 2007 and two major IEEE prizes in 2009. She is a Fellow of IEEE and has won several conference paper awards.

One of the main contributions of Médard's group and her collaborators is the recognition that codes can be built in simple randomized and distributed ways, while maintaining optimality with high probability. This technique, dubbed random linear network coding (RLNC), has spawned considerable follow-on work internationally, both in academia and industry, in diverse application areas such as data transport, video distribution, cloud storage, and wireless transmission, and serves as the technological basis for several start-ups. Her group's and her collaborators' recent work on integrating RLNC with TCP, a standard means of managing Internet data transport, has shown how the flexibility of RLNC allows its integration into traditional protocols. Her group also implemented RLNC in a low-power integrated circuit.

Professor Médard is an outstanding mentor and received the EECS Graduate Student Association Mentor Award last year. She has served as the President of the IEEE Information Theory Society and editor for several journals, and is currently the Editor-in-Chief of the IEEE Journal on Special Areas in Communications. She served as undergraduate housemaster for many years, served on and chaired the Institute Faculty Committee on Student Life, and co-chaired the Institute Task Force on Student Life. Médard teaches several graduate courses, including 6.450 (Principles of Digital Communication) and an advanced course on network coding. ■

Heldt, Sze and Vaikuntananthan join EECS Faculty

Thomas Heldt joined the EECS Department in July 2013 as Assistant Professor of Electrical and Biomedical Engineering. He was also appointed to MIT's new Institute for Medical Engineering and Science, where he holds the Hermann von Helmholtz Career Development Professorship. Thomas studied Physics at Johannes Gutenberg University, Germany, at Yale University and MIT. In 2004, he received the PhD degree in Medical Physics from MIT's Division of Health Sciences and Technology and commenced postdoctoral training at MIT's Laboratory for Electromagnetic and Electronics Systems. Prior to joining the faculty, Thomas was a Principal Research Scientist with MIT's Research Laboratory of Electronics, where he co-founded and co-directed (with Prof. George Verghese) the Computational Physiology and Clinical Inference Group.

Thomas's research interests focus on signal processing, mathematical modeling, and model identification to support real-time clinical decision making, monitoring of disease progression, and titration of therapy, primarily in neurocritical and neonatal critical care. In particular, Thomas is interested in developing a mechanistic understanding of physiologic systems, and in formulating appropriately chosen computational physiologic models for improved patient care. His research is conducted in close collaboration with colleagues at MIT and clinicians from Boston-area hospitals.

Thomas has been active in teaching Quantitative Physiology (with Prof. Roger Mark) and has co-taught Cellular Biophysics and Neurophysiology (with Prof. Jay Han). He is looking forward to developing a course on Physiological Systems Modeling and Identification that puts equal emphasis on formulating mechanistic mathematical models of physiological systems, and on using these models to interpret clinical and physiological data.

Vivienne Sze joined the EECS Department in August 2013 as an Assistant Professor and a member of RLE and MTL. She received the BASc. degree in Electrical Engineering from the University of Toronto in 2004, and the SM and PhD degrees in Electrical Engineering and Computer Science from MIT in 2006 and 2010, respectively. From September 2010 to July 2013, she was a Member of Technical Staff in the Systems and Applications R&D Center at Texas Instruments, where she designed low-power algorithms and architectures for video coding.

Vivienne's research focuses on pushing the power and performance limits through joint design of algorithms, architectures and circuits to build energy efficient and high performance systems for portable multimedia applications. Her work on implementation-friendly video compression algorithms was used in the development of the latest video coding standard HEVC/H.265.

Vivienne has received numerous awards for academic achievement including the Jin-Au Kong Outstanding Doctoral Thesis Prize in 2011, the 2008 A-SSCC Outstanding Design Award, the 2007 DAC/ISSCC Student Design Contest Award, the Natural Sciences and Engineering Research Council of Canada (NSERC) Julie Payette fellowship in 2004, the NSERC Postgraduate Scholarships in 2005 and 2007, and the Texas Instruments Graduate Woman's Fellowship for Leadership in Microelectronics in 2008. In 2012, she was selected by IEEE-USA as one of the "New Faces of Engineering".

Vivienne Sze was appointed the Emmanuel E. Landsman (1958) Career Development Assistant Professor in October 2013, and was awarded the 2013 RLE Jonathan Allen Junior Faculty Award.

Vinod Vaikuntanathan joined the EECS Department as an Assistant Professor of Computer Science in September 2013. No stranger to MIT, Vinod earned his SM and PhD in Computer Science in 2005 and 2008, respectively.

Following graduation from MIT, Vinod was the Josef Raviv Postdoctoral Fellow at IBM T.J. Watson Research Center (from 2008 – 2010), a Researcher in the Cryptography group at Microsoft Research, Redmond (from 2010 – 2011), and an Assistant Professor in the Computer Science Department at the University of Toronto (from 2011 – 2013).

Prof. Vaikuntanathan's research is in the area of theoretical computer science, where he studies information-theoretic and computational techniques to achieve authenticity and privacy in computation and communication. In particular, he is interested in techniques for computing on encrypted data and programs including, fully homomorphic encryption, functional encryption and program obfuscation. He also develops new mathematical tools in cryptography, drawing from the theory of integer lattices. Prof. Vaikuntanathan was recently cited by the MIT News Office for his work with Prof. Shafi Goldwasser and Prof. Nickolai Zeldovich on securing the cloud while letting web servers process data without decrypting it, a work that they presented at the Association for Computing Machinery's 45th Symposium on the Theory of Computing in early June.

Vinod Vaikuntanathan is a recipient of the George M. Sprowls PhD thesis award from the MIT EECS Department, an Alfred P. Sloan research fellowship and a University of Toronto Connaught New Researcher award. He was appointed the Steven G. ('68) and Renée Finn Career Development Assistant Professor in October 2013.

Faculty Leadership News

Dennis Freeman appointed DUE Dean, succeeded by Albert Meyer

Dennis Freeman, professor of electrical engineering, has served as MIT's dean for undergraduate education since July 1, 2013. In announcing this apointment, then Chancellor Eric Grimson noted, "He brings to the job many years of dedication to undergraduate teaching, curricular innovation, thought advising and mentoring and creative experiments in lab-based and online-based education." Freeman served as education officer in MIT's EECS Department from 2008 to 2011 and was the deparment's undergraduate officer.

An exceptional educator, Freeman has received numerous teaching awards, including the Ruth and Joel Spira Award for Distinguished Teaching, the Irving M. London Teaching Award and the Bose Award for Excellence in Teaching. He has been a MacVicar Faculty Fellow since 2006, and has on three occasions been the students' selection as the best academic advisor in EECS.

Albert Meyer, the Hitachi America Professor of Engineering (since 1991) and principal investigator in the Computer Science and Artificial Intelligence Lab (CSAIL), has authored 60 papers spanning theoretical computer science. Meyer is a pioneer of the "flipped" classroom for 6.042, a class which he has taught since 1999. As a result of his recent responsibility for several large introductory courses, he has become interested in active learning and educational technology.

As an ACM Fellow (1999), Professor Meyer has guided 27 PhD thesis graduates — many now prominent faculty members in leading departments, including at MIT. Among his new responsibilities as the Undergraduate Officer, Prof. Meyer will have oversight of the undergraduate and the Masters of Engineering (MEng) program and will be responsible for MEng admission decisions and participate in USAGE meetings to get student input on a variety of initiatives.

Faculty News: Leadership at MIT

Bulovic is new School of Engineering Associate Dean for Innovation; del Alamo becomes MTL Director

Vladimir Bulovic, the Fariborz Maseeh (1990) Professor of Emerging Technology was selected to head the newly formed Institute-wide Initiative on Innovation as School of Engineering Associate Dean for Innovation. MIT President L. Rafael Reif in announcing this initiative and leadership (also including Fiona Murray as MIT Sloan's Dean for Innovation), cited Bulovic's earlier leadership accomplishments as the director of the Organic and Nanostructured Electronics laboratory (the ONE lab), co-director of the Eni-MIT Solar Frontiers Center — one of MIT's largest sponsored programs, and as the director of the Microsystems Technology Laboratories (MTL) — supporting over 700 investigators and $80M of research programs from across the Institute. Read more in the MIT News Office 17, 2013 article.

Jesús del Alamo, the Donner professor of Science in the EECS Department and a MacVicar Faculty Fellow, was named director of MTL – a position he assumed on Oct. 28, succeeding Prof. Bulovic. In an email announcement to the MTL community, School of Engineering Dean Ian Waitz said he is looking forward to del Alamo's "creative and energetic input as MTL continues to evolve, especially under the institute's newly announced Innovation Initiative." Read more in the Oct. 28, 2013 MIT News Office article about del Alamo's work and leadership in both silicon and compound semiconductor transistor technologies and in the iLab Project, which he founded in 1998.

Grimson assumes new role of Chancellor for Academic Advancement; Schmidt becomes Provost

MIT President Reif wrote to the MIT community on Oct. 22, 2013 to announce the formation of a new role for MIT Chancellor **W. Eric Grimson** to work with the institute's faculty and students to ensure that their needs and priorities are reflected in the upcoming multiyear multibillion-dollar capital campaign. As noted in the MIT News Office, Oct. 22, 2013 article, Grimson, the Bernard Gordon professor of Medical Engineering (and former head of MIT's largest department, Electrical Engineering and Computer Science) will assume the new ad hoc position of "Chancellor for Academic Advancement" — a key role in making the case for MIT's fundraising priorities with alumni and donors around the world. Read more in the Oct. 22, 2013 MIT News Office article.

Martin A. Schmidt, an electrical engineering professor who has served as associate provost since 2008 and as acting provost since last fall (2013), has been named provost on a permanent basis, President L. Rafael Reif announced in an email to the MIT community on Feb. 3, 2014. As associate provost, he has played key roles in the allocation of physical space on campus; in co-leading the Institute-Wide Planning Task Force, which shaped MIT's response to the global financial crisis; and in developing MIT's plans for the future of Kendall Square. With a strong interest in entrepreneurship and innovation, Schmidt has served in key roles including faculty lead in a White House request for MIT to help drive its Manufacturing Partnership. Read more: MIT News, Feb. 3, 2014.

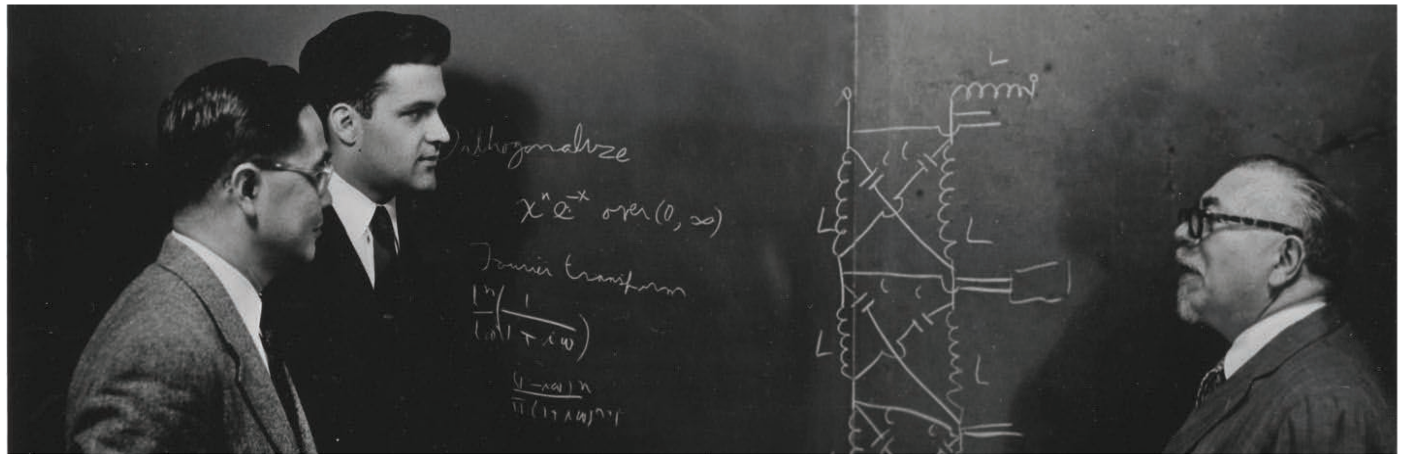
Dahleh appointed as Acting Director of the Engineering Systems Division (ESD); Perreault appointed as EECS Associate Department Head

Munther Dahleh, professor of electrical engineering and computer science, was appointed acting director of the Engineering Systems Division and director-designate of a potential new organization that would incorporate the people and programs of ESD, the Laboratory for Information and Decision Systems, a significant new initiative in statistics, and potentially other programs and entities. The new appointment and examination of possible implementation was announced by School of Engineering Dean Ian Waitz. In addition to serving as associate head of EECS, he was associate director of the Laboratory for Information and Decision Systems and acting director for one year. Read more in the Nov. 26, 2013 MIT News Office article.

David Perreault, professor of electrical engineering and member of the MIT faculty since 2001, was appointed as EECS Associate Department Head, succeeding Prof. Dahleh. In announcing this appointment, Department Head Chandrakasan noted that Prof. Perreault is known internationally for his contributions to design and application of power electronics. Three startup companies have been founded based on research in Prof. Perreault's group, including Eta Devices. Prof. Perreault has served in numerous professional roles including the Administrative Committee of the IEEE Power Electronics Society from 2001-2011. He served as Associate Director of MTL in 2012 and as a member of the Research Laboratory of Electronics Board.

Honoring Three Faculty Luminaries

In Appreciation: Dr. Amar Bose, 1929 - 2013



On the news of the passing of Amar Bose, EECS Dept. Head Anantha Chandrakasan shared the following note with the EECS faculty and broader communities. [Photo: Amar Bose, center, with mentors Y.W. Lee, far left, and Norbert Wiener, far right, at MIT's Research Laboratory of Electronics in 1955. (Image courtesy of MIT Museum.]

"Prof. Amar Bose made tremendous contributions to the EECS department and was known to all of us – and to the students who were fortunate enough to interact with him – as a truly remarkable educator, researcher and mentor. Professor Bose carried out his doctoral research in RLE, on nonlinear systems, supervised by Professors Yuk-Wing Lee and Norbert Wiener and received his Sc.D. degree in 1956 in EE. He always had a passion for research and relished the challenge of accomplishing what others thought was impossible. This passion was evident in his research within RLE which was heavily focused on audio and acoustics. It is deeply embedded in the research-driven company that he founded. Professor Bose is internationally known for the premier audio products that carry his name and his many groundbreaking innovations in the audio industry.

As Prof. Bose describes in a video clip of one of his wonderful talks, he had never intended to pursue an academic career, but was "talked into" joining the faculty by Prof. Jerry Wiesner. He approached the challenges of teaching with creativity, enthusiasm, energy and an innovative spirit. During his faculty career he became one of the department's legendary teachers. His first major teaching assignment was the basic undergraduate circuits course, which had previously been taught for many years by another legendary faculty member, Prof. Ernst Guillemin. His re-design and teaching of this course resulted not only in a classic text, Introductory Network Theory, co-authored with Prof. Ken Stevens, but in many innovations in lecturing a large course. He established weekly meetings with a group of recitation section representatives. These meeting were incredibly popular and the students elected by their recitation sections cherished the role. During the semesters that he was lecturing the course, he was devoted virtually full time to preparation. This resulted in consistently charismatic lectures, deep and thoughtful problem sets and exams, and very high expectations of commitment and seriousness of purpose from the teaching staff and the students. An indication of his standards and expectations is well reflected in the incident captured in the article http://alum.mit.edu/pages/sliceofmit/2010/10/24/when-bose-walked-out/

Professor Bose also became legendary for his teaching of his acoustics course, 6.312. A sense of his style and approach to acoustics is nicely conveyed in the video recording of his introductory 6.312 lecture, http://techtv.mit.edu/videos/13775-mit-acoustics-course-6-312-lecture-1-9-7-1995.

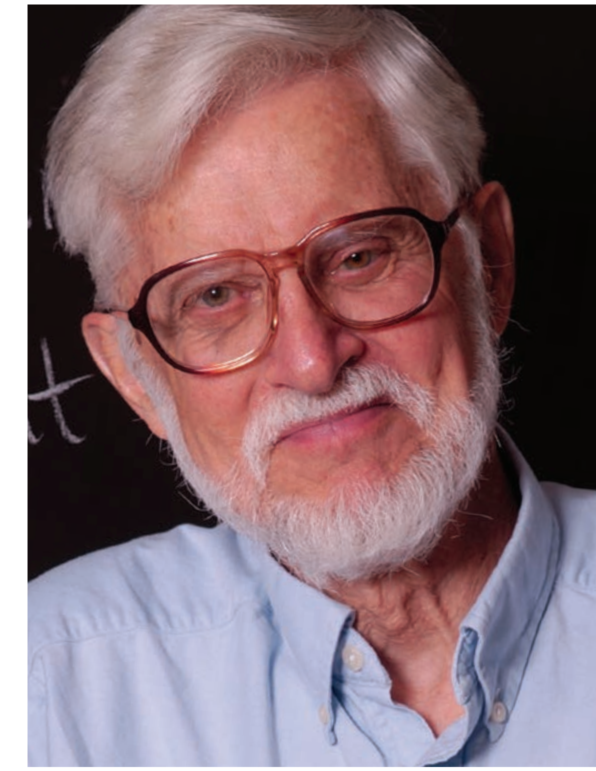
Throughout his teaching career Prof. Bose set exceptionally high standards for himself, his staff and his students. He put tremendous emphasis on mentoring the graduate student teaching assistants, working closely with them to help them develop their teaching skills and working collaboratively with them to teach them the skill of creating outstanding homework problems. He routinely worked with the same TAs over multiple semesters, with the intent of helping them to become gifted teachers and mentors.

The EECS community is very fortunate to have benefited from his passion and dedication for teaching. He has inspired many generations of engineers and showed them the path to commercializing research innovations. His contributions will continue to impact our department and many generations of students to come. We will greatly miss him."

Remembering Kenneth N. Stevens, 1924-2013

Dedication to research in speech communication helped earn him the National Medal of Science

The following is adapted from an August 22, 2013 MIT News story written by Larry Hardesty of the MIT News Office.



Kenneth Stevens, the Clarence J. LeBel Professor Emeritus of Electrical Engineering and Computer Science at MIT, whose pioneering work at the intersection of engineering and linguistics helped earn him the National Medal of Science, died Aug. 19 in Clackamas, Oregon. He was 89.

Born in Toronto on March 23, 1924, to British-born parents, Stevens lived there until 1948, earning both bachelor's and master's degrees in engineering physics from the University of Toronto. Having lost an eye to cancer when he was four years old, Stevens was ineligible for military service during World War II, so after completing his master's, he stayed at the university for three more years to teach returning soldiers — including his older brother, Pete.

In 1948, Stevens came to MIT as a doctoral student in electrical engineering. He would spend the next 59 years at the Institute, joining the faculty in 1954 and retiring, in 2007, at age 83.

Although he completed his master's in control theory — a "big thing" at the time — he happened to be discovered by Leo Beranek, MIT professor of communications engineering and one of the founders of BBN Technologies, a research and development organization that is now a subsidiary of Raytheon Co. Since Stevens had taken a course in acoustics, he was tapped to be a teaching assistant for a class on that subject.

Originator of the 'quantal theory of speech'

That chance transition launched him on a career that culminated in his winning of the National Medal of Science in 1999. Stevens is best known for his "quantal theory of speech," which explored why — despite the apparent diversity of sounds across different languages — human speech actually exploits only a small fraction of the sounds that the vocal tract can produce.

In 1952, while he was completing his doctorate, Stevens collaborated with the MIT linguist Morris Halle and Halle's two colleagues Gunnar Fant and Roman Jakobson, on a theory to describe all human speech based on sound formation. The resulting Quantal theory was also directed to understanding speech recognition. This work required years of careful investigation, which Stevens carried out both experimentally and through mathematical modeling, frequently with Halle, and, later, with Samuel Jay Keyser, another MIT linguist.

A draw for graduate students

Along the way, he advised more than 60 graduate students — including four after his retirement, when he and his second wife, Sharon Manuel, moved to Oregon.

"When I was looking for a place to get my doctorate, all I knew was that I wanted to study with Ken Stevens," says Victor Zue, the Delta Electronics Professor of Electrical Engineering and Computer Science at MIT. "I didn't come to MIT and then find Ken Stevens. I wanted to study with Ken, and OK, he's at MIT, so I guess that's where I will apply."

"I always remember Ken as an incredibly tolerant advisor," Zue adds. "He always allowed people the latitude to explore areas that weren't central to his own interests." As Dennis Klatt, who developed the speech synthesizer used by Stephen Hawking, among many others, as a researcher in Stevens' group once put it, "As a leader, Ken is known for his devotion to students and his miraculous ability to run a busy laboratory while appearing to manage by a principle of benevolent anarchy."

Honoring Three Faculty Luminaries, *continued*

James K. Roberge, 1938-2014
A dedicated teacher and talented analog systems designer

James K. Roberge, professor of electrical engineering in the Department of Electrical Engineering and Computer Science (EECS) since 1967, died Friday, Jan. 10, 2014. Roberge continued teaching in the department through the fall 2013 term.

Born in Jersey City, New Jersey in 1938, Jim Roberge came to MIT in 1956, earning the SB, SM and ScD degrees, all in electrical engineering. For nearly all of his professional career, Jim worked for MIT – from postdoctoral research associate to full professor (in 1976). Since 1969, Jim performed research at Lincoln Laboratory.

His research interests in the area of electronic circuits and systems design led him to work in a division at Lincoln Laboratory involved in space communications, instrumentation, and optical communications. His designs have flown on nine satellites.

EECS colleague Vincent Chan, the Joan and Irwin Jacobs Professor of Electrical Engineering and Computer Science, headed the division at Lincoln Lab in which Jim worked. Chan notes that Roberge's two most important contributions are ultra-high-efficiency power converters for spacecraft and high-precision optical tracking electronics for space laser communications.

"[Jim] brought together his knowledge of circuit designs, control system theory and a large dose of ingenuity to design these systems," Chan notes. Despite the fact that some of his work was done in the 1980s and 1990s, Chan says, "it [Roberge's work] still represents the state of the art."

James Roberge is noted by the colleagues he worked with over the years for his mentorship to not only students but to newer faculty just beginning their careers at MIT. Charlie Sodini, the LeBel Professor of Electrical Engineering and member of the MIT EECS faculty since 1983, notes about Jim's influence on him: "I taught 6.301, [Solid-State Circuits] and 6.302, Feedback Systems, as a recitation instructor for Jim. It was a pleasure to learn the material from someone who had it in his DNA."

Jim Roberge had a good-natured and approachable way with colleagues and students. Several of his students who are now following in his academic and research footprints attested to his impact. David Trumper, member of the MIT Mechanical Engineering Department since 1993, began his association with Prof. Roberge as an undergraduate student taking 6.301 and 6.302 – classes, which, Trumper says, "opened up analog circuits as a design discipline." Roberge served as his undergraduate thesis advisor and later (1987-90) his PhD advisor. Trumper says all will remember Jim for his "keen insights and easy confidence that pretty much any problem could be solved if you looked at it from the right perspective."

Kent Lundberg, who was a student with Prof. Roberge while he earned his SM and PhD in electrical engineering, is currently a Visiting Senior Lecturer in the EECS Department and Visiting Professor at Olin College. Having taught 6.331 with Prof. Roberge since 1994 and helped Prof. Roberge teach that class this past term (fall, 2013), Lundberg says, "Knowing Professor Roberge was the best part of my education at MIT."

Through his research and eye for practical application, Jim Roberge authored 12 patents and worked with more than 160 consulting clients. He was Co-founder of Hybrid Systems Corporation, which was later acquired by Sprague, and Aerogage Corporation.

EECS Department Head Anantha Chandrakasan summarized Jim Roberge's impact in his announcement to his colleagues saying: "Jim was a wonderful colleague, teacher, researcher and mentor. He was legendary for his teaching of analog circuits (6.002, 6.301, 6.302, 6.331) and his approach to these subjects had a profound influence on generations of students." ■

Celebrating Milestones in Academic Families

CEL60

Celebrating Charles E. Leiserson's 60th birthday was a major reunion for 33 years of students, their families and MIT colleagues at the Stata Center on Sunday, Nov. 10, 2013. Photo by Robert L. Krawitz.

Over the years faculty in general, and particularly here in the MIT EECS Department, guide many generations of students through the process of earning one or more degrees – a bit like being a parent and, at the very least, a mentor. So when a faculty member's 50th, 60th or later birthday is reached, their students naturally want to help their thesis advisor and mentor celebrate.

Roughly a year ago, members of Prof. Charles E. Leiserson's research group, known as Supertech Research Group, proposed such an event to mark his 60th birthday (Nov. 10, 2013). Despite the considerable effort it would take to bring multiple generations of students together, Leiserson knew it would be worth the effort. "One of my first thoughts was how much time it would take to carry out the event. But then I realized that it would be a convenient excuse for all my students from over the years to see each other again. When I looked at how long and hard they had worked in my research group, the effort for planning the event seemed minor." In fact, it took a committee and then some.

Leiserson has continued to enjoy friendships and connections with students spanning 33 years of teaching, because he is both interested in them and loves what he does. When asked about the big milestones in his academic career, he recalled working with a student one Friday night on a paper – as a sort of adversarial argument, which they called the 'recycling game.' The two of them worked well into the night, since the paper was due the next day. "Early in the morning, we just started laughing and laughing!" he exclaimed. "My student said, 'Here it is Friday night, and this is our social life: working on a game that isn't even a game!'" This kind of bonding experience, he notes, is what he treasures — above major accomplishments.

Dr. Bradley C. Kuszmaul, one of the lucky Leiserson students, has been a Research Scientist working with him for the past 12 years. Following his first exposure to Prof. Leiserson when he took a class from him in the spring of 1982, Kuszmaul later convinced him to go to Thinking Machines in 1987 for a sabbatical year to work on the Connection Machine CM5 supercomputer – for its day, the world's most powerful computer. They worked afternoons on the project, while in the mornings Leiserson joined his colleagues Tom Cormen and Ron Rivest to write the milestone text *Introduction to Algorithms*. Kuszmaul then continued as Leiserson's Ph.D. student in 1990, and since then, they have enjoyed numerous research collaborations.

Despite his admission that project management is not his forte, Dr. Kuszmaul was pleased to take on the Leiserson 60th chair responsibilities. The event – "still highly guided in every detail by Leiserson," Kuszmaul notes – included an all-day symposium interspersed with ample visit time for the nearly 200 guests, followed by a reception in the Stata Center lobby and a banquet nearby.

With the goal of creating an occasion for so many to gather and share both technically and socially, Dr. Kuszmaul and the committee created something for all. The symposium, headed by Prof. Bruce M. Maggs, '89, included nine presenters following chronologically from the oldest (longest) association with Leiserson to the most recent. Requests for presentations were purposely left open in terms of topic, and the result was a combination of big picture talks, current research talks, and historical retrospective talks.

Perhaps the most riveting presentation – and the last of the symposium talks – was delivered by Leiserson's former PhD student and current postdoctoral associate Dr. I-Ting Angelina Lee and current PhD student in Supertech, Mr. Tao B. Schardl. Their talk titled "On-the-Fly Pipeline Parallelism" was a perfectly choreographed, contrapuntal performance.

Leiserson noted afterwards, "Their joint lecture was just brilliant!" Relating their work to teaching, he notes: "Good teaching comes in part from being adequately prepared. But preparing something difficult and imaginative well beyond the call of duty – showing that they really cared about the audience's experience – made this lecture truly memorable. That kind of dedication will serve them well in their careers."

The birthday present was unveiled during the first break. Leiserson wanted to give people who enter the Stata Center something to do while waiting for the Gates elevators to the lab (CSAIL). He has always been inspired by how much fun with computing goes

CEL60, *continued*

on in CSAIL; and, since his childhood, he has been fascinated with a mechanical calculating device called the DIGI-COMP II, a 1960's educational toy invented by John "Jack" Thomas Godfrey (1924-2009). Leiserson arranged for a giant DIGI-COMP II to be built, and his students, colleagues, and friends donated it to CSAIL.

Leiserson spent many hours working with the manufacturers (Evil Mad Scientist LLC) and many people at MIT to ensure that the giant DIGI-COMP II exhibit could be displayed properly and would meet all safety requirements. He is grateful to all those who contributed to making it possible.

Now, long after his birthday celebration has passed, Leiserson is thrilled not only with the memories of the event, but with how the giant DIGI-COMP II exhibit embodies the ideals of good technical education. He observes: "The first thing people do when they see it is watch the billiard balls rolling down the huge board, knocking mechanical flip-flops this way and that. Some just watch it for a short time, but others linger for hours, studying the instructions and figuring out all it can do. Some have now mastered it to the extent that they bring friends to teach them how it works. Teaching – one of the most salient human traits – emerges spontaneously from the giant educational toy. I just stay out of the way." And, Leiserson's philosophy of teaching carries on.

Dubbed "CEL60," the event is viewable at: http://supertech.csail.mit.edu/cel60/. It was supported by Akamai, CSAIL, CSAIL Industrial Affiliates Program, MIT EECS, VMware, and anonymous donors.

Charles Leiserson unveils the giant DIGI-COMP II exhibit, demonstrating the basics and launching this hands-on computational tool permanently installed at the entrance to the Gates Tower in the Ray and Maria Stata Center. Photo by Robert L. Krawitz.

Celebrating the work of Butler Lampson at 70

In mid February, computer science luminaries —including seven Turing Award winners and Eric Schmidt, Google's former CEO and current executive chairman — either attended or contributed appreciations in celebration of the 70th birthday of Butler Lampson, adjunct professor in the EECS Department at MIT since 1987 and a technical fellow at Microsoft Research, Cambridge.

As one of the founders of Xerox's Palo Alto Research Center (PARC), Lampson helped create the Alto, the first computer to feature a mouse and graphical user interface (GUI) — the progenitor of both the Apple Macintosh and the Windows operating systems. Schmidt said about Lampson: "Butler is probably the broadest and smartest computer scientist today. We all just tried to keep up with him — and almost always fell behind. His contributions made much of our world possible, and I am beyond grateful."

Education Updates

Classes at the forefront of technology

Developing classes that respond to technology's cutting edge *by Jacob White, EECS Co-Education Officer*

During the last few decades, the computer has been at the heart of EECS and of our core curriculum. The pursuit of ever-faster processing has neatly tied together our broad interests in technology, circuits, software, systems, and algorithms. But as computing becomes ever more pervasive, and more commoditized, harnessing it in new ways has become as important as increasing its performance. What is capturing the imagination of ever more students and faculty is the challenge of using computing to comprehend, to control, and to create.

This shift is evident at the senior and graduate level. We have new, or newly popular, classes that invoke computing to solve problems in robotics, molecular biology, security, medicine, language and vision. Our technology and circuit classes are transitioning, and placing more emphasis on aspects of sensing, transduction, and actuation. And our students, eager for the appropriate mathematical tools but often lacking the appropriate background, are overwhelming our upper-level and graduate classes in optimization, machine learning, estimation, numerics, and cryptography.

Computing's now-ubiquitous role in engineering has triggered a re-evaluation of our core curriculum, driven only in part by the changing background needs of our students. A new nexus is emerging for EECS, as evidenced by converging approaches in historically disparate subjects like machine learning and signal processing, or algorithms and information theory, or control and robotics. And even though we do not yet know the totality of this new nexus, we do know that our students need more computationally-focused foundations in probability and statistics, optimization, dynamics, and linear algebra.

In the sections that follow, we describe three of our efforts at providing our students with computationally-focused foundations. Our two new introductory classes in inference and machine learning provide students with computational perspectives on probability and statistics, linear algebra, and basic optimization. Our new class on computational fabrication reenforces many of these ideas in the context of 3-D printing. Together, they form a first step in preparing our students to help architect the computation-centric world we expect, but do not yet understand. ■

6.008: Intro to Inference

Instructors: Polina Golland, Gregory Wornell, Costis Daskalakis, Lizhong Zheng and Devavrat Shah

In today's world, we have a daunting volume of data at our disposal, and a critical need to efficiently extract information from it. Such challenges touch almost every facet of EECS, and as a result there has been a growing recognition in the department that the curriculum needs to better prepare Course VI students to meet these challenges, right from the start of their undergraduate program.

From this recognition emerged the concept of a foundational subject devoted to inference and the key problems of extracting information from data and modeling large complex phenomena. This highly innovative, self-contained, first-principles subject with minimal prerequisites would emphasize the statistical, informational, and computational aspects of inference, and their interconnections.

In response to a challenge from the department in 2011, Professors Polina Golland, Gregory Wornell, Lizhong Zheng, Costis Daskalakis and Devavrat Shah set out to build such a class. After more than a year of initial development, a pilot version of the subject, titled "Introduction to Inference," was offered in fall 2012. Prof. Wornell notes that this was an ambitious and often all-consuming undertaking, and part of a broader, intensive rethinking of key aspects of the undergraduate curriculum.

Prof. Costis Daskalakis lectures Intro to Inference in spring term 2014.

6.008 Intro to Inference, *continued*

With no precedent for such a class in any existing undergraduate EECS curriculum, the faculty involved had to build the subject entirely from scratch. Prof. Wornell also credits the three outstanding inaugural graduate student TAs—George Chen, Gauri Joshi and Ramesh Sridharan—for playing a strong role in not only developing key materials for the subject, but also for helping set the tone and shape the experience for a pilot group of 16 brave students.

George Chen, one of four TAs teaching the class again this year, was one of those three "founding" TAs. He calls his experience a "once-in-a-grad-school opportunity." When he took a related graduate class as an undergraduate at Berkeley, Chen considered it the best class he had taken—a reaction shared by many similarly-minded MIT undergraduates who have taken graduate inference subjects offered at MIT. So he was extremely excited as a graduate student to share that magic with MIT undergraduates at the earliest stages of their education, and to help build the subject from the ground up.

Chen says that the students who took the class were enthusiastic beta testers—really more like "alpha" he suggests—eager to learn the material. The instructors worked hard to enhance and enrich the educational experience in a variety of ways—including Khan-Academy-style instructional videos, and a sequence of engaging, hands-on design projects that included localizing a robot, building an email spam filter, developing a simplified web search algorithm for movie information, and separating objects from background in images—all applications that resonate strongly with students today.

Graduate TA Ramesh Sridharan was equally excited for the students who are now able to get this exposure as undergraduates. He also found the teaching experience immensely rewarding—including developing so many new materials.

Graduate TA Gauri Joshi notes that much of the challenge was "figuring how to convey to undergraduates in simple, accessible, and empowering ways, fundamental concepts and ideas that had only been attempted in the past at the graduate level."

Graduate students (from left) Ramesh Sridharan, Gauri Joshi and George Chen were instrumental in the development of Intro to Inference — an inspiring experience despite the hard work that went into it.

This spring term the subject is going through its final test run and fine-tuning with four TAs and over 50 students, in preparation for its official debut with its permanent number 6.008 this fall. In addition to the veteran George Chen, this term's TA staff includes new graduate TAs Oren Rippel and Aldo Pacchiano, and the subject's first undergraduate TA Chelsea Finn '14.

Finn appreciates interacting with a staff of such broad spectrum of interests and experiences with the topic, and says, "I love that you can do so much with the material, from programming a robot to move in an unfamiliar environment, to segmenting foreground/background of an image, to classifying tweets on Twitter—all homework examples taken from the class!"

One of the students commented in the Fall '12 course evaluations, "This is the sort of material that just about everyone should know, coming out of MIT." With this kind of reaction, 6.008's importance in the EECS curriculum is expected to grow strongly in the coming years, and serve an ever-expanding spectrum of students from across the department (6-1, 6-2, and 6-3) and beyond. And with application domains that include machine learning, search and retrieval, data mining, computer vision and imaging, voice recognition, communication and compression, natural language processing, robotics and navigation, computational biology and bioinformatics, medical diagnosis, distributed sensing and monitoring, statistical physics, and finance, 6.008 will ultimately serve as a springboard to a host of more advanced subjects. Prof. Golland notes, "Perhaps the most immediate impact will be the preparation it provides for students with interests in AI (including Machine Learning) within CS, and Information and System Science (including communication, control, and signal processing) within EE, but over time the subject's influence will no doubt be felt even more broadly." ■

6.036 Intro to Machine Learning

Instructors: Regina Barzilay, Tommi Jaakkola

Machine Learning is everywhere! At least, this statement is believable when you realize how this discipline can be applied to predict answers to important questions in just about any real world situation that involves data. Machine learning algorithms are being used to automate many data associated needs such as recognizing the signs of cancer, predicting stock prices, translating languages, detecting credit card fraud, recommending movies — and the list goes on. All these instances involve questions requiring predictions driven by data – extremely challenging for individuals to specify or know exactly how to solve each situation.

Until a year ago, undergraduates in Course 6 at MIT didn't have a chance to study this blossoming field unless they wanted to join an advanced and large graduate class (6.867) that has an imposing list of pre-requisites. So, with the motivation that EECS (and a wide swath of MIT) students, regardless of their trajectory, will encounter machine learning in the course of their careers, Intro to Machine Learning was first offered in spring 2013. Today, 6.036 has become a magnet for engineering and computer science students. Nearly 300 students fill 10-250 twice a week to take in the 6.036 lectures by Professors Regina Barzilay and Tommi Jaakkola.

MEng. student Eric Shuy, one of five TAs for this year's offering, took the class last year. Now he is enjoying the chance to learn more by teaching others. Besides motivating him to explore the subject more deeply through classes, online resources, and research, upcoming 6.036 programming projects in the class give Eric and the students a chance to get real-time exposure. Among the projects, students will be applying the machine learning principles they've studied to real problems such as predicting the sentiment of a Twitter post. Shuy suggests that the class goes over so well because the students get to apply what they learn to problems that they care about.

Xinkun (Sheena) Nie, took the class last year and is very enthusiastic about what she learned and how much she enjoyed the class. "The best parts of the class [were] the assignments and projects," she says. She still remembers that the projects involving facial recognition and Tweet classification were both fun and challenging to implement. "[This] hands-on component of the class definitely helped me conceptually understand the materials," she says, "and made it stand out among the other Course 6 classes I was taking at the time."

During the summer following her taking the class, Sheena Nie interned at Hunch, a machine learning startup that had been acquired by eBay. It was very exciting for her to apply what she had learned in Intro to Machine Learning to real-world industrial applications.

6.036 Intro to Machine Learning, *continued*

Students in 6.036 will have another meaningful experience when current researchers come to talk to the class about their work and how they apply machine learning. Sheena remembers one such talk last spring on the topic of robot planning problems. Fascinated by the topic, she introduced herself following the class to the speaker and landed a UROP in his group. Overall, she says, the class has given her the foundation to tackle problems in data science and robotics.

Two project examples are illustrated below. The first project involved applying dimensionality reduction, clustering, and classification algorithms to face images. Students used the Principle Component Analysis algorithm to find lower-dimensional approximations of the images—e.g. in the figure with 10x dimensionality reduction, the right images have about 10x less data (thus requiring 10x less space) but still manage to approximate the left images pretty well. By implementing the K-means algorithm, the students were able to automatically find clusters of similar face images. They also used Support Vector Machines to automatically distinguish between different face images of two different people. (Figure 1 below)

For the second project (Figure 2 below), students classify a Twitter tweet as being a negative or a positive movie review. Students used the Perceptron and Passive-aggressive algorithms to learn how strongly particular words are related to a positive or negative sentiment. ■

Figure 1: Dimensionality Reduction

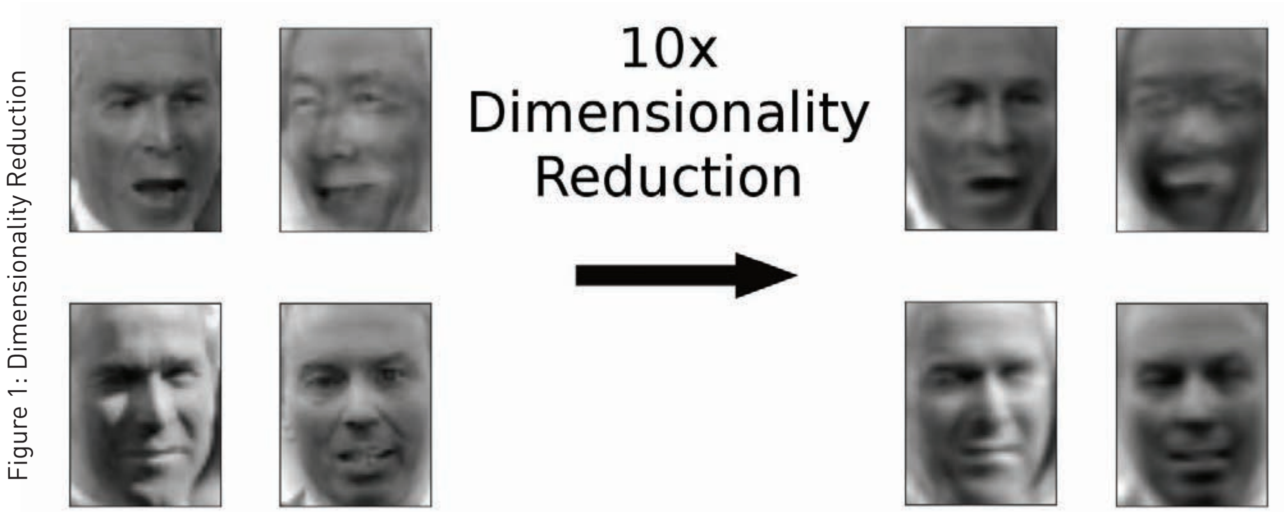
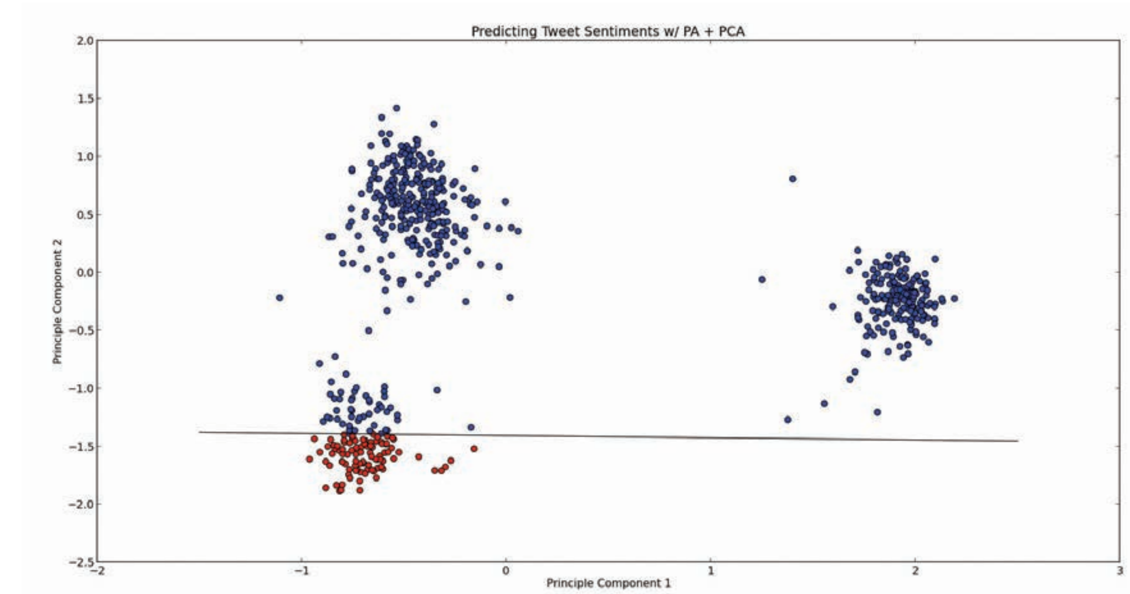


Figure 2: Predicting Tweet Sentiments



6.S079 Computational Fabrication

Instructors: Wojciech Matusik, David Levin

Prof. Wojciech Matusik, left, helps students to master 3D imaging using Microsoft Kinect.

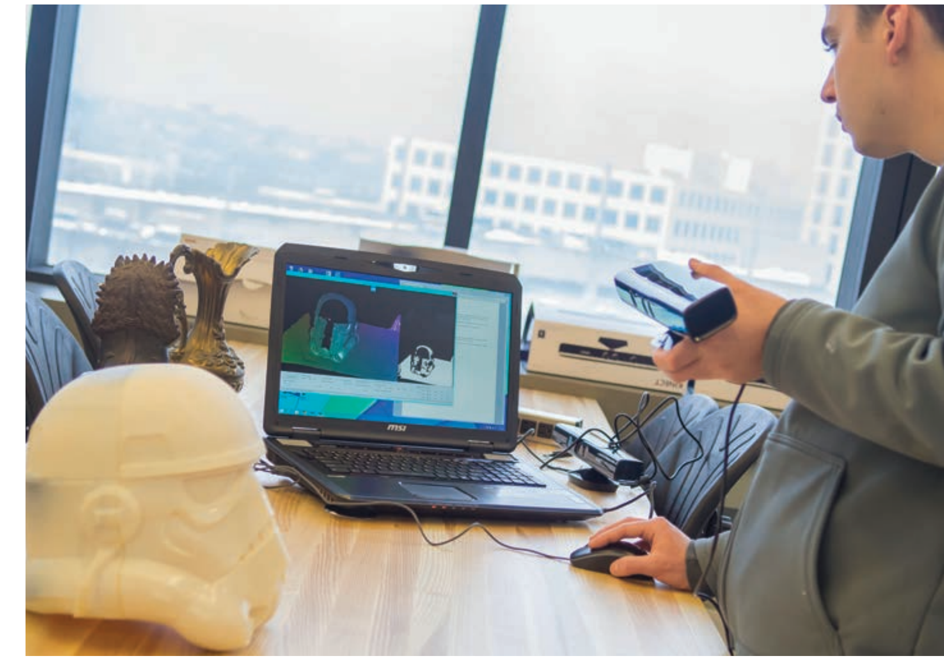
Hardly a 21st century day goes by without a reference to 3D printing and the revolution it is projected to cause in engineering and manufacturing. This enthusiasm is shared among hobbyists and within a vibrant maker community. Formally designated computational fabrication, 6.S079 provides a broad overview of both hardware and software for additive manufacturing. In particular, students are introduced to methods for parametric modeling of solid objects that take into account fabrication constraints. In the lab, they master computing models of physical objects using real-time 3D scanning. They also study and implement advanced physically-based simulation methods. The students explore the kinematics of mechanisms, such as four-bar-linkages, and finite element methods in the context of deformable solids. These techniques are fundamental in the engineering community and are crucial for designing highly predictive tools for 3D print preview. Using these tools, many variations of a virtual solid object can be interactively analyzed without committing to fabrication.

The course also covers optimization methods that are applied to automate the design process. After learning this basic toolset, students analyze many instances of recent computational fabrication systems that seamlessly blend interactive design, simulation, and optimization, for example, the interactive designing of printable automata. In the second part of the semester, students work in groups on large open-ended projects. The primary goal of the class is to give students both a practical and a theoretical knowledge of every stage in the computational fabrication pipeline – raising awareness about this rapidly expanding field.

Professor Wojciech Matusik, the class instructor, believes that this class will help in developing future engineers who have interdisciplinary knowledge, balancing both computational and physical perspectives. This is accomplished by having programming assignments and complementary hands-on labs. For example, students implement a finite-element simulator for elastic objects and in a companion lab they 3D-print deformable structures and measure their mechanical properties. Another assignment involves the construction of parameterized virtual objects using a domain specific language for computer aided design. The students use these designs to generate families of objects that are 3D-printed in the lab. By the end of the course, the students will build many pipelines that transform virtual designs to physical objects.

David Levin, the co-instructor, notes that the class works well for advanced undergraduate students who have good competency in software engineering, algorithms, and basic mathematics (calculus and linear algebra). As he helped out in one of the initial labs (see the photos), David explains that this lab was about acquiring object geometry using Microsoft Kinect. This system employs an infra-red projector and a camera to estimate where, in 3D space, a point on an object is. Using this system, the students can build a complete volumetric model of a physical object. They interactively scan the object by combining multiple measurements from different viewpoints. The complete geometry acquisition and processing pipeline that was recently studied in class is put to a practical use in this lab.

And, yes, the lab class, held in the new Engineering Design Studio, results in actual objects that are produced by 3D printers in the lab. Noting that the students are really into the class, Levin says "There's something inherently fantastic about being able to draw an object into the real world."



Sarah Edris, a 6-3 major who has focused on software and web development but had no experience with fabrication, decided to take Computational Fabrication as followup to a Computer Graphics class. One of her favorite topics was learning about constructive solid geometry and procedural modeling. "Learning about the 3D printing pipeline and process was also interesting, and made me realize just how much room for improvement there is, as it's still a relatively young field." With so much current research going into 3D printing, she says that the class feels very relevant — particularly since multiple papers are being introduced in each class.

Several design and programming assignments executed by current 6.S079 students are illustrated below in Figures 1 and 2.

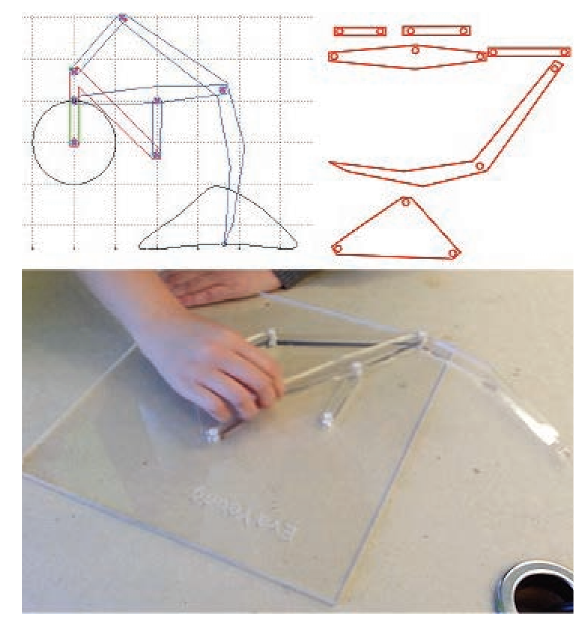


Figure 1. A Klann linkage designed by Eva Yeung. Top row: A simulation of the linkage and the exported design for fabrication. Bottom row: the manufactured linkage.

Figure 2. A parameterized birdfeeder model built by Shannon Kao using a procedural modeling language. The design features parameterized roof, number of stories, number of sides. Top row: many instances of the same virtual design. Bottom row: one 3D printed birdfeeder.

Student News

Embracing Student Leadership in EECS

by Elizabeth Dougherty

When Anantha Chandrakasan, the Joseph F. and Nancy P. Keithley Professor of Electrical Engineering, took the helm of MIT's Department of Electrical Engineering and Computer Science (EECS) in 2011, he quickly set two big ideas into motion. One was to make the Undergraduate Research Opportunities Program (UROP) more appealing to EECS majors. The goal was to offer Course 6 undergraduates more research options within the department, as well as chances to work on longer-term, sustained projects.

The other was to form the Undergraduate Student Advisory Group in EECS (USAGE) to help him understand the student perspective. This group provided pivotal feedback that helped guide decisions about UROPs. Giving the students a stronger voice has transformed the department into more than a place where students come to learn about devices, signals, theory and systems — Course 6 is also a place where students become leaders.

Group dynamics

Aside from coursework, one of the ways students engage with the department is through student groups. The new USAGE group joined established ones that include Eta Kappa Nu (HKN), the EECS National Honor Society; ACM/IEEE, a nationwide organization; EECS Refs, a group of graduate peer mediators; the Graduate Student Association (GSA); and GW6, the graduate women students' association.

Typically these groups enhance the department environment by organizing social activities and providing peer mentoring and support. These groups also provide key perspective on new departmental initiatives to advance and strengthen the department.

To bring a student perspective to the selection of new faculty members, Chandrakasan and the two associate department heads, William T. Freeman and Munther A. Dahleh, set up a new group composed of undergraduate and graduate students to evaluate faculty candidates. While students had met with faculty candidates in the past, the department had never before formally requested student input in such decisions.

In this role, the students met as a group with the individual candidates and provided integrated written feedback based on their impressions. "I liked the idea of giving student input," says Victor Pontis, a junior. "There are so many great candidates, why not choose the ones able to connect with students?"

Members of USAGE (above). Leaders of the Graduate Student Association, fall 2013 (below). Visit the EECS homepage for details: www.eecs.mit.edu/

The experience also gave students a glimpse into what they might someday go through, should they choose an academic career. "I got to see an insider's view of how the hiring process works," says Phillip Nadeau, a fifth-year doctoral student. "I think we brought a different perspective that was valuable to the faculty in their deliberations."

"Student input was a useful addition to the many dimensions we consider in faculty hiring," Chandrakasan says. "I was really delighted that they took this job very seriously."

Embracing Student Leadership in EECS, *continued*

EE and CS network

Given the resonant theme of leadership in the department, student groups have begun to act on the department's initiatives on their own. Several groups in EECS already have two of the department's top priorities for the current academic year — entrepreneurship and building community — on their radar.

For instance, the GSA recognized that having more than 700 graduate students distributed across 120 faculty groups in the largest department at MIT made interaction difficult. In addition, student and faculty interests vary widely, from solar cells to mobile apps, and from circuitry to cryptography. With CS students working in one building and EE students in others, "students don't mingle much," says Rachael Harding, co-president of the GSA.

So she, co-president Joel Jean, and the rest of the group took action. They started up the GEECS (pronounced "geeks") Coffee Hour on the 8th floor of Building 36, with a great view of the city. They also started a research support network, in which a dozen or so students get together each month to hear students present their research informally over dinner. "I've been learning about solar cells and signal processing," says Harding, a member of the Computer Science and Artificial Intelligence Lab (CSAIL).

Students get feedback on their presentations — valuable input for burgeoning academics. In one instance, a student learned that needed equipment was available in another EECS lab. Over pizza, a collaboration between student researchers was born. "It was really exciting to see that kind of an exchange in an informal venue," Harding says.

By organizing and participating in departmental activities — such as running student and laboratory conferences, mentoring undergraduate researchers, and tutoring and counseling fellow students — EECS graduate students are taking important steps toward becoming professionals themselves. "That's also leadership," Chandrakasan says. "We'd like to give our students as much opportunity as possible to participate in shaping their futures and the future of the department."

Photos left Top: Graduate Student Association "GEECS" coffee hour on top floor of building 36. *Middle:* EECS REFs front l to r: Lawson Wong, Jenna Wiens, Audrey Fan, Becky Asher, Ermin Wei, and back, l to r: Ramesh Sridharan, Samantha Gunter, and Eric Winokur. *Bottom:* HKN Officers, l to r, front: Helen Li, Erika Yi, Yin Fu Chen, Stephanie Chang; l to r, back: Benoit Landry, Rishabh Kabra, Cody Coleman, and Dawit Zewdie.

Worldviews

Back in 2011, when Chandrakasan began to design the new UROP program, he started by talking with the faculty. "We thought about it a lot and came up with a program focused on giving our students a way to generate publication-worthy research," Chandrakasan says. "We were all excited."

But when he ran the idea by students at one of his first USAGE advisory meetings, it was clear he needed to adjust the proposal.

Catherine Olsson '12, MEng '13 represented one view. She had bypassed summer UROPs even though she was interested in a research career because internships offered pay and prestige that was just too hard to pass up. "We needed to make these research opportunities more glamorous and financially attractive," explained Olsson, who is now a doctoral student in computational neuroscience at New York University.

Denzil Sikka '13, who is now working at Microsoft in Mountain View, CA, represented another view: "It's hard to fit UROPs into the Course 6 workload, especially since grades are so important for students interested in going into industry."

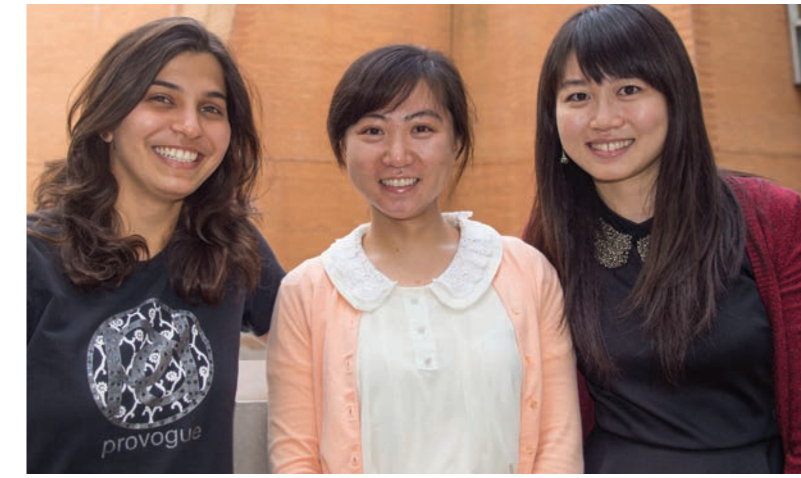
The students didn't all agree with one another during USAGE meetings, but because the conversations were open and focused on positive change, they gravitated away from tension and toward solution. "Ideas just bubbled out of these very organic conversations we were having," Olsson says. "It was a really productive back-and-forth."

Chandrakasan contributed a big part of that dynamic. "It felt like we were being heard and that he was giving a lot of consideration to what we were saying," Sikka says.

Indeed, he was: The department added prestige by funding selected Research and Innovation Scholars, and offered both research and industry-focused projects. The EECS SuperUROP program is now considered an enormous success, with participation in both short- and long-term projects up substantially and continuing to grow. Several projects in the first year of operation have gone on to become the seeds of new ventures and new research agendas.

Perhaps more importantly, the program might never have gotten off the ground if students had not been given a voice. According to the students, the leaders in the department have given generously of their time, attention and consideration.

This, Chandrakasan says, is the point. "We look to students to come up with things that we don't see. That's the power of student input." ■



GW6 (Graduate Women in EECS-Course 6) co-presidents as of fall, 2013 include (from left) Gauri Joshi, Qing He, Bonnie Lam. The three share the leadership responsibilities. (Courtesy GW6).

Members of USAGE gather for their first meeting, fall 2013.

"Ideas just bubbled out of these very organic conversations we were having," Olsson says. "It was a really productive back-and-forth."

— Catherine Olsson '12, MEng '13 discussing her USAGE experience

SuperUROP raises the bar for undergraduate research and innovation *by Danielle Festino and Patricia Sampson*

Anantha Chandrakasan, left, and Dennis Freeman, right, instructors for the SuperUROP seminar class 6.UAR, pose at the Sept. 26 kickoff reception for SuperUROP with (left to right) Jesika Haria, undergraduate TA, Nivedita Chandrasekaran, 6.UAR TA, Susan Hockfield, MIT president emerita and speaker at the event, and Aakanksha Sarda, undergraduate TA. Professor Hockfield also posed with SuperUROP students, eager to meet and talk with her (below, page 63): (Photos pp 62 and 63 Bethany Versoy)

SuperUROP, in its second year, features guest speakers Susan Hockfield and Ray Stata at its Sept. 26, 2013 reception

The MIT Department of Electrical Engineering and Computer Science (EECS) held a kickoff reception at the Stata Center on Sept. 26 for 80 of its juniors and seniors who recently started their yearlong participation in the Advanced Undergraduate Research Opportunities Program (or SuperUROP).

Speakers at the reception praised SuperUROP, now in its second year, for continuing to raise the bar at MIT for undergraduate research and innovation, while fostering collaboration between faculty and industry.

In his welcoming remarks, Anantha Chandrakasan, the Joseph F. and Nancy P. Keithley Professor of Electrical Engineering and head of EECS, recollected his own experience at the University of California at Berkeley, where he was able to conduct extended research as an undergraduate. This experience not only excited and prepared him for graduate school and an academic career, but also inspired him to create the SuperUROP.

Chandrakasan discussed the critical role that the SuperUROP seminar class 6.UAR (Preparation for Research), which he co-teaches with MIT professor Dennis Freeman, plays in acclimating students to the program — including introducing them to social and networking opportunities (such as the kickoff event). "We recognize how important it is for our students to get to know each other and develop a sense of community," he said.

Chandrakasan acknowledged the generous support from the 15 companies and several donors who support the Research and Innovation Scholars Program (RISP), which funds the SuperUROP students and provides some discretionary funding for the host research group. The RISP program makes the SuperUROP possible, he said. "The industry mentors provide not only suggestions and research directions," he said, "but detailed feedback on the technical aspects of the project."

At the reception, SuperUROP mentor Steve Muir, director of the VMware Academic Program, was excited about returning to the program — particularly about the wide range of research projects available to the students. "We are looking forward to seeing what the VMware SuperUROP scholars can accomplish this year," he said.

"We are also encouraged by the addition of a dedicated staff member to manage industry relationships," he added, referring to MIT's Ted Equi, who is serving as a SuperUROP industrial liaison.

SuperUROP is more than a 'warm-up'

MIT president emerita Susan Hockfield welcomed the SuperUROP crowd, saying, "[The program] is as obvious as the sun in the sky." She noted that not only do 85 percent of graduating seniors participate in a UROP, but also that UROP research is more than a "warm-up" for these students — it is real.

Hockfield praised the extraordinary ability and capacity of MIT students, saying, "If it's OK for undergraduates to take graduate-level classes, why not graduate-level research?" She continued, "SuperUROP meets our students where they are." She also congratulated and thanked EECS and Chandrakasan for taking on the SuperUROP "experiment."

Gustavo Goretkin '13 followed Hockfield in speaking to encourage the new SuperUROP class. In a unique position, Goretkin was a member of the original Undergraduate Student Advisory Group in EECS (USAGE) in 2011 and 2012 that helped shape the development of SuperUROP. He was also a member of the inaugural SuperUROP class and now, as an EECS graduate student, was given the chance to speak about his experience.

"SuperUROP not only made it possible for me to apply for graduate school with strong recommendation letters, but it prepared me well to present my research," he said. "Most useful, was hearing from the 'rock star' people who presented to the [SuperUROP] class members during the year."

The many legs of SuperUROP

Ray Stata '57, SM '58, chairman and co-founder of Analog Devices, was one of the first RISP partners for SuperUROP. In his remarks, Stata enthusiastically noted that as SuperUROP embarks on its sophomore year, the program presents "lots of learning on the how and why to engage industry." He noted that the unique way that the program pairs faculty and industry in a shared mentorship, presents incentives and opportunities for building research collaborations.

Stata gave a historical perspective on what he termed the two pillars that MIT has built so successfully over the years: education and research. Now, he noted, there is increasing focus by MIT — in a very deliberate way — on innovation and entrepreneurship. The SuperUROP program, Stata said, is contributing to this process. He also pointed to the need in industry for cross-disciplinary teaming in order to learn from and solve complex problems — something that is at the root of the SuperUROP.

Zoran Zvonar, Fellow and senior director at MediaTek, found resonance with what he heard at the SuperUROP reception. Since MediaTek joined SuperUROP in 2012, he noted, "We are eager to leverage existing relationships with research centers at MIT such as the Center for Integrated Circuits and Systems (CICS) and Wireless@mit, and expand to building new relationships with a broader talent pool of MIT students and faculty. This year we are approaching the program with more focused projects, representing the intersection of research initiatives defined by MIT faculty and students and technology areas that interest the company."

From the student perspective, SuperUROP represents deep research with the best possible support, and, for some of those students, it might provide the opportunity to feed this work into a startup.

Angela Zhang wants to accomplish both. As an MIT EECS-Amazon Undergraduate Research and Innovation Scholar, Zhang is working with the Database@CSAIL group under professor Sam Madden and postdoc Aditya Parameswaran. Excited about this work, Zhang said, "This fall, I hope to build out the fundamentals of the database platform so we can later experiment using different approaches to solve the problem of data visualization." Her goal in taking on this SuperUROP, she said, "is to answer some very big unanswered questions as well as to potentially develop my research project into a startup."

"Regardless of the SuperUROP students' goals — for graduate school, career in industry or launching a startup — the program, "Chandrakasan said, "has demonstrated a new way to innovate how students, faculty and industry work together to generate ideas while building new leaders."

EECScon 2013: a new Undergraduate Research Conference

Photo left: Dr. Brian Brandt, MIT Visiting Scientist and Distinguished Member of Technical Staff at Maxim Integrated's design center in Chelmsford, MA, discusses the work titled "Gestural Applications in the Mobile Space" presented by EECScon participant David Way '13. Photo right: One of the six EECScon participants selected to give oral presentations, Denzil Sikka '13 presents her research to the conference.

Research posters and displays lined the walls of a large conference hall at the Kendall Square Marriott on Tuesday, April 16, as invited industry guests along with self-registered MIT students (graduate and undergraduate), staff and faculty came to the three hour event that featured the work of nearly 30 EECS undergraduate students. The conference, titled EECScon 2013 marked the launch of a new, professional-level venue to showcase the original and innovative research conducted by both UROP and SuperUROP students in the Department of Electrical Engineering and Computer Science at MIT.

EECScon co-chair Dylan Hadfield-Menell (SB '12, MEng '13) opened the event attended by over 120 and introduced the first two of six oral presenters. Each speaker had been selected on the basis of his/her "elevator pitch" (basically a five-minute speed talk on their project). Speaking quality and substance of research progress and contribution formed the basis for their selection.

The 22 other (poster) presenters at EECScon were selected on the basis of their research abstract. Co-chair Frank Li ('13) explained, "We accepted everyone who provided evidence there was a legitimate research-oriented project that showed significant progress and/or results."

SuperUROP student Denzil Sikka ('13), the first speaker, discussed her work under Professor Rob Miller, titled "Facilitating the peer review process." Based on the online concept that no one works alone (NOWA), Sikka developed an online peer review game to motivate high school and college students to evaluate the quality of work done by their peers. Following six months of project development, Sikka has been able to test her prototype concept with CSAIL students.

Although a concrete research outcome was not required, the presentations were praised for the high level of work. Dr. Stephan Kolitz, Director of Education at Draper Laboratory, attended the conference with Draper colleague Dr. Milton Adams. Dr. Kolitz noted: "We were impressed with the quality of the technical work, as well as the communication skills of the students." Dr. Adams added, "All of the students were well prepared to discuss their work from 50,000 feet down to a few millimeters."

Poster presenter and SuperUROP student Minshu Zhan ('13), who has worked with advisor Stefanie Shattuck-Hufnagel, Research Scientist in MIT's Research Laboratory of Electronics (RLE), on modeling variations of acoustic cues in speech production, was encouraged by her experience at EECScon. Zhan was pleased saying that the experience was not intimidating to her as an undergraduate and made her feel more connected to the research community.

EECS Department Head Anantha Chandrakasan noted that the new undergraduate workshop evolved directly from the 2012 EECS Strategic plan with the goal of highlighting the exciting research done by EECS undergraduate students. He said: "EECScon, a student-led conference, provided an excellent forum for our undergraduates to present their research related to EECS themes and network with other students, faculty and industry members. The students did an outstanding job presenting their research contributions to the community."

EECScon was unique not only because it focused on undergraduate research, but also because a student organizing committee set the format, selection processes and all the other details that made it a success. EECScon faculty advisor Joel Voldman noted "Faculty have more experience than students and can help avoid some known issues. But other than that," Voldman noted, "the student committee came up with format, selection processes, etc."

John Sun, EECS graduate assistant in RLE, was formerly an undergraduate student at Cornell University, where his experiences to present at a couple of student conferences strongly influenced his decision to go to graduate school. "I think EECScon will have the same effect on a lot of the presenters," Sun said, "which makes me glad EECS organized this event."

Rising Stars in EECS *by Lauren J. Clark*

MIT's Rising Stars conference encourages top women in EECS to become professors

Pursuing a faculty position can be intimidating, even for a top researcher such as Aditi Muralidharan. She earned her bachelor's in physics and in electrical engineering and computer science at MIT in 2008 and is a PhD student at the University of California-Berkeley.

"You need a lot of credentials, and you're never sure if you're actually good enough," she said. Industry careers are easier to launch, she added, because "companies recruit you. Universities don't."

While that contrast reflects the fact that there are more jobs in industry than academia, universities do work to attract the most talented faculty—and they want to expand the historically low numbers of women in their science and engineering departments.

That's how Muralidharan recently wound up at MIT with 40 other elite female PhDs and postdoctoral candidates from around the country for a gathering, now in its second year, called Rising Stars in EECS. She presented her innovative research on text analysis in the humanities and social sciences. And she networked with colleagues, as well as faculty from MIT and elsewhere, who represented a range of EECS disciplines rarely encountered in one place.

The annual event, which MIT EECS department head Anantha Chandrakasan initiated, invites top graduate and postdoc women for two days of scientific discussions and informal sessions aimed at navigating the early stages of an academic career. They participate in panel discussions with faculty that cover topics such as the interview and promotion processes, and balancing research, teaching and life outside work.

"We hope that the participants get to know each other and form connections that will persist through their careers," said Chandrakasan, who worked with faculty from prominent EECS-connected laboratories to organize the event: the Research Laboratory of Electronics, the Computer Science and Artificial Intelligence Laboratory, the Microsystems Technology Laboratories and the Laboratory for Information and Decision Systems.

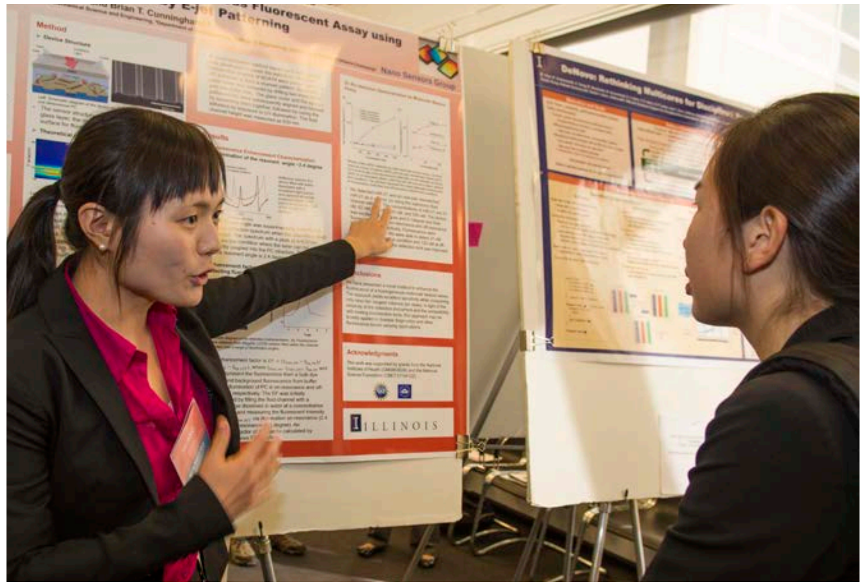
"The scarcity of women EECS faculty impacts all of us," added Judy L. Hoyt, EECS professor and associate director of the Microsystems Technology Laboratories. "Diversity is critical to the health of the profession."

Katabi and Hoyt found the attendees' oral presentations and posters impressive. A number of MIT faculty members turned out to interact with the presenters during the afternoon poster session on Rising Stars' first day.

MIT School of Engineering Dean Ian Waitz, who launched a program similar to Rising Stars in 2008 when he was head of the Department of Aeronautics and Astronautics, shared his colleagues' admiration in his welcome remarks on the second day of the event. He told the attendees that they are among the best in their schools and future leaders of their fields. "It is an honor to have you visit MIT," he said. "I hope that in a small way we can help accelerate you even further on the very strong professional trajectories you are on."

Yemaya Bordain, who uses innovative techniques in atomic force microscopy to evaluate and improve nanoscale electronic devices, said that she was one of only a few women in her PhD program at the University of Illinois at Urbana-Champaign for the first few years. She was also the only African-American woman. "I know what lonely is," she quipped. "That, coupled with the challenges, such as getting tenure, that all junior faculty face, make pursuing an academic path seem daunting," she said.

But during a poster session at which attendees presented research encompassing everything from aircraft control to image processing to medical procedures, Bordain was inspired to think seriously about a career in academia.



Rising Stars shared their high level work through poster and oral presentations — giving each participant a new view of the breadth and depth of current EECS research.

"The people who are around me right now are going to lead research and technology in the coming years," she said. "I think that women and people with diverse backgrounds have a unique perspective. And I think you see that here."

The conference attendees were unanimously appreciative of the breadth of research they encountered at Rising Stars. Tamara Broderick of Berkeley embraced the opportunity to venture outside her discipline, machine learning. "What's so nice about [the conference] is that I get to learn about a huge array of different research that I normally wouldn't be exposed to," she said.

Broderick is not unfamiliar with MIT, having participated as a high-school student in the inaugural year of the Women's Technology Program in 2002. The program, whose executive director, Cynthia Skier, spoke at the conference, has been effective at channeling women into the science and engineering career pipeline.

One of the goals of Rising Stars is to strengthen that pipeline by helping women in EECS develop an esprit de corps. Gillat Kol, who studies theoretical computer science and math at the Institute of Advanced Study in Princeton, New Jersey, found it refreshing to be among a group of researchers with whom she could discuss issues that don't usually come up in a professional setting but that are nonetheless significant.

"Sometimes, we have trouble asking for things," she said of herself and her female colleagues. "For example, I hate asking for recommendation letters, because I know it's extra work for the letter writers. But when you hear that other people experience the same thing, you feel like you are not alone."

Several of the women said that the schedule flexibility and intellectual freedom of an academic career appealed to them. Franziska "Franzi" Roesner plans to apply for faculty positions when she completes her PhD work in digital security and privacy at the University of Washington next year.

"It's good to get some perspectives from different people, and it's nice to hear and see examples of women who have been successful," she said.

One of those examples was Shafi Goldwasser, an EECS professor in MIT's Computer Science and Artificial Intelligence Laboratory. This year, she won what is considered the Nobel Prize for computer science, the Turing Award, for her pioneering work in the fields of cryptography and complexity theory. At a dinner during Rising Stars, she discussed the evolution and impact of the field of cryptography, as well as the excitement of research.

Another successful engineer, Christine Ortiz, gave a lunchtime talk about a career guided by intellectual curiosity. The MIT dean for graduate education and professor of materials science and engineering said that after watching her parents, an electrical engineer and a computer health care specialist, spend their careers in industry, she decided early on to pursue a career in academia.

"I wanted creative freedom, and I wanted to collaborate with scientists from other countries and cultures," she explained. She described her research on the biomechanics of ancient fish skeletons and exoskeletons, which informs technology in areas such as tissue repair and military armor.

Muralidharan was inspired by Goldwasser and Ortiz. "It's really cool to be a professor," she said. "It's supposed to be a great lifestyle. Hearing about it and connecting with other [like-minded] people makes me feel like it's a viable career path for me."

In addition to MIT, Berkeley, the University of Illinois at Urbana-Champaign, the University of Washington and the Institute of Advanced Study, invitees came from Carnegie Mellon University, Columbia University, Cornell University, the Georgia Institute of Technology, Harvard University, New York University, Princeton University, Stanford University, the University of California-San Diego, the Lawrence Berkeley National Laboratory, and the Tyndall National Institute of Ireland. ■

A New Initiative strengthens the Postdoc Identity in EECS

The EECS leadership group in response to suggestions made by the 2013 Visiting Committee created a new initiative to give greater identity as a group to Postdoctoral Associates in the department. With over 200 postdoctoral associates contributing their expertise on key research carried out across the EECS Department at MIT, a new association for these researchers is aimed at building the quality of their experience. Following several informal gatherings to organize and gain insights on the most constructive ways to build this new group, the Postdoctoral Group in EECS was formally inaugurated with a day-long workshop held Jan. 30, 2014.

Industry and innovators panelists included (from left to right) Dr. Samson Timoneer, founder, Scalable Displays, Ms. Marina Hatsopoulos, Windystreet, Dr. Wei Li, Eta Devices, Dr. Jay Thornton, Mitsubishi Electric Research Labs, and Dr. Ce Liu, Microsoft Research New England.

Over 40 postdoctoral associates (and several graduate students who plan to become postdocs) attended the event which featured two panels aimed at the academic career and then the startup and industry career paths most commonly followed by postdocs. Under the direction of Associate Department Head William Freeman, the first panel explored the positive and negative aspects of working in academia. Avoiding administrative overload was the common negative amongst the five member panel; while positives involving research and teaching included the liberation of being your own boss and have the freedom of changing research direction. The startup and industry panel members made many suggestions from learning how to package your research to finding the right grant opportunity to learning how to manage the many demands of a startup.

Panel members from academia included (from left to right) Prof. Magrit Betke, Boston Univeristy, Prof. Franklyn Turbak, Wellesley College, Prof. Daniel Sanchez, CSAIL, MIT, and Prof. Hanspeter Pfister, Harvard University.

The workshop participants eager to ask questions of each set of panelists also stayed on through a full afternoon of presentations which were aimed at professional development. Prof. John Guttag talked about how to get a faculty job. Among his strong recommendations, write a strong resume and cover letter, introduce yourself at conferences, and make sure you present yourself as likable. His other findings included – apply broadly, remember that no doesn't always mean no, avoid fatigue if traveling, and always present only your best material.

Prof. Charles Leiserson led a workshop exercise on how to develop your mission/research statement. Through small group and activity worksheets, Prof. Leiserson led the group members to explore values touching on the stories of Antoine de Saint Exupery and Grace Murray Hopper.

Prof. Al Oppenheim ended the session with a lively discussion of teaching and mentoring based on his 50 years teaching at MIT. He shared some of his teaching secrets such as avoiding competition with your students and using role reversal. From periodically extending yourself outside your comfort zone to being exquisitely familiar with the material you are teaching, Prof. Oppenheim's suggestions were convingly delivered based on years of classroom exposure.

Prof. Freeman wrapped up the workshop asking for suggestions for speakers as three more gatherings of the new Postdoc Group in EECS are prepared for the 2014 Spring term. ■

Staff Features

A Conversation with Francis Doughty

Administrative Assistant to Associate Dept. Head Bill Freeman

Q **How did you manage to be such a nature lover though you grew up in the Boston area near the city?**

A I grew up in Roslindale, not far from the Arnold Arboretum — the word arboretum is Latin for "tree place" — a place that attuned me to the natural world, and shaped me as a person. I went there as a young kid to play and explore and roam, and over the years growing up and into adulthood I frequently returned to the Arboretum in all sorts of weather and all seasons.

I also started birdwatching as a very young kid, and that is still an important activity in my life. Birds – listening to them, watching them, and identifying their songs – I love being in the presence of wild birds.

Not well-known or observed is a residence within the confines of the Arnold Arboretum — a house near Peters' Hill located in the dark shade of overhanging white pines and Douglas firs. To me it was "a house in the woods" and when I was young I thought it was the neatest concept, the idea of living in the woods. That planted the seed of an idea that enchanted me and shaped my life. This idea was strengthened in my mind and heart upon reading two influential books: "Walden" by H.D. Thoreau, and a book by homesteading pioneers Helen and Scott Nearing, called "Living the Good Life." Years later, I married Laura, who also works at MIT, and we bought a piece of land on a gravel road in a rural hill-town; we saved, planned, designed and finally built and moved into our house, fulfilling my youthful dream — my house in the woods.

Q **Are there things about MIT, that like your connections with nature as you were growing up, have shaped you during your more than 25 years at the Institute?**

A Putting aside the many interactions and great experiences with people at MIT, what I perhaps enjoy the most about the campus has to be the sculpture, the landscaping including some particularly beautiful trees, and also the breath-taking architecture. Planted throughout MIT are a wide variety of trees, shrubs, grasses and flowering plants. The Arnold Arboretum engendered in me a love of trees – and, familiarity with trees, like anything, teaches the eye and brain to see nuance, changes, and individuality.

To me beautiful architecture and landscaping are a kind —sculpture — certainly they are art. And, best of all, we are able to inhabit them! While arguably MIT's most dynamic architectural entity is the Stata Center — some dislike it — it continues to thrill me, and seems to constantly offer new interior viewpoints and surprises.

A Conversation with Francis Doughty

continued

Q So you have chosen to follow your life-long dream of living close to nature. Can you describe how and why this works for you?

A Actually, my home life is in many respects completely opposite from the worlds of MIT and Cambridge. I live in a heavily forested, small, rural "hill-town" which has a population of about 850 people and our house in the woods is on a quiet, dirt road abutting a 2,000-acre wildlife sanctuary.

Now here's the part that's going to sound really alien, probably especially to anybody at MIT: I don't use or have (or really want) a whole slew of modern things, like high-speed Internet, an iPod or a smart-phone. So I don't do web-streaming video or the like. I've never "texted" anyone, or used Skype, or Facebook or Twitter. I don't own a GPS device. Moreover I stopped watching television 25 years ago. I am just personally happy to live without these things.

I want to be careful here so as to not to be misunderstood that I'm in some way, "anti-science". Much to the contrary: I'm a rather passionate defender of science and the scientific method, which continue to widen our understanding of the world, and provide amazing life-improving advances in medicine and technology.

Laura and I balance our time with vegetable gardens and firewood heating, and also spending precious time with the two cats we love so much, and all of the lovely distractions of the natural world around us.

Q You are a musician and apparently have many other pastimes. Please describe how you balance everything!

A I play a folk guitar: it's a steel-string acoustic guitar, and I play both 6- and 12-string. I'm an instrumental guitar-player and song-writer. My own song-writing and style of playing is strongly influenced by Leo Kottke. I have recorded 2 CD's and I'd love to produce a third CD, it's kind of been in the works off and on for about 7 years. Guitar playing and composing songs is an integral part of my daily life and how I define myself – it's sort of like a healthy addiction. Overall, my interest in music starts and ends with Johann Sebastian Bach. His music is food for the brain! But after Bach, I listen on a weekly, if not daily basis to the music of Leo Kottke—my secret mentor in terms of his inventive playing style and compositions for guitar.

Sometimes I think that I have too many interests. I realize that I'm a curious person, and I love learning! (I am particularly interested in geology and meteorology.) So, as a slow but avid reader, I end up reading several books concurrently. Over the recent months I've been (slowly) reading Jonathan Franzen's "Corrections", "The Swerve" by Stephen Greenblatt, and, "The Divine Wind – the History and Science of Hurricanes" by MIT professor Kerry Emanuel.

It really can be hard to balance it all, especially when the work responsibilities crank up. But I have no complaints, and I enjoy living the partial-home-steading lifestyle we've chosen. I feel very grateful towards MIT and the people here who have made so much of my lifestyle possible – I'm grateful for everything!

Meet some EECS Staff members

A Conversation with Alicia Duarte

Administrative Assistant to Graduate Officer Leslie Kolodziejski

Q Where did you grow up and what kind of influence has that had on your life?

A Growing up in the small seacoast town of Truro, MA on Cape Cod, I enjoyed the benefits of a tight knit community with the added year-round vacation feel — even when the summer tourists were home for the winter! During our summer vacations, my sister and I helped our parents with their businesses. Also I have such great memories of swimming and hiking along Cape Cod Bay and taking pottery and photography classes at the Castle Hill Center of the Arts.

To this day I enjoy visiting extended family and friends.

Q Did you have any memorable experiences as a student?

A The summer of 1989, before my freshman year of college, I was selected for and traveled with the People to People American-Soviet Youth Exchange Program, in which 32 high school students from Massachusetts and Vermont toured throughout Russia meeting with local teens and learning about their culture and art in addition to practicing our Russian and English translations. For nearly a month, we visited some of the major cities including Moscow, Leningrad, Kiev, Tallinn, Estonia in the Baltics and Novosibirsk, Siberia. Despite our great distance geographically and culturally, we shared many interests including pop culture and music – and hopes for closer relations between our countries.

Q Have you had other international experiences?

A In fact, while I was attending Endicott College in Beverly, MA, where I received my Associate Degree in Liberal Arts/Humanities in June 1991, I had two internships. In January, 1991, I interned at the American Chamber of Commerce in London (England). Working with a former Member of Parliament, I learned a lot about international commerce and relations—a heightened area since this was during the Gulf War. We worked closely with the US Embassy helping a team to organize security briefings for U.S. businesses working overseas during the crisis. The workshops included dealing with bomb threats, kidnapping by terrorists and general safety measures for U.S. company employees in worst-case scenarios. Luckily, there were no major troubles while I was there.

continued

Q It sounds like you have learned how to work comfortably in many different situations. When you went to college and then grad school what was your focus?

A At Roger Williams University in Bristol, RI, I majored in political science, graduating in May 1993. I was quite interested in US and international studies, town administration and was a member and then president of the Model United Nations Club. We participated in the Harvard Model UN Clubs debates.

Based on this background and my earlier internships while at Endicott – one at the Provincetown Town Hall where I worked with the Town Manager, learning about many aspects of local government and the other at the Provincetown Tax Collectors office – I decided to continue in graduate school at Emerson College in Political Communications and Public Relations. There my studies explored the various aspects of local, state and international business and communication studies.

Q What other positions have you held before coming to MIT?

A I interned for two years at Goldman & Associates in Boston, MA, a private consulting firm, which provides private and public sector clients with a wide range of public relations, and media relations. After graduating from Emerson College, I worked for DeeDee Chereton & Associates, a Boston-based public relations firm, which promotes Broadway show performances to the Boston theater districts. It was exciting to work with Andrew Lloyd Webber's production team and local media outlets to promote "The Phantom of the Opera" to the Wang Theater in Boston.

Q Your experience is so varied but definitely not in the academic realm. How did you decide to work at MIT?

A Through my college networks, I learned about a position for Course Manager in the Physics Department (1997-2006). Working with many talented administrators including the late Professor George Koster, the Physics Department Education Officer and Course Administrator of 8.01 and 8.02 was a great way to start out my MIT career. Despite the tremendous pressures of overseeing 1,000 students and 26 recitation sections, Prof. Koster's patience and approachable personality was remarkable. I also worked with fifteen other undergraduate and graduate level physics courses each term giving me the opportunity to work closely with many professors within the Physics Department.

Q Since you joined the EECS Department Graduate Office in Fall 2006, how has your work evolved?

A This has been a positive move for me – to be exposed to new skill sets since I work primarily with current SM and PhD EECS graduate students. At the same time, my previous MIT knowledge and experiences blend well. For example, having maintained the Physics Undergraduate Majors database, I am quite comfortable with my current responsibilities that include maintaining multiple database qualifier requirements with the faculty and students. I also oversee the SM and PhD thesis submissions for the three degree lists each year, which satisify the requirements for the Institute Archives Library. What I particularly enjoy here is being involved in special event projects – particularly the new graduate admitted students — Visit Days in beginning of March . Arranging the welcome bags and other special touches that we collaboratively create in advance, I am impressed with the way these occasions are orchestrated by EECS Graduate Officer Professor Leslie Kolodziejski, Graduate Office Administrator Janet Fischer and colleagues in the Graduate Office Claire Benoit, Joycelyn Thompson, and Kathy McCoy. I was also privileged to have worked with Marilyn Pierce, who retired in 2008, Professor Terry Orlando and with the late Professor Arthur Smith.

Q Are there any other experiences you've had at MIT that you couldn't leave out?

A Over the years, I have enjoyed being a volunteer during Commencement Ceremonies. Graduation is a rewarding celebration culminating the educational journey at MIT of so many students — including those we have known in EECS. It is inspiring to think of the different roads they each will travel — leaving remarkable imprints on our society along the way.

Meet Some EECS Staff Members

A Conversation with Jessica Kraus

Outreach and Events Coordinator for Dept. Head, Anantha Chandrakasan

Q How did you find your way to working at MIT – eventually here in EECS?

A I came to MIT right after I graduated from college in 2006. Literally, I graduated on a Sunday, and Monday morning at 9am I was sitting at a desk, drinking coffee and responding to emails! I spent just over five years at the Sloan School of Management as a Global Engagement and Events Coordinator before making my way over to EECS. At this point, I'm a lifer here at MIT!

At the time I took my first job at MIT, I was just coming off of being rejected from about every law school to which I'd applied … and I was having a bit of an early twenties crisis. I didn't know what I wanted to do, or what I was good at doing. Then, my boss went on maternity leave and asked me to coordinate a series of events in her absence. After a while I realized, hey! I'm pretty good at this! And, then I realized, hey, I really like planning events! And the rest is history.

Q Now that you are in EECS, what are the fun (and unexpected) things that you find yourself doing?

A I love interacting with people. My favorite parts of my job are the amazing events that I get to plan for the students, faculty and my fellow colleagues. It's really rewarding to coordinate the events that reinforce to our participants how valued they are here in EECS.

Q Was it difficult for you to leave New York City, where you grew up?

A I used to think that I'd never leave New York. Who leaves the best city in the world? However, as I got older, I realized that I wanted (and needed) to get away for a few years for college. That's how I found myself at Boston University. I actually didn't even visit BU before sending in my deposit. I just had a feeling that Boston could be right for me. Turns out that I was correct about that!

A Conversation with Jessica Kraus

continued

Q As a marathon runner, how does your work complement your running habit — or vice versa?

A Marathon training is time intensive — to say the least. It takes a lot of planning and multi-tasking to make sure that I'm prepared for race day. Working here at MIT is no different. There's always something going on, and usually several things at one time!

Q Did you run a lot when you were growing up and how did you find that in comparison with the running you do around the Boston area?

A I never ran so much as a full mile before coming to Boston.

NYC had those yearly physical fitness tests and one of them involved "running" a mile in less than 15 minutes. Let's just say that I didn't even run that straight through. I wasn't a runner growing up, but I was very active. I played a lot of sports, albeit not very well! From a young age I was on the swim team and also played soccer, basketball, and tennis, the latter of which I played through high school and into college.

The summer before my junior year of college, I managed to completely tear my ACL while working as a counselor at a tennis and sports camp. It was awful, and painful, though not as awful and painful as recovering from surgery.

I remember my checkup appointment where my surgeon told me that I'd probably never run without pain, a little by-product of the two screws that would forever be in my knee. I also remember thinking "Yea, sure, whatever." Six months after surgery, I was running (mostly) pain free. Since then I've run so many races, including 11 half marathons, and 3 full marathons.

Q What are your favorite Boston things to do – as opposed to what you did in New York?

A I love exploring the city. New York City has always felt huge to me. But, in Boston you can literally walk from one side of the city to the other in one day. It's pretty neat that I've started a run in Somerville and made my way through almost every neighborhood in the city.

Q If you got to do your wildest dream job, what would you be doing?

A In my wildest dreams, I'd be planning fundraising events for a non-profit organization. It wouldn't hurt if I could also travel the world!

Alumni Features & Awards

Limor Fried, '03, MEng '05

Inspirational electronics sparks a new generation of makers

The following is adapted from a May 30, 2013 MIT News story written by Rob Matheson of the MIT News Office.

Although she admits that she did not create electronics before she came to MIT as a student, Limor Fried spent a lot of time with her Brookline, MA high school friends coming to MIT to hang out – soaking up the hacking culture in the process. She says her friends were really interested in this new thing called the Internet.

"We heard that MIT had a connection to it," she says, "so we used to walk into the W20 cluster, log in as root and run Mosaic on the Sparcs." Then at night, she says, she and her friends would go to Anime Club or LSC. She remembers thinking "Wow! This is incredible. I wish I was a student here, everyone is so smart and there is so much fun stuff to do. I want to learn everything there is to know!"

Initially a computer science major at Boston Univeristy, Fried transferred to MIT EECS in her junior year so she could become more involved in electrical engineering. By the time she entered the MEng program in EECS, Fried was happiest when she could work late hours assembling electronic devices — unique gadgets that she began to sell online—while freely sharing her design plans. At this stage in her life, Limor Fried had taken on the moniker "Ladyada," after a 19th-century female mathematician and first computer programmer, so it was only natural that she named her startup company Adafruit Industries.

From then to now

Since its startup phase, Adafruit has become a multimillion-dollar company that's been called a leader in the open-source hardware industry. And Fried now Adafruit's CEO, is lauded as a pioneer of the "maker movement," a rising culture emphasizing do-it-yourself technology that has proved to be a profitable niche.

In January 2013, Fried was named "Entrepreneur of the Year" by Entrepreneur magazine. In 2012, she was the first female engineer featured on the cover of Wired, and was included on Fast Company's "Most Influential Women in Technology" list. In 2009, she was awarded a Pioneer Award by the Electronic Frontier Foundation, a digital-rights group.

"There are many amazing people working hard and inspiring the maker movement every single day," Fried says of her tech-celebrity status. "We all have our roles and little parts we can do to make the world a better place through learning and sharing."

Adafruit primarily sells "kits" of build-your-own electronic devices, complete with open-source licenses, encouraging customers to modify the final products. But its primary focus is on teaching engineering to the world, Fried says — "an educational company that just happens to have a gift shop at the end."

While flattered by the publicity, Fried hopes her fame across makerdom will help promote science, technology, engineering and math (STEM) education — and show that there's a way to combine a passion for engineering with entrepreneurship.

"I think this represents opportunity for more makers and hackers to see it's possible to be a good cause and a good business," she says. "Anyone who wants to help teach people electronics and how to make things can make a business out of it."

Paving the Entrepreneurial Road at MIT

Nine years ago, when Fried was still combining her MIT graduate student status with launching her startup, there was a lot of uncertainty. But, she kept at it.

MIT — with its emphasis on diligence and experimentation — became a safe haven. "MIT is a great place to come face-to-face with what you know and what you don't know, and to power through the discomfort of not knowing 100 percent of what you're doing," she says.

Many of her creations took place in MITERS, a student-run lab stocked with electrical engineering equipment and "a great resource for creative engineering,"

Fried says. There, she developed some of her early commercial devices — such as the MiniPOV, whose LED display makes words appear to be floating in air, and the Minty MP3 player, which fits inside an Altoids tin. (A version of the latter, the MintyBoost Kit — an Altoids tin-based charger for portable devices — is now Adafruit's best-seller, with more than 50,000 units sold.)

Fried provided the design plans for these devices through her personal website and, in 2005, began selling preassembled kits to a steady influx of customers — laying the foundation for Adafruit, which Fried officially opened a year later in New York.

In its 12,000-square-foot industrial space in Lower Manhattan since 2013, Adafruit's employees — now more than 60 — ship hundreds of products per day. Last year the company sold about $22 million worth of its famed do-it-yourself kits and other products.

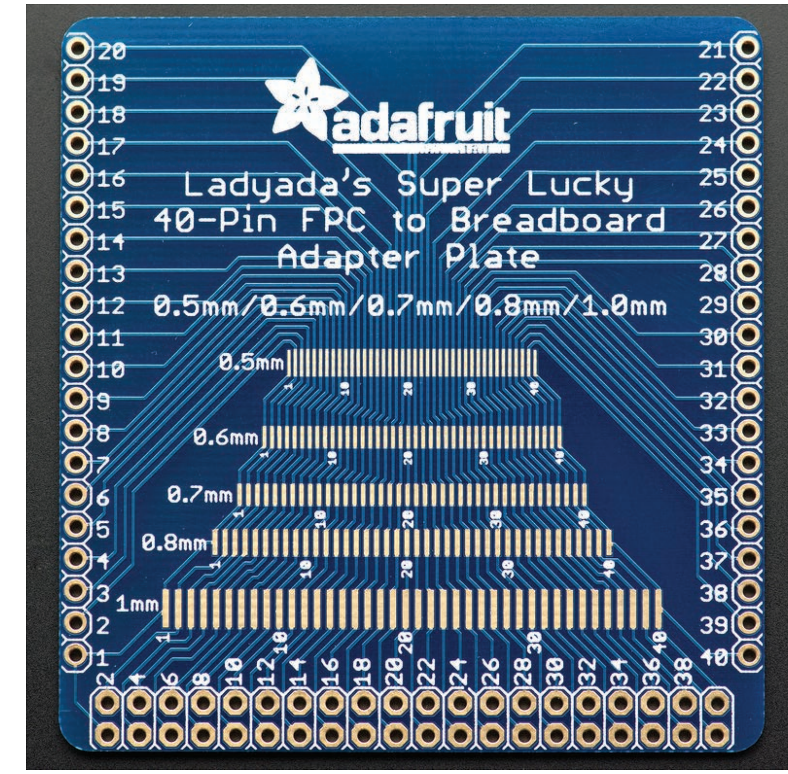
Looking back, Fried says the competitive, entrepreneurial ecosystem at MIT helped inspire her to launch her business. "The entrepreneurial culture is strong at MIT," she says, "and when I saw how many of my friends were starting companies out of college it made me think, 'Hey, if they can do it, I can do it too. Let's do this thing!' I think that's part of the healthy competition that MIT is known for."

Fried also notes that starting and running a company is just hard work. "Either you make something people want or you go out of business! There is nothing more helpful to starting a company than a gritty determination," she says adding: "Every student should have a blog where they publish their projects! Some really cool designs come out of classwork or IAP but they are rarely shared outside of a class or living group. There should be a tumblr-requirement for graduation!" she quips.

Creating the Pixar of educational electronics: "A is for Ampere"

As a maker-movement pioneer, Fried says she hopes to inspire a "culture of makers" by sparking people's interest in building not only their own electronics, but also their own tech startups. "Adafruit not only wants to make more makers, we want to help inspire people to make businesses — and make even more makers," she says.

Apart from selling kits, original devices and providing hundreds of guides online, Adafruit works around the world with schools, teachers, libraries and hackerspaces — community technology labs — to promote STEM education, designing curricula in circuitry and electronics, among other initiatives.



The company has released an online children's show called "A is for Ampere." On a weekly Wednesday night program, "Ask an Engineer," anyone can ask Fried questions online or show off their original devices.

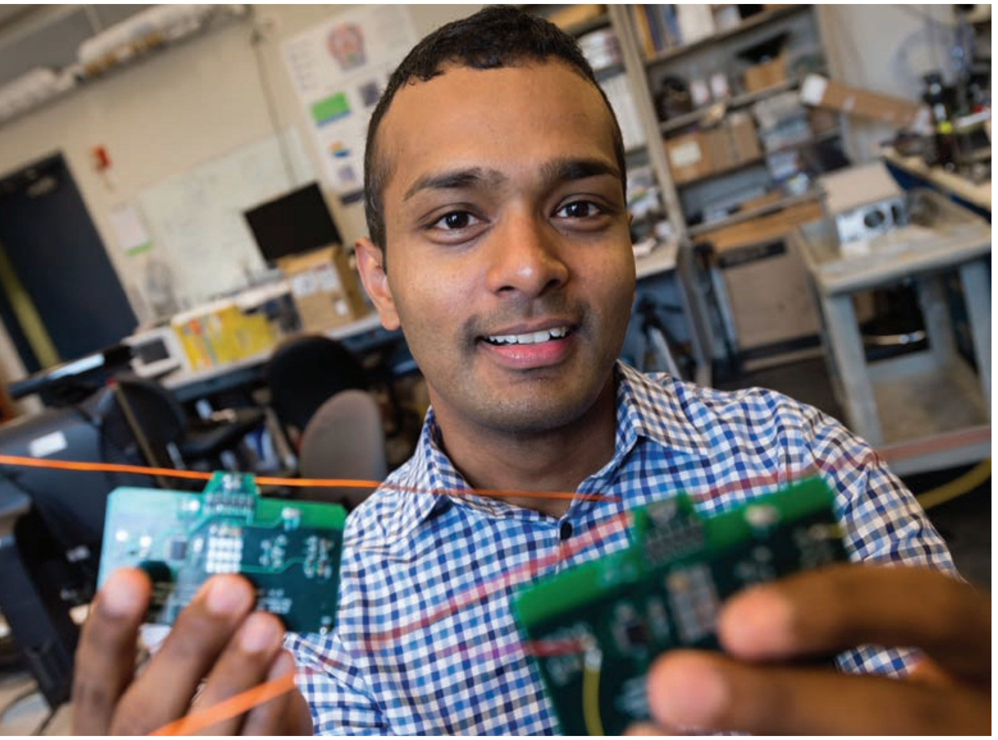
As Adafruits has become a phenom in the online maker world, Fried is enthused by its growth and influence. "I'd like to think we'll become the "Pixar of educational electronics" - in other words, telling amazing stories, teaching, sharing with the best place online to get the best educational electronics. As the maker movement has grown and flourished, so has Adafruit." Adafruits has tripled (216%) year-over-year, she notes, allowing the company to add more products and designs. "We try to be the best," Fried says, "and the maker community has rewarded us with the support and orders."

One of Fried's favorite stories, from a young viewer of "Ask an Engineer," illuminates what she sees as the growing diversity of engineering. "A parent emailed us after watching the show with his daughter," she says. "I had another engineer on the show with me — my friend Amanda — and this parent's daughter asked, 'Dad, are there boy engineers too?'"

Ultimately, Fried says, her mission is to inspire everyone to be makers and entrepreneurs. "If there's one thing I'd like to see from this," she says, "it would be for some kid to say, 'I could do that,' and start the journey to becoming an engineer and entrepreneur."

Shyam Gollakota, PhD '12

Wherefore go the networks?



As a computer science undergraduate student at IIT Madras, Shyam Gollakota was well aware that his research interests at the time in security and cryptography would be well served by continuing as a graduate student at MIT. So he applied to the PhD program in the EECS Department in Theory.

Though he had done some networking research as an undergraduate, he was pleasantly surprised when he received a call from Prof. Dina Katabi, who invited him to come study at MIT. "She talked about her interdisciplinary research that bridges theory with practice," he recalls "and we connected immediately. Her energy and drive were palpable even over the phone," he continues. "I decided right then to join MIT and I think it was one of the best decisions I have ever made!"

Now that Shyam Gollakota is Prof. Gollakota at the University of Washington (UW) – a position he accepted following his graduation with a PhD in Computer Science from MIT in 2012 — he looks back at what it was like to be a student in MIT EECS. He says "The drive to achieve big things was contagious at MIT and hard not to catch!" He describes the times he worked with Prof. Katabi as fun and intellectually stimulating — including discussions about research that extended to the early morning hours.

In fact, Prof. Katabi joined her students – including Shyam Gollakota – in taking classes to learn material in other domains such as digital wireless circuit design and compressive sensing. He admits, "It was a cultural shock to me that my advisor would attend classes with me!"

[You can also get some idea of his teaching and the group's research by checking his group's website built by his students. http://netlab.cs.washington.edu/]

Now, he gets to follow in Prof. Katabi's footsteps. "I hope to sustain that kind of drive as a faculty member and motivate my students to do the same," he says.

The ambition and energy inherent in his goals are reminiscent of his EECS roots. He says: "My goal is to change our fundamental understanding of what is possible, by designing and building novel systems that challenge conventional wisdom." By connecting what look like unrelated fields, Gollakota is driven to explore new approaches in his research. "Beyond building prototypes of my research," he continues, "my goal is also to take the research to its logical extreme by building production-quality systems that can be deployed in the wild. I believe this is just as important for systems research as is coming up with new ideas."

Prof. Gollakota also loves working with students, both in the classroom and in the lab. He makes no excuses saying, "Being a great teacher and mentor is also part of the plan."

Another beauty of reaching his status as a researcher and professor at UW CSE is that he can work collaboratively with other faculty across different disciplines. "This has significantly changed the direction of my research," he notes. Gollakota's thesis work was about improving the performance and security of wireless networks. But, since joining UW, his research is now focused on the intersection of wireless and other domains like HCI and power systems.

Waving for wi-fi

For example, at UW Gollakota's group built WiSee, the first system that leverages existing wireless signals (e.g., Wi-Fi) to enable sensing and recognition of human gestures at a large scale (e.g., throughout an office or a home). "Gestures enable a whole new set of interaction techniques for always-available computing embedded in the environment," he states. As an example, he suggests that a hand swiping motion in the air could enable a user to control the radio volume while showering – or change the song playing on the stereo in the living room while you are cooking in the kitchen.

Gollakota says that the approaches offered today to enable gesture recognition – by either installing cameras throughout a home/office or outfitting the human body with sensing devices – are in most cases either too expensive or unfeasible. So he and his group members are skirting these issues by taking advantage of the slight changes in ambient wireless signals that are created by motion. Since wireless signals do not require line-of-sight and can traverse through walls, he and his group have achieved the first gesture recognition system that works in those situations. "We showed that this approach can extract accurate information about a rich set of gestures from multiple concurrent users, "he says.

This work has been covered by the BBC, the Washington Post and Wired and won the Best Paper Award at MobiCom 2013. (You can also join the 300k+ viewers on YouTube to see the group's video demo at: http://www.youtube.com/watch?v=VZ7Nz942yAY

Powering networks out of thin but heavily networked air — in urban areas

In collaboration with Josh Smith and David Wetherall at UW, Gollakota has recently explored connections with research in extremely low-power systems. They asked themselves the question: "Can we enable devices to communicate using ambient wireless signals as the only source of power?"

They reasoned that since ambient RF from TV, cellular and Wi-Fi communications are widely available in urban areas — 24/7 indoors and out, then devices that can communicate using ambient wireless signals as the only source of power could enable ubiquitous communication in smart interactive environments. Such communication would also scale and work in locations previously unfeasible and also be used in personal health and fitness devices and new applications waiting to be created.

The challenge in designing such a communication system, however, is that the simple act of generating a wireless signal for communication typically requires much more power than can be harvested from ambient radio signals. To address this, Gollakota's group recently invented ambient backscatter, a new communication primitive that enables two devices to communicate without either device generating radio waves! "Since this does not require a dedicated power infrastructure and can enable communication between two battery-free devices," Gollakota says, "it brings us closer to the vision of cheap battery-free devices." This work recently received the Best Paper Award at ACM SIGCOMM, 2013 and significant media attention including *Tech Review*, the *NY Times*, and *Scientific American*, and has more than 350,000 views on YouTube at: http://www.youtube.com/watch?v=gX9cbxLSOkE.

Based on Gollakota's vision, traditional wireless networks used primarily for communicating bits from one point to another will become much more pervasive. "I think the future wireless signals and networks are going to be transformed from being just a communication medium to much more," he notes. "This would include being a human-computer interaction sensor (e.g., gesture recognition) and a source of power for battery-free devices. I think this is where the future is heading."

"My goal is to change our fundamental understanding of what is possible, by designing and building novel systems that challenge conventional wisdom."

William Irving, '87 (6-1), SM '91, MEng '92, PhD '95

Quantitative theory backs up investment instincts

Growing up in suburban Denver, Bill Irving stood out as a math and science kid. "For many years in elementary and junior high school, I was left to my own devices to learn math and science – rather than be bored in class," he says. This isolation finally abated in the summer before his senior year when he went to the Frontiers of Science Institute at the University of Northern Colorado. Following this very affirming experience, Bill decided to study engineering at MIT — specifically chemistry followed by medicine.

As an undergraduate at MIT, Bill Irving was struck by two realities: how positive he found his experience being part of the Chi Phi fraternity and how potentially demoralizing it was to keep up with all the brilliant people in his classes. Fortunately, Bill's frat brothers remain life long friends and ultimately he found at MIT that he was inspired by his very bright classmates and that "feeling humbled was not such a bad thing."

Not just about circuits

By his sophomore year, Bill Irving was tending towards Course VI particularly because of his experiences taking several classes such as Al Drake's 6.041, Probabilistic Systems Analysis. His eyes were opened by the diversity of Course VI. "It wasn't just about circuits," he notes. From his doctoral studies, his engineering career in battlefield surveillance and even his career in finance, Bill still relies on the skills he learned in 6.041 for probabilistic modeling.

Taking Alan Oppenheim's 6.341, Digital Signal Processing at the time that compact discs were usurping records as the preferred medium for music storage, Bill found it really cool that sound could be digitized and then filtered using the techniques taught in the class. He also notes "Prof. Oppenheim's textbook '*Discrete-Time Signal Processing*' was a masterpiece – representing a culmination of many decades of dedicated thought and research."

Estimation theory and cycling through Vermont: the path to graduate school and beyond

Following his undergraduate years, Bill Irving worked full time for two years at MIT Lincoln Laboratory. His Lincoln colleagues Rick Barnes and Dennis Blejer were particularly influential. Rick taught him the essentials of detection and estimation theory, and was an enviable master of back-of-the-envelope calculations. Dennis taught him the essentials of electromagnetic wave theory and also the beauty of cycling through the hills of Vermont.

Lincoln Lab also fostered Bill Irving's move back to graduate school by funding his studies through their Staff Associate program, and he continued to work for them during the next five summers.

Back at MIT, Bill joined the Laboratory for Information and Decision Systems (LIDS), working with Professor John Tsitsiklis on his Masters thesis and with Professor Alan Willsky on his doctoral thesis.

"My graduate career taught me that learning can be a very personal, human endeavor; initiative and hard work are important, but more so are the interactions and collaborations with others. With regard to these others, my tremendous good fortune was to be surrounded by top-notch advisors, teachers, colleagues and friends."

From a sea of red ink to performing on radio and television — lessons in communication

Of the skills he developed through his graduate studies, Bill singles out the value he gained in developing crisp, effective communication – both written and oral. "Alan Willsky used to mark drafts of my papers with a sea of red ink," he notes, yet through collaboration with his Lincoln colleague Shawn Verbout, Bill learned that "the key to clear writing is painstaking, hard work."

Bill Irving transitioned from engineering to finance around 15 years ago when he began a new career in the fixed-income division of Fidelity Investments as a quantitative analyst. His first job was to build and maintain tools for valuing mortgage-backed securities (MBS). At the time, he notes, "he knew close to nothing about bonds or finance. But I was fearless," he continues, "as my MIT training had given me a level of confidence that was not easily shaken." In fact, interacting with traders and portfolio managers who knew the inside jargon did not dissuade him. Today, Bill is a portfolio manager at Fidelity where he leads a team that manages about $40 billion in fixed income assets, mainly MBS.

Bill not only entered the financial world as an MIT PhD trained engineer, but was still getting his boots on the ground when the 2007-2009 financial crisis hit. "I feel like I gained about 15 years of experience in that short, turbulent period," he notes. In fact, Morningstar nominated one of his MBS funds for 'bond fund of the year'. Although the fund didn't win, he says, "I was fortunate to survive and emerge smarter and more experienced [through this period]."

Although nearly 15 years of experience in the market have given Bill Irving an instinctive feel for how things work, he says he can still back this up with a good understanding of the underlying quantitative theory. Although he rarely develops algorithms anymore, he has been a regular in various tv and online interviews. You can hear him present his sought-after analytically-based financial reports on Bloomberg media and CNBC. Go to: http://media.bloomberg.com/bb/avfile/News/Surveillance/vVwczf6W79b4.mp3 and http://video.cnbc.com/gallery/?video=3000105695&play=1

Bill's eyes were opened by the diversity of Course VI. "It wasn't just about circuits," he notes. From his doctoral studies, his engineering career in battlefield surveillance and even his career in finance, Bill has and still relies on the skills he learned in 6.041 for probabilistic modeling.

Conor Madigan, '00 PhD

Founding Kateeva to put flexible and large-size OLEDs in the mainstream

If you had the choice to be a professor in electrical engineering at potentially any major university, or to start a manufacturing company to produce a new high technology product that would be at the forefront of a new industry, what would be your choice?

Conor Madigan is a thorough kind of person – especially when it comes to decisions. This particular choice in his career came as he completed his PhD in 2006 under Prof. Vladimir Bulovic and was working as a postdoc on printing OLED materials for low-cost scalable manufacturing. His decision required careful thought and a bit of time. Fortunately, good faculty positions at that time were hard to find.

Working with his colleagues (EECS graduate students) Gerry Chen, who was advised by Bulovic, and Valerie Gassend (then Valerie Leblanc) who was advised by Prof. Marty Schmidt, brought Madigan the satisfaction of returning to work that was related to several projects he had enjoyed as an undergraduate at Princeton under Prof. Jim Sturm. He had learned at the time that he was fascinated by working with OLED science and engineering, and one of these two projects ironically involved inkjet printing to produce OLED.

So Conor Madigan took advantage of his long association with Vladimir Bulovic to discuss his career choices following his postdoc. The two had met at Princeton when Vladimir was finishing his own postdoc and preparing to start his new lab as a faculty member at MIT. He invited and convinced Conor to come to MIT as one of his two new graduate students. With Seth Coe Sullivan, Madigan jumped in to build the Bulovic lab (in the summer of 2000).

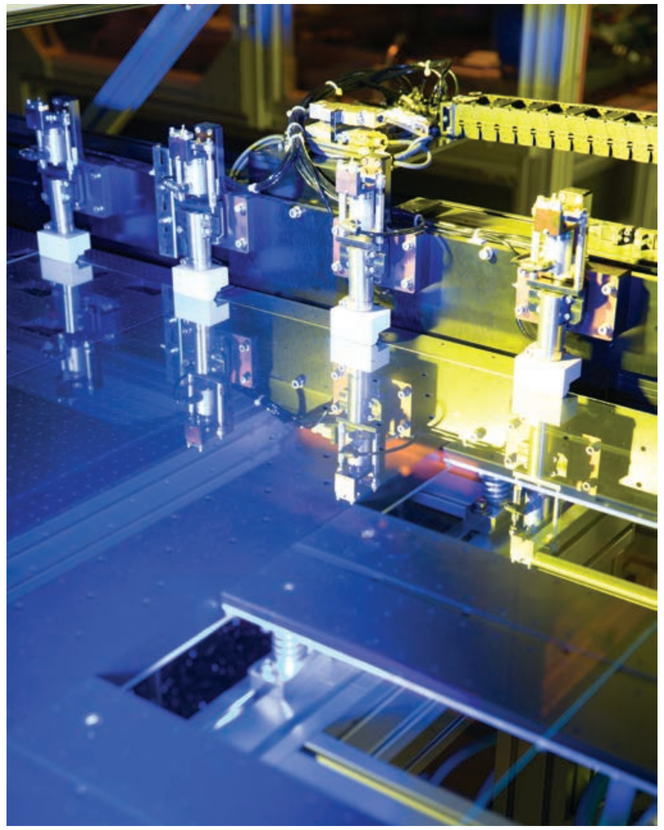
In 2007 Madigan found his answer to his career choice was increasingly weighted towards building a new company. Developing his startup pitch deck was an exciting process. And jumping into two business classes at the Sloan School got him closer to his choice. By late 2007, he asked Vladimir, Marty, Gerry and Valerie to join him in the new company and halted faculty position applications.

Conor's recounting of the steps that led to forming Kateeva is an exercise in startup knowhow.

Incorporating Kateeva (in Delaware) was as simple as following online instructions. In less than a month, Conor gave the first pitch presentation at the logical starting point — a printed electronics investor conference in Silicon Valley. The value of associations instantly kicked in, as Conor met with Dr. Sass Somekh, former EVP of Applied Materials and former President of Novellus—fortuitously arranged through Marty Schmidt. "Sass is considered a legend in the Silicon Valley semiconductor equipment industry – the architect of key products that made Applied Materials a $10B company," Madigan notes.

Madigan gets excited as he relates the next steps: "At that first meeting, I pitched Sass on the idea of forming a company to commercialize our MIT technology to enable low-cost OLED manufacturing. He was intrigued."

Sass Somekh was not just intrigued. Following a successful meeting with a potential customer in Asia, Sass joined Kateeva as the sixth and final co-founder, also becoming the executive chairman. He held that position until retiring from the Kateeva board in mid-2013.



Print-head Module on Kateeva's YIELDjet [tm] Platform. Courtesy: Kateeva

"The key to the Kateeva pitch was OLED, "Madigan notes. OLED in early 2008 was just getting commercial visibility following earlier hype-bust cycles. Sony's release of an expensive but gorgeous TV that offered better color, contrast ratio and viewing angle than LCD – and paper thinness and flexibility, lower power and (ultimately) lower cost was perfect timing for Madigan's pitch. Sony's release helped Madigan persuade potential investors that by changing the production economics, OLED could seize the $100B/year flat panel display industry from LCD – potentially opening up a $1B+/year market opportunity for equipment manufacturers like Kateeva.

Following a marathon pitch day with six VC firms, all of them requesting additional meetings — Kateeva accepted a term sheet for a $10M investment led by a premier VC. By the end of April, Madigan moved to SF, closed the MIT patent license and the first investment round and Kateeva was up and running. "I was so busy that I never stopped to think that 90% of the things I was doing every day were completely new to me," he recollects.

Conor Madigan continues to build Kateeva through collaboration, learning on the fly, timing, and being ultra-nimble in the face of change. Kateeva's key proprietary inkjet printing technologies were developed through close collaboration with leading OLED manufacturers. Madigan has learned that a startup CEO needs to be ready to "do it all," though he credits Kateeva's steady and speedy growth to the contributions of his team — including an engineering brain trust — individuals who are passionate about inventing. Fortunately, OLED has been growing explosively since 2008 – now a $10B a year industry and heavy-weight advocates Samsung and LG are pushing OLED as the display technology of the future. Kateeva also turned on a dime several years ago successfully rebuilding their printing approach.

"Turns out it was a smart move," Madigan notes about this nimble turn around in Kateeva's production technique approach. "Since then, we've executed well. We have first prototype systems in the field with first production systems planned for shipment this year."

"By any measure", he continues, "that's tremendous progress for a complex science-based hardware product in such a short time frame. Beyond that, we've also recently expanded our executive team. We recruited Alain Harrus, PhD, a semiconductor industry veteran and respected VC, as our new CEO to help position Kateeva for the next growth stage and I have stepped into the role of President. Overall, it's exciting momentum. And we're pretty proud!"

Kateeva's YIELDjet [tm] Platform. Courtesy: Kateeva

Bill Thies, '01, MEng '02, PhD '09

When the alternative path is the right path

Bill Thies was a top student. At the end of undergrad, he had a perfect GPA and a world of opportunities. When he graduated from MIT with his PhD in computer science in 2008, Bill was at the top of his field with tenure-track faculty offers from Stanford and Berkeley. He was also interested in a dramatically different alternative — to live in India and develop technology to impact global disparities in health, education and livelihood.

How and why he made this choice is the perfect story that follows.

As an undergraduate, Bill was seeking ways to learn about developing countries. The question was how to find the resources at MIT to help in this search. Coincidentally, he learned about a lecture series run by EECS Prof. Saman Amarasinghe on disseminating health information in remote rural areas. In fact, Michael Dertouzos, then LCS director, spoke at this event about the lab's commitment to targeting technology for the benefit of global health and well-being. Bill notes about this convergence: "I was stunned, not only by the resonance with my interests, but by a divine coincidence: Saman was already supervising my UROP on an unrelated topic! Herein was born the greatest gift that MIT would offer me: a deep connection with a mentor and role model who championed my personal development for almost a decade."

Things moved quickly after that. Without hesitation (or applying to other graduate schools), Bill enrolled for his PhD at MIT continuing with Prof. Amarasinghe. Soon Bill traveled with him to explore opportunities in Sri Lanka and India where new technology could have an impact on poor communities. He notes: "Saman already knew the ropes – both as a native of Sri Lanka, and as founder of the first Internet Service Provider in the country."

For Bill, everything in India and Sri Lanka was new and unfamiliar. To get his feet wet, Bill helped in the 2002 development of several projects including Time Equals Knowledge (TEK), an email-based search tool for users in low-connectivity environments. In collaboration with LCS affiliate Libby Levison and many students, they deployed this tool and logged usage from diverse individuals – students, farmers, even priests – in remote areas out of Internet reach.

Although he says it was gratifying to have a taste of technology's impact in these surroundings, Bill recalls the development of his thinking: "The more we worked to enable information retrieval in developing regions, the more we realized that the most profound unmet need was not in consuming information, but in producing information. The Internet took off only with the rise of user-generated content – Facebook, YouTube, Twitter – where everyone has a voice and a global audience. For a low-literate farmer in rural India, owning a basic mobile phone and speaking only the local language, producing content may have very different meaning. A number of questions followed. Can we give this population a 'voice'? And will an international audience listen? Can farmers leverage this ability to improve their daily lives?"

With Saman's group, Bill helped build a prototype of an 'audio wiki': an Interactive Voice Response (IVR) system to enable callers to both record and listen to audio content. In audio format, the content became accessible to low-income populations – without smart phones or Internet connectivity or even literacy.

This prototype was launched in India in 2010 as a real-world deployment called CGNet Swara (http://cgnetswara.org/). CGNet Swara provided a new way for rural citizens and social activists to voice news, grievances and cultural stories that otherwise would go unnoticed. Soon, urban activists, government actors and members of the mainstream media were monitoring the system – amending many of the problems that were voiced.

To date, CGNet Swara has released about 4,000 messages and has received about 300,000 calls from listeners. Many reports have had a documented impact on rural communities. For example, reported bribes have been returned; lost wages have been paid; and overdue services have been delivered. Every impact story is detailed on the CGNet Swara website.

Bill's attraction to work in India was also based on his joining a team for the 2007 MIT IDEAS competition and the Yunus Challenge to Alleviate poverty. The focus of the challenge that year was to improve adherence to tuberculosis medications. The group, led by Manish Bhardwaj, SM '01, PhD'09, developed a low-cost electronic pillbox to monitor and improve medication adherence. Winning the challenge and earning recognition in other collegiate business competitions opened up many doors for the team. Bill notes about this milestone: "The most important outcome of our entry was not the technology – which met with difficulties during deployment – but our exposure to the problem domain. As part of the challenge, Manish and I traveled to India and saw the impediments to rural healthcare delivery first hand."

When the time came to graduate, Bill could have taken a faculty position in the United States, building on his dissertation research in programming languages and compilers. The other choice was to take a position at the new Bangalore branch of Microsoft Research (MSR). The interdisciplinary group at MSR India aimed to apply technology to the needs and aspirations of poor communities — a focus that resonated for Bill. And, Kentaro Toyama, the founder of this group was deeply inspiring to him. The decision, though difficult, was obvious.

Moving to India in 2008 allowed Bill and the Yunus Challenge team to bring their ideas to real-world impact. Using his knowledge of TB in India, Bill worked with Operation ASHA to develop a new system using biometrics to track patient visits to health centers. Not only has this system been deployed across 100 clinics and served over 6,000 patients in India, but it is also the focus of a randomized controlled trial by MIT-JPAL. Since Bhardwaj and Thies reported on their non-profit called Innovators in Health in the 2011 MIT EECS Connector, the group has been awarded a grant from the Gates Foundation, USAID, and IKP to pursue a brand new approach to monitoring medication adherence— a development that was only possible after spending several years observing the context, Bill notes.

Sometimes, undergraduate students approach Bill about work at the intersection of technology and global development. "No matter how good your technical chops are," he suggests, "it's almost impossible to create a successful intervention in a socio-economic context that is radically foreign to your own. Even after living in India for five years (and marrying the girl in the office next to mine!), I still find that my intuition is severely lacking. Nevertheless, he says, "Living in India makes it possible to quickly adapt and evolve. When my intuition is wrong, I can at least *fail fast*—testing ideas with local users and organizations within a few days, as opposed to the weeks or months required from afar."

His recommendations for similarly minded students? Check out classes such as D-Lab for the best possible introduction to the domain, as well as the MIT India program for supporting trips and internships to labs such as his. "If you're considering a visit to Bangalore," Bill adds, "please do get in touch! My email address is thies@microsoft.com."

"Living in India makes it possible to quickly adapt and evolve. When my intuition is wrong, I can at least *fail fast*–testing ideas with local users and organizations within a few days, as opposed to the weeks or months required from afar."

Andrea Wong, '88

"It's a great time to be in television!"

Andrea Wong grew up in Silicon Valley attending the high school that Steve Jobs and Steve Wozniak went to. Technology was all around her. "I was a good math student, so everyone told me that I should be an engineer. I wanted to go to the best school possible, and MIT was it."

Though she is used to working hard, Andrea says that studying Electrical Engineering at MIT was the hardest she ever worked in her life. She says about her training, "I think every woman or girl who is even remotely interested in science should get an engineering degree because it trains your mind. When you walk away from MIT, it just trains you to break down very difficult problems."

While she was at MIT, Andrea Wong never questioned that she would be an engineer. So, it took her a while to figure out that she could do something else. But once she did, she realized she could do anything. She started at an investment bank as a financial analyst, followed by a job at Pepsico. Both positions allowed her to master the fundamentals of business and professionalism.

From this point, however, Andrea knew that to reach a really fulfilling career, she needed to focus on what she was passionate about. For her that meant what people do for entertainment – how people relax and escape, how they use their leisure time and income. Shaping her ideal life's work took the kind of analytic and focused attention that she had built during her MIT experience.

While gaining her MBA at Stanford Graduate School of Business, Andrea explored the worlds of entertainment, travel and leisure, and food and wine. "I talked to anyone in those fields that would give me ten minutes and read everything about those industries."

Andrea fell in love with TV news when she got a summer job at NBC. So, when she graduated from Stanford in 1993, she decided to start all over again, at the bottom of ABC News as a production associate making less money than she made in her first job out of MIT. But, she climbed the ladder from there.

She also made use of her thorough exploration of entertainment as she built her career at ABC. As executive vice president of alternative programming, specials and late night, Andrea developed hit shows such as "The Bachelor", the U.S. version of "Dancing With the 'Stars'" and the Emmy-award winning "Extreme Makeover: Home Edition".

Again, the discipline she gained at MIT played a key role – but with a twist. "In engineering at MIT, she explains, "you're trained to take a whole bunch of complex issues and solve them down to an answer. But when I went into the creative world, I had to train my brain to do exactly the opposite — take a kernel of an idea and grow it into a show."

In terms of technology's impact, Andrea notes that technology is making tv more powerful every day because it is allowing people to consume more and more content — how and when they want.

In 2007 Wong followed her multiple contributions at ABC, taking a new position as president and CEO of Lifetime Networks, where she quickly guided the company to strong ratings with shows like the top-rated original series "Army Wives" and "Project Runway". Both of these shows were the highest rated series on Lifetime. She also oversaw the development of digital experiences aimed as a destination for women online.

Today (and since fall, 2011), Andrea is the president of international production for Sony Pictures Television (SPT) and international president for Sony Pictures Entertainment. In her SPT position, Andrea oversees the studio's international television production business – including eighteen owned and joint venture production companies around the world.

As the global tv audience continues to expand, Andrea is also exploring content creation for a wide range of geographic and cultural diversity. She says, "One of the most exciting things about my job right now is that I get to make tv all over the world. We make comedies in Russia; we make talk shows, game shows, and tele-novellas in the Middle East; we make tele-series in Colombia and Mexico. It's endlessly interesting." On her way to Stockholm, she points to the potential tv markets not only in Scandinavia but also in India, China, South Africa, and eventually in Australia.

How is it possible to relate to all these varied markets? Andrea says: "There are certain things that resonate or provoke people and the best global hit tv shows tap into that, and that allows great shows to travel around the world. For example," she continues, "we own 'Who Wants to be a Millionaire?'. This show has been in 88 countries. It resonates because it's about betting on your own knowledge and it's something that is universal."

Although she is responsible for overseeing content creation companies worldwide — regardless of technology platforms — Andrea's electrical engineering background has meant a lot in terms of her awareness of the benefits of constantly evolving technologies. She notes that although technology may occasionally provide a degree of freedom creatively — such as interactivity — technology developments provide more opportunity for distribution.

Paired with her love for her work, Andrea credits her success to the fearlessness that she got from her MIT engineering education. "The greatest thing I got out of that education was I have absolutely no fear about solving problems because I will never solve harder problems than I did on a daily basis when I was at MIT."

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"The greatest thing I got out of that education was I have absolutely no fear about solving problems because I will never solve harder problems than I did on a daily basis when I was at MIT."

Almni in the news

A few awards and recognitions. Please share your news!

Fill in the form at eecs.mit.edu/people/alumni to send us your information so we can post it!

Alumni Awards

Roozbeh Ghaffari, '01, MEng '03, HST PhD '08, was selected for the TR35 in 2013 as an innovator creating novel ways to integrate elctronic devices with the body to address health issues. He is co-founder of MC10 and leads advanced technology development there.

Sanjay Ghemawat, EE '90, with Jeffrey Dean was recipient of the 2012 ACM-Infosys Foundation Award in the Computing Sciences. They led the conception, design, and implementation of much of Google's revolutionary software infrastructure, which underlies the company's web search and indexing, as well as numerous applications across the industry.

Kota Murali, EE '06, won 3 awards in 2013 including IBM's Corporate Outstanding Technical Achievement Award, the Materials Research Society of India Medal, and the Indian National Science Academy Young Scientist Award. Kota is the Chief Technologist for Nanotechnology at the IBM India Semiconductor Research and Development Center.

Yogesh Ramadass, EE '06, was named Innovator of the Year in the ACE Awards for his pioneering work in energy harvesting circuits. The Texas Instruments lead design engineer helped craft the TPS 62736, an ultra-low power converter that manages microwatts generated from solar, thermoelectric, magnetic and vibration energy.

Irwin Jacobs, SM '57, ScD '59 was selected for the Computer History Museum's 2014 Fellow Award — a distinction that recognizes technology leaders who have forever changed the world with their accomplishments. Jacobs is cited for his pioneering work in digital mobile telephony, data and communications technology.

Alumni Recognition

The Atlantic has recently featured two women computer scientists — both MIT graduates. Irene Greif, the first woman to receive her PhD in computer science from MIT (in 1975) and Radia Perlman (PhD, 1988), who (also) remembers being one of just a few dozen women out of a class of 1,000. Read each article, now available on the alumni section of the EECS website: eecs.mit.edu/people/alumni

Irene Greif graduated from MIT, (EECS) with a PhD in computer science — the first female CS PhD graduate. In her interview for *The Atlantic*, March 5, 2014, Greif talks about her experiences at MIT, when her class had the highest ratio of women to men yet (50 out of 1,000).

Recently retired from IBM, where she based her career since the mid '90s,Greif hopes to devote some time to encouraging young women to go into STEM fields and to coaching them to stick with these areas.

Following her years at MIT, **Radia Perlman** became a leader in the field of computer science, developing the algorithm behind the Spanning Tree Protocol (STP), an innovation that helped to contribute to making the Internet possible. Currently, she is a Fellow at Intel.

She modestly notes about her contributions to Internet infrastructure, "no single technology really caused the Internet to succeed. ...sometimes, things get invented multiple times until the time just happens to be right."

Donor Recognition

Photos over the next three pages were taken at the kickoff reception for Start6, held in the Media Lab's Silverman Skyline Room on January 15 for Start6 participants and EECS Alumni. Photo credit: Bryce Vickmark Photography

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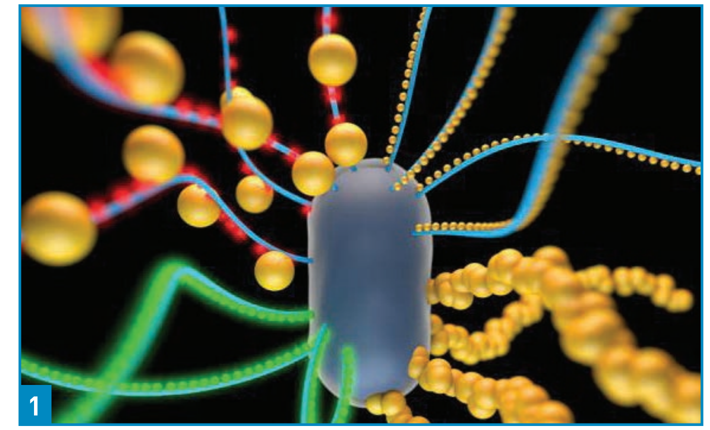
Research Snapshots, just a few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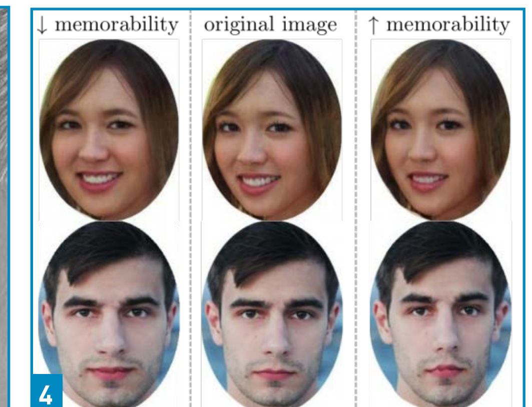

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Look familiar?

Check the EECS homepage for details on each of these research stories from 2013-2014. 1. Tim Lu: Living-materials; 2. Daniela Rus: Robotic Fish; 3. Anantha Chandrakasan: cochlear implants with no external hardware; 4. Antonio Torralba: never forget a face; 5. Sam Madden: MIT Big Data challenge; 6. David Karger: preference for Exihibit tools for data visualization; 7. Dina Katabi: 3D through-walls motion tracking; 8. Sangeeta Bhatia: paper diagnostic for cancer; 9. Dirk Englund: graphene for cheaper optical chips.

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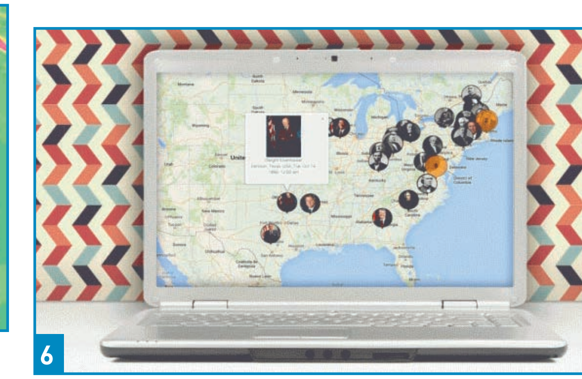
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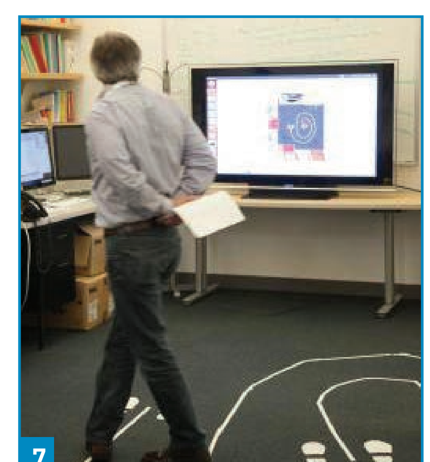
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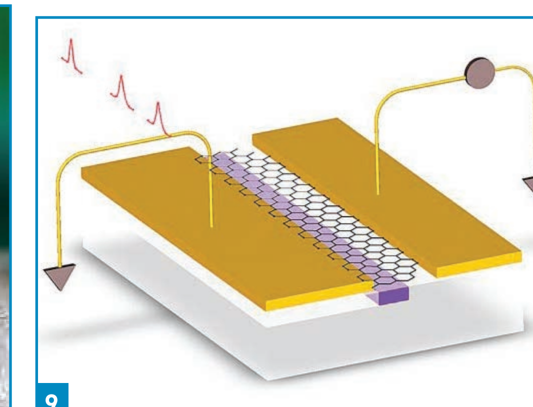
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MIT EECS ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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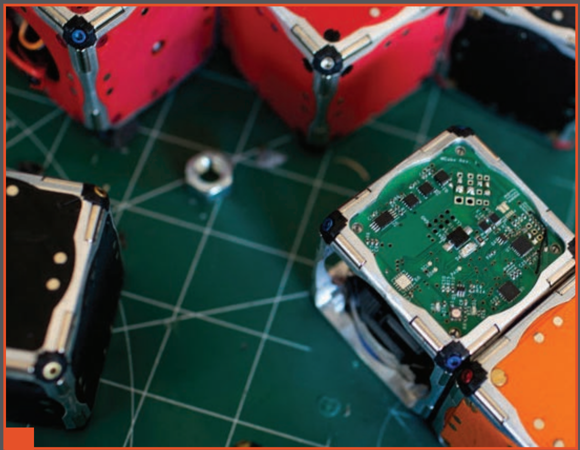
Tim Berners-Lee's 25-year-old World Wide Web helps Prof. Daniela Rus's stackable robots story go viral!



M-Blocks, the self assembling robots with no exterior moving parts can propel themselves forward, jump on top of each other, and snap together to form arbitrary shapes.

[Photo by M. Scott Brauer, courtesy MIT News Office/MIT]

MIT EECS professor Daniela Rus and researchers John Romanishin and Kyle Gilpin in her group in the Computer Science and Artificial Intelligence Lab (CSAIL), the Distributed Robotics Laboratory (DRL), have built cube robots that they call M-Blocks. With no external moving parts, the M-Blocks are able to climb over and around one another, leap through the air, roll across the ground, and even move while suspended upside down from metallic surfaces.

Since the MIT News Office reported this research in early October 2013, the story has had more visits than any other they have published (and tracked).

Several months following the M-Blocks story, we celebrated the 25th anniversary of MIT EECS professorTim Berners-Lee's proposal of a new system for managing general information about accelerators and experiments at CERN, the European Organization for Nuclear Research based in Geneva, where he worked at the time as a software engineer. He proposed building a distributed (global) hypertext system which he initially called "Mesh", updating it a year later to the "World Wide Web". Berners-Lee is a member of CSAIL, where he directs the W3 Consortium, an open forum of companies and organizations with the mission to realize the full potential of the Web.