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most significant bits

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UW CSE professor Luis Ceze and research scientist Lee Organick prepare DNA encoded with digital data for sequencing. *Photo: Tara Brown Photography*

Big-data breakthrough: UW CSE and Microsoft Research team up to develop DNA-based digital storage system

The sum total of the world's digital data — from cat memes and vacation selfies, to global financial records and the Internet of Things — is expected to reach 44 trillion gigabytes by the year 2020. That's a ten-fold increase in the span of only seven years.

How will we store all of that data? A team of UW and Microsoft researchers in the new Molecular Information Systems Laboratory think they have the answer. Members of the MISL are building the next generation of digital data storage modeled after nature's own tried and tested storage system: DNA.

"Life has produced this fantastic molecule called DNA that efficiently stores all kinds of information about your genes and how a living system works," explained UW CSE professor Luis Ceze. "It's very, very compact and very durable."

How durable? In the right conditions, DNA can last for thousands of years. Contrast this to existing data storage systems that rely on optical or magnetic

From where I sit...



This has been another exciting year for UW CSE: our faculty continue to attract accolades for being leaders in our field, our alumni are blazing new trails (and also collecting their share of honors along the way), and we are one step closer to seeing our ambitious plans to increase our space — and with it, our capacity to provide unparalleled education and research opportunities — come to fruition.

Professors Shwetak Patel and Luke Zettlemoyer recently returned from our nation's capital, where they each received a Presidential Early Career Award for Scientists and Engineers (PECASE) from President Barack Obama. Shwetak was nominated by the National Science Foundation for his work on home sensing systems, and Luke was nominated by the Department of Defense for his work on novel approaches to natural language processing. It is very rare that two faculty members in the same department would receive PECASEs in the same year, and we are very proud of Shwetak and Luke for this amazing achievement.

Still on the topic of amazing achievements, we were delighted to celebrate professor and UW CSE alum Tom Anderson's election to the National Academy of Engineering — one of the highest professional honors granted to an engineer — and professor Anna Karlin's election to American Academy of Arts and Sciences, where she joins an esteemed company of individuals who are among the most accomplished in their fields.

We are also very proud of alumni Albert Greenberg of Microsoft and Jeff Dean of Google, who were elected to the NAE and AAAS, respectively, and of Stefan Savage

— now on the faculty of UCSD — who will collect the ACM-Infosys Foundation Award in Computing Sciences this month. We are recognizing Albert's and Stefan's achievements in our own way by giving them UW CSE Alumni Achievement Awards during our graduation celebration. Last month, we were thrilled to have an opportunity to celebrate the early career achievements of another alum, Mesosphere founder Ben Hindman, at the UW College of Engineering's Diamond Awards dinner.

We are also looking forward to recognizing the many contributions of our friend and colleague Alan Borning, who announced his impending retirement. Alan's research on constraint systems was decades ahead of its time, as was his initiative to apply computing to important public problems, such as city design and transportation. In addition to his research and teaching contributions, Alan always brought a positive attitude into all that he did in CSE. We are planning a special event in the fall to celebrate his career.

Last but not least, we are making progress on our plans for the second building and aim to begin construction early in 2017. Just like the Allen Center was transformational when it came online in 2003, I am confident that this new building will take UW CSE to the next level in terms of our ability to educate more of Washington's students for the jobs of tomorrow, recruit top faculty and graduate students, and offer a research and teaching experience that is second to none.

To our graduating students: all of us here wish you the very best for your futures. Thank you for being part of the UW CSE family, and please keep in touch!

A handwritten signature in purple ink, reading "Hank".

Henry M. Levy
Chairman and Wissner-Slivka Chair

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UW CSE alum Ben Hindman honored with 2016 Diamond Award for Early Career Achievement

More than 90 companies — from Airbnb to Yodle — rely on the Apache Mesos infrastructure software to manage their data centers. Mesos is working behind the scenes when we watch a Netflix movie, discover a new restaurant on Yelp, ask Apple's Siri a question, or post on Twitter. Power players in science and industry, including CERN — home of the Large Hadron Collider — and Time Warner Cable, use Mesos, too.

Ben Hindman (B.S., '07) is co-creator of Mesos and co-founder of the company Mesosphere. For this work, the UW College of Engineering honored Hindman with its 2016 Diamond Award for Early Career Achievement.

Hindman grew up in the Rocky Mountain town of Carbondale, Colorado. His high school did not offer any classes in computer science, so Hindman talked his math teacher into letting him learn programming as an independent study. Having grown up in a community focused on outdoor adventure — Hindman is a serious telemark skier who also enjoys road biking and surfing — Hindman chose to enroll in UW after high school for its proximity to mountains as well as the strength of its CSE program.

"I couldn't have asked for a better place to become a computer engineer. UW CSE set the stage for me, grounded me in fundamentals that have been invaluable for solving problems, and gave me a sense of vision and inspiration for what we can really accomplish in our field," says Hindman.

As an undergraduate, Hindman worked on several research projects and was a teaching assistant for CSE professor Dan Grossman, an expert in programming languages and current holder of the J. Ray Bowen Professorship for Innovation in Engineering Education.

"My colleagues and I have always admired Ben as a gifted student, stunning engineer, and charismatic individual, but now we also get to watch in awe as his Mesos software system has become instrumental infrastructure for many of the most innovative and widely successful Internet services," says Grossman.

After earning his bachelor's in computer engineering with distinction from the UW, Hindman spent seven months as a software engineering intern at Google before pursuing a Ph.D. at the University of California, Berkeley. In a research paper published in 2011, he and his fellow Berkeley researchers presented *Mesos*:



A Platform for Fine-Grained Resource Sharing in the Data Center, a groundbreaking new system that would enable companies to run all of their applications on the same set of servers.

Hindman took a lead role in the development of the Mesos prototype and was instrumental in making the software quickly available to industry, where it was put to the test thanks to the crushing loads experienced by sites such as Twitter and Airbnb. By eliminating the need for companies to run different data services on separate, expensive, and energy-consuming hardware systems, Mesos offered a timely, effective solution to a vexing problem.

"In the early days, Twitter was known for what they called the 'fail whale,' and it looked like it was going to kill the company unless they could solve that problem," says Brad Silverberg, a former Microsoft executive and co-founder of venture capital firms Ignition and Fuel Capital. "Ben went to Twitter to help."

Rapid industry adoption of Mesos over the next three years, plus Hindman's entrepreneurial skills, enabled him to secure the venture capital to found Mesosphere, Inc., in 2013. The company provides features and services under the Apache Mesos banner to supplement the open-source Mesos software. With tens of millions of dollars raised to date, more than 150 employees, and offices in San Francisco, California and Hamburg, Germany, Mesosphere is a hot infrastructure computing company that has operated largely out of the public eye — but people would miss it.

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UW CSE 2016 Alumni Achievement Awards

CSE honored two extraordinarily accomplished alumni — Albert Greenberg and Stefan Savage — during its June 10th graduation ceremony. UW CSE's Alumni Achievement Awards have two purposes: to celebrate alums such as Albert and Stefan, and to affirm to new graduates that they are joining a community of UW CSE alums who have changed the world.

Albert Greenberg (Ph.D., '83)

Master of Cloud Computing Datacenter Networks

Albert Greenberg has worked on the front lines of grand scale networking and cloud computing for more than two decades, first at Bell Labs/AT&T and since 2007 at Microsoft. Today, he directs development of networking for Azure, Microsoft's global cloud computing infrastructure platform that spans millions of servers around the globe — encompassing analytics, database, storage, and other services — and helped make Seattle a major player in the booming arena of cloud computing.



Winning UW CSE's Alumni Achievement Award is the latest in an impressive string of honors for Greenberg. Earlier this year, he was elected to the National Academy of Engineering, the profession's highest honor. He is one of five UW CSE graduate program alumni who are NAE members (along with Tom Anderson, Jeff Dean, Ed Felten, and Hank Levy).

A native of New Orleans and educated at Dartmouth College in New Hampshire, Greenberg found his way into computer science and to the Pacific Northwest though his love of math and statistics. "I was fascinated with combinatorial algorithms and generating interesting objects and sequences," he says. "I took all the usual computer science classes and thought I could program anything, but that was not true with combinatorial algorithms and so I wanted to dig deeper into everything to do with computer science."

From Dartmouth to UW

A Dartmouth professor was collaborating on a project with Bob Ritchie, then chair of UW CSE, who encouraged Greenberg to apply for admission to the graduate program. Once he arrived in Seattle, Greenberg worked with CSE professors Richard Ladner and Martin Tompa in theoretical computer science, and with Ed Lazowska on a networking project.

"As a research and teaching assistant, I loved the camaraderie in the department and with the faculty, and I picked up really good skills across diverse areas of CS. Their passion for their work also was a great influence," Greenberg says.

After earning his doctorate in 1983, Greenberg headed back east to begin his career at Bell Labs/AT&T in New Jersey, where he rose to division manager for network measurement engineering and research, and then to executive director and an AT&T Fellow. By 2006 his work in cloud computing had caught the attention of Microsoft. The following year, he joined the Redmond company as a Principal Researcher, helping to establish the vision and program direction for the projects that would lead to Azure.

For the past six years, as a Microsoft Distinguished Engineer, he has led the design and development of networking for Azure, overseeing the work of teams in Redmond, Mountain View, Hyderabad, Dublin, and Beijing. His responsibilities extend over physical and virtual datacenter networking design and management, to create and build the public cloud infrastructure to allow customers to bring their own networks to the cloud. Azure is available in 140 countries across 32 announced regions worldwide, providing the platform for services such as Bing, MSN.com, Office 365, Xbox Live, and more.

Greenberg's latest project is Microsoft's SmartNIC, a hardware component to help speed up software-defined networks. "The cloud is growing at an unbelievable pace and more new businesses will be born there. The challenge will be to scale to keep up with the demand, so the cloud is an unbounded space available to everyone," Greenberg says.

Breadth and Depth

"Albert is remarkable in many ways, not the least of which is the extent to which his career has spanned theory and practice, research and engineering," says CSE's Lazowska. "He came to UW as a graduate student in theory. He went to AT&T, and then to Microsoft, as a networking researcher, but his research had tremendous impact on practice. Now he's the Director of Development for Azure Networking. Truly astonishing breadth and depth."

"Software is everything to networking, and everything I've done has been about opening up and virtualizing networks through software — now dubbed Software Defined Networking (SDN)," says Greenberg. "The cloud scenario provided the tools and economic imperative we needed to write the code to virtualize networking,

the counterpart of virtual machines but for networking. Our software lights up large fully functional, secure networks, each private and dedicated to a customer, reliably and on demand in milliseconds. To make this happen at massive scale, there's no book, no precedent, so we got to invent the ideas and write the code as a team — a huge and ongoing thrill."

Greenberg's pioneering work has brought him many accolades from leading organizations in the field in recent years, including the IEEE Koji Kobayashi Computers and Communications Award in 2015 for his "fundamental contributions to large-scale backbone networks and datacenter networks," and the ACM SIGCOMM Award that same year in recognition of his lifetime contributions to the theory and practice of operating carrier and datacenter networks. He also received the ACM SIGCOMM Test of Time Award in 2015, and the ACM SIGMETRICS Test of Time Award in 2013. It all boils down to be being one of the SDN fathers.

"I'm really humbled by the recognition from CSE and being part of the University and the computing scene in the Seattle area," Greenberg says. "It's awesome that Microsoft and UW have such a strong tie, and there is even greater potential for growing closer and collaborating on projects aligned with faculty and student interests."

Stefan Savage (Ph.D., '02)

Cyber Security Sleuth and Trailblazer

As a leader in the Systems & Networking and Computer & Network Security groups at the University of California San Diego, professor Stefan Savage has journeyed across the cyber crime universe, tackling everything from computer worms and online scams, to distributed attacks, insidious global consumer fraud networks, and automobile systems hacking. The stars align for him in June, when he will collect double honors for his outstanding research in network security and innovative efforts to clamp down on cyber crime. On June 10th, Savage will collect CSE's Alumni Achievement Award. The following day, in San Francisco, he will accept the 2015 ACM-Infosys Foundation Award in the Computing Sciences.

Savage's route to a career in computer science academia was unorthodox. His combination of abundant curiosity, enthusiasm and good humor — mixed with the confidence to bend the rules — contributed to an "I'll find my own path" mentality. His father, a sociology professor raised in Renton, and his mother, a native of Yugoslavia, met in Paris when she was organizing student protests against the Vietnam War. They moved to Manhattan when Savage was a toddler, and by third grade he had "extreme

independence" to explore the streets of New York as long as he was back by dinnertime. Family legend has it that he caught the computer bug around age 8 or 9: when his father absentmindedly left a Radio Shack store without him, the manager set the younger Savage up at a TRS-80 to keep him occupied until his father returned.



Eclectic Education, Fateful Connections

When he arrived at Carnegie Mellon University as an undergrad, Savage plunged into a double major in physics and cognitive science. He was eager to "learn the truths of the universe and of the human mind — the two biggies." He dropped physics but earned almost enough credits for a cognitive science degree, until a contretemps with a Nobel Laureate professor.

"I was too young and too stupid to stop incessantly arguing with him. We finally agreed I should not be in his class," Savage recalls. The door thus closed on a CogSci degree, he earned his bachelor's in Applied History instead, enjoying the focus on reasoning, analysis, and rhetorical skills.

After receiving thumbs-down in response to his CS grad school applications, Savage remained at CMU for two more years, working in a CS lab and taking over project management after the faculty director left. One fateful day, Savage asked Brian Bershad for a job in his lab.

"Brian said he was leaving for the University of Washington and invited me to come along. I have no idea what he saw in me given my checkered academic record, but we hopped in his car and headed for Seattle," Savage says. A year later he was accepted to the UW CSE doctoral program, focusing on operating systems.

Around the time Bershad took leave from UW CSE to launch a startup, the Internet was taking off and a visiting speaker told students it was a waste of time to work on operating systems. "Game over, we needed to find something new. A few grad students got together, and we taught ourselves networking, then approached Professor Tom Anderson and pressed him into service to start a research group," Savage recounts. Together, Bershad and Anderson, themselves former UW CSE Ph.D. graduates who had swum back home from faculty positions at CMU and UC Berkeley, served as his doctoral advisors.

Continued on page 13

DataBlade: Slicing into the mushrooming clouds of big data analysis

In the heart of Midtown Manhattan at media giant News Corp, Allen Chen (B.S. '07) and Jeremy Brudvik (B.S. '08) observed a big problem. Data analysts were spending an inordinate amount of time wrangling data in disparate formats from many sources and laboriously creating the infrastructure needed to manage their analyses.

"Their workload was really cumbersome, so we started to think more broadly about how we could help analysts more efficiently access, aggregate, and organize data to avoid doing the same manual steps over and over," says Chen, DataBlade's co-founder and CEO. "We know good data people are really hard to find, and too much time devoted to manual tasks is not a good way to spend company dollars."

They built what they believe to be a unique, cloud-based platform that offers new tools for extracting data from different silos and automatically integrating various formats into a standard Excel format. DataBlade makes it easy to plan and automate data analysis so that business units are able to access and mix and match data for specialized needs.

Chen and Brudvik followed different paths after graduating from UW before eventually launching their professional collaboration at News Corp. Both had grown up in the greater Seattle area. They struck up a friendship when they crossed paths in their CSE classes, before being bitten by the entrepreneurship bug. Brudvik saw it as a goal for the future, but first he headed to Georgia Tech to pursue a master's degree focused on human-computer interaction, followed by three years as a software engineer at Intel.

Chen felt drawn to entrepreneurship early, but like most of his classmates, opted to take the "default route" of a job at a local tech giant immediately after graduation. After five years as a software development engineer at Amazon, he jumped into the startup arena as co-founder (along with fellow UW CSE alums Bobby Mathews and Mohamed El-Zohairy) and CTO of NileTap, which developed a cross-platform engine for rendering interactive children's books. NileTap morphed into CloudPress, an interactive content-creation platform for media companies.

"It's super to see UW CSE alums do exciting things like this, do them together, and get them going in UW's Startup Hall!" - Ed Lazowska



Co-founder and CTO Jeremy Brudvik (left) and co-founder and CEO Allen Chen (right).

When News Corp acquired CloudPress in January 2014, Chen moved to New York to serve as director of platform engineering in the executive office. His fellow CSE alum, Brudvik, signed on as a full-time consultant, making frequent trips to New York. Although exciting, the big city, big media environment couldn't inoculate them from startup fever and a long-held desire to collaborate. The pair worked on the DataBlade platform in their free time, eventually returning to Seattle to officially launch the company in July 2015.

"Once you do startups, it's hard to get out of that mindset," Chen notes. "Everything else seems slow and antiquated, and you want to get back to that level of passion for your work."

Once back in Seattle, Brudvik and Chen landed in the office of CSE professor Ed Lazowska, who had a keen interest in the burgeoning field of big data. They described their concept to remove the grunt work from data search and compilation, allowing analysts to focus on the primary goal — new insights for business.

"Ed said 'Give me a second' and sent off an email to Chris DeVore, Managing Director of TechStars Seattle," Brudvik recalls. "Even though we weren't fully prepared, we talked to Chris the next morning, and that was our application to TechStars."

Seed funding of \$118,000 and six months of mentoring from TechStars advisors at UW Startup Hall incubator provided enough forward thrust for Chen and Brudvik to secure a small office at the WeWork collaborative space in South Lake Union. They progressed rapidly through a soft beta test launch of their experimental

first platform to secure a year-long contract with one major client, refine their product, hire a small staff, and launched a second beta round in early May.

They discovered their first product was too technical for their targeted user base, given the shortage of highly skilled coders and analysts. "We thought it was phenomenal when we turned a task that took 100 to 200 lines of code into a 5- to 10-line program," says Brudvik, DataBlade's CTO. "It turns out that even this little code is hard for the business intelligence people who primarily use Excel, so we took it down to zero coding in our new product."

"This opens up a new world of possibilities for people who don't code at all," Chen says. He notes that a fully cloud-based platform is one way to avoid relying on the expensive, rigid data warehouse and pipeline systems.

"We have owned up to the reality that data will continue to exist in many places and that we need to provide tools to help people access each source individually in a way that makes the most sense for each source, so the process is scalable and repeatable. We are not aiming for a lowest common denominator solution."

For strategic reasons, their initial customers are in the media field, a rapidly changing industry where

DataBlade

they have a strong network. "The traditional ways media companies made money are no longer working, and many are looking to revamp their business models," Chen notes. "A new wave of companies will be digital only, and some will distribute primarily on social networks to build incredibly large platforms of followers." DataBlade, which works with both traditional and new media companies, wants to build a product for the next wave and then expand into other business arenas. "We need that crystal ball," he laughs.

Later this year Chen and Brudvik plan to seek angel or early-stage venture investment. The immediate goal, they say, is to "nail our software formula" and determine the platform features that most resonate with beta testers and potential customers so they can start building out the marketing and sales team and grow the company.

Their challenge — sharpen the blade, polish the crystal ball, and blaze trails through the jumbled clouds piling high and wide in the booming data universe.

For more information, visit datablade.io.

Continued from page 3

Hindman Diamond Award (continued)

"We're looking to make Mesos become even more fundamental to the way software that runs in datacenters and clouds is programmed. We're doing that by building a distributed systems operating system that we call DC/OS," Hindman says.

"Twitter itself probably wouldn't be what it is today without Mesos," observes Florian Liebert, co-founder of Mesosphere. "Apple's Siri team publicly announced that Siri is powered by Mesos... I think it's important to look at both the impact Mesos has as a system...and the impact it has in terms of ideas that seeded an entire industry."

The company's name seems particularly fitting given its relatively anonymous but dynamic position in the tech universe. The mesosphere is the middle, little-studied layer of the Earth's atmosphere tucked above the stratosphere of high-altitude flight and below the thermosphere where satellites orbit. And yet, this region of strong winds, atmospheric tides, and gravity waves shakes up global circulation the way Mesos has shaken up the middle space between network servers and users' electronic devices.

"UW CSE set the stage for me, grounded me in fundamentals that have been invaluable for solving problems, and gave me a sense of vision and inspiration for what we can really accomplish in our field." - Ben Hindman

"Mesosphere has the opportunity to be one of the most impactful, powerful and valuable companies in the computing technology space," Silverberg says. "As the inventor of technology that could underlie the way most companies do computing, Ben could be one of the top luminaries in our industry — as both a technology and business person."

The College of Engineering celebrated Hindman's achievements at its annual Diamond Awards ceremony on May 20th.

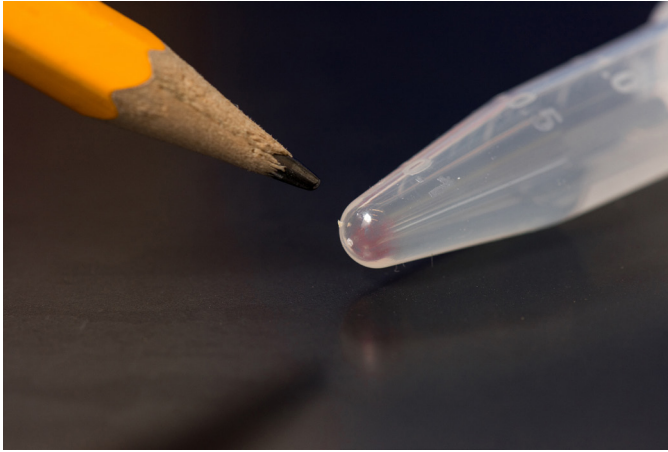
View the College's video profile of Hindman at tinyurl.com/HindmanProfile.

Learn more about Mesos at dcos.io and more about Mesosphere at mesosphere.com.

Continued from page 1

DNA-based digital storage system (continued)

media: optical disks last up to five years, and magnetic tape lasts around 30 years under reasonably controlled conditions.



The future of digital storage: 10,000 gigabytes fills a space smaller than the tip of a pencil. *Photo: Tara Brown Photography*

The extreme density of DNA is another advantage. The densest form of commercially available data storage can handle around 1 gigabyte per cubic millimeter. DNA, on the other hand, has a raw limit of 1 exabyte per cubic millimeter — that's one billion gigabytes of data.

DNA is also unlikely to fade into obsolescence any time soon. As the researchers point out, as long as there is DNA-based life, there will be strong reasons to read DNA. The same could not be said for those floppy disks now gathering dust on a shelf.

"With DNA, we have the gift of eternal relevance," Ceze pointed out.

The trick to successfully storing digital data in DNA is to convert the 1's and 0's into the four bases of DNA: adenine, guanine, cytosine and thymine — and make sure the data can be retrieved later. According to joint CSE and Electrical Engineering professor Georg Seelig, "How you go from ones and zeroes to As, Gs, Cs and Ts really matters because if you use a smart approach, you can make it very dense and you don't get a lot of errors. If you do it wrong, you get a lot of mistakes."

Once the data is synthesized, the DNA molecules are dehydrated and preserved. The team made sure they could reassemble the data in digital form. To selectively recover the data, the researchers used a technique commonly used in molecular biology, called Polymerase Chain Reaction or PCR. This enabled them to identify the

addresses corresponding to the data they were looking for, and then to use their address encoding scheme to reassemble the original information in the correct order.

The MISL is one of only two research teams in the nation that have demonstrated the ability to perform random access, identifying and retrieving the correct sequences of encoded data from a large pool of random DNA molecules.

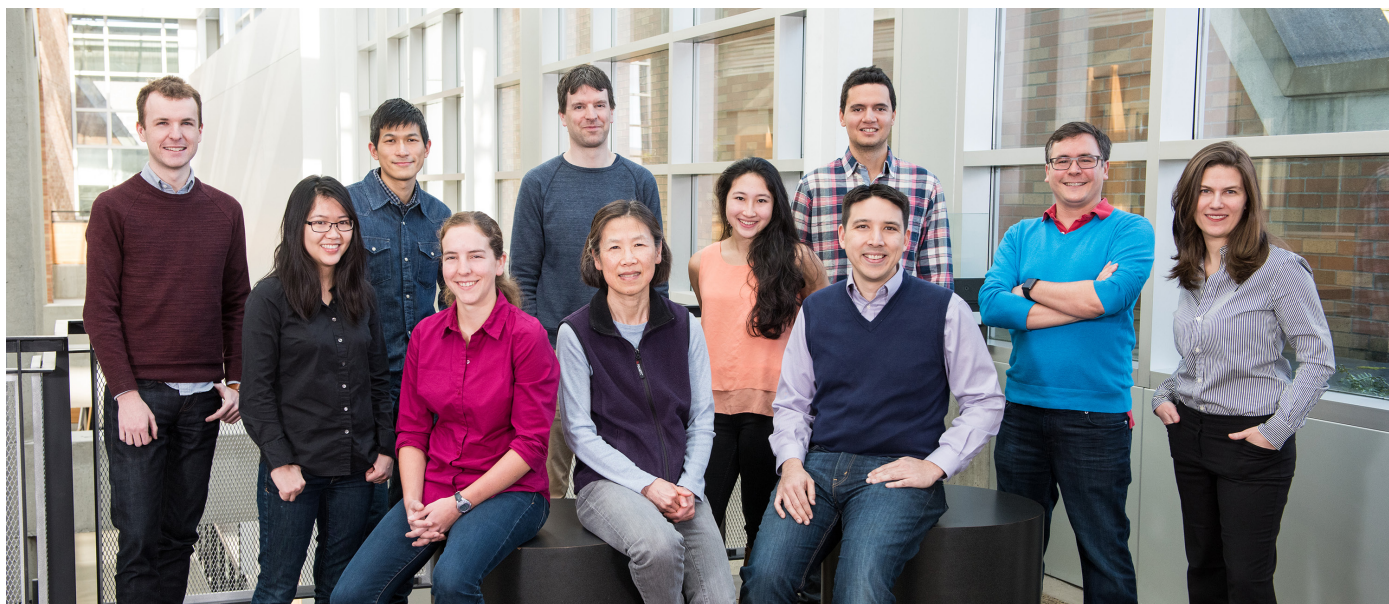
The team's approach borrows from error correction schemes commonly used in computer memory. "This is an example where we're borrowing something from nature — DNA — to store information. But we're using something we know from computers — how to correct memory errors — and applying that back to nature," Ceze said.

The researchers demonstrated the effectiveness of their system by encoding and then retrieving image files into snippets of synthetic DNA — including the requisite cat photo — without losing a single byte of information in the process. In a later demonstration, they encoded and retrieved data that authenticates archival video files from the UW's "Voices from the Rwanda Tribunal" project.

UW CSE Ph.D. student James Bornholt, Bioengineering Ph.D. student Randolph Lopez, and Microsoft researchers and UW CSE affiliate professors Karin Strauss and Douglas Carmean co-authored the paper that outlined the successful experiment with Ceze and Seelig. The team presented its results to the Association for Computing Machinery's International Conference on



UW CSE postdoc Chris Takahashi prepares DNA samples in the lab. *Photo: Tara Brown Photography*



The MISL research team. Front, left to right: Bichlien Nguyen, Lee Organick, Hsing-Yeh Parker, Siena Dumas Ang, Chris Takahashi. Back, left to right: James Bornholt, Yuan-Jyue Chen, Georg Seelig, Randolph Lopez, Luis Ceze, Karin Strauss. (Not pictured: Douglas Carmean, Rob Carlson, Kritika D'Silva.) *Photo: Tara Brown Photography*

Architectural Support for Programming Languages and Operating Systems (ASPLOS 2016) in Atlanta, Georgia earlier this year.

The team envisions its system as the last, archival level of a deep storage hierarchy, since access times would be on the order of hours or days rather than seconds or minutes. At present, the high cost and low efficiency of DNA synthesis and sequencing renders it unviable as a commercial storage solution. However, the MISL team is bullish on its long-term potential. Advances in biotechnology have led to exponential improvement in both, with the growth in sequencing productivity outpacing Moore's Law.

As the authors of the ASPLOS paper wrote, "Biotechnology has benefited tremendously from progress in silicon technology developed by the computer industry; perhaps now is the time for the computer industry to borrow back from the biotechnology industry to advance the state of the art in computer systems."

The MISL's interdisciplinary approach has proven invaluable to moving the DNA data storage project forward. Housed in the basement of the UW Electrical Engineering Building adjacent to the Paul G. Allen

Center for Computer Science & Engineering, the team is able to draw upon expertise in computer architecture, programming languages, synthetic biology and molecular biology to conduct simulated and wet lab experiments.

The DNA data storage project is backed by Microsoft and the National Science Foundation. Microsoft also recently agreed to purchase 10 million long oligonucleotides of synthetic DNA from Twist Bioscience to advance this research.

"The collaboration between Microsoft Research and University of Washington has been very productive," said Strauss. "We've created the MISL to learn and tackle difficult challenges in making DNA storage a reality. The lab has already been producing really interesting results, and I am looking forward to what's to come next."

A DNA-backed storage system that can archive all of the world's data and last for centuries? Even Grumpy Cat would approve.

To learn more about the MISL and the DNA data storage project, visit misl.cs.washington.edu and research.microsoft.com/en-us/projects/dnadatastorage/.

UW CSE celebrates professor Alan Borning's 35-year career



Alan Borning, an outstanding mentor and gifted researcher who spent a large portion of his career advancing computer science as an agent of positive societal change, announced his retirement from UW CSE this spring. UW CSE was his first and only faculty position during a long and distinguished career that spans programming languages, human-computer interaction, accessibility, and value sensitive design.

Borning discovered computer science as an undergraduate at Reed College, where he majored in mathematics. At the time, Reed did not offer courses in computer science — but it did keep an IBM 1130 computer in the basement of Eliot Hall.

"It was like a personal computer with punch cards," Borning recalled, "and students were given free run of the machine. So I learned programming on my own and from my peers, and ended up doing my senior thesis on computational number theory."

Following his graduation from Reed in 1971, Borning headed for Stanford University. There, he embarked on a formal study of computer science, earning his M.Sc. in 1974 and his Ph.D. in 1979. For his dissertation, Borning developed ThingLab, a constraint-based simulation laboratory written in the Smalltalk-76 programming language. ThingLab provided an environment in which users could construct dynamic models of experiments in geometry and physics. It was also used to model other objects, such as a graphical calculator and document layouts. (ThingLab still exists today, running in a Smalltalk-78 emulator in Javascript.)

After completing a postdoc at the University of Edinburgh, Borning arrived in Seattle in 1980 to join

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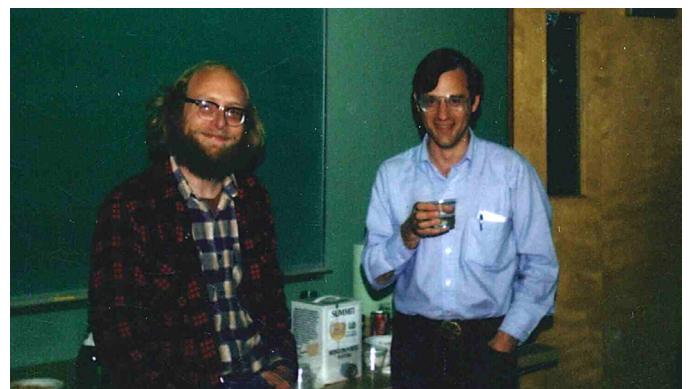
the UW CSE faculty. Borning's initial teaching and research followed his early focus on constraint-based programming. But mid-way through his career, Borning began shifting his attention to other projects — ones that enabled him to use computer science in projects with more immediate societal impact by advancing civic participation, supporting public transportation, and promoting smarter urban planning.

"Being on the faculty of UW CSE afforded me a fair amount of freedom," said Borning. "I was able to switch directions rather drastically. I had always been interested in social and environmental issues — for example I did some work on computer system reliability and nuclear war, and was one of the original members of Computer Professionals for Social Responsibility in the 1980s — but around 1998 I decided to focus my UW research on these kinds of projects."

One of the directions this led him was OneBusAway — the mobile app beloved by transit riders across the Puget Sound region and, increasingly, across the continent. OneBusAway started out as a project by one of Borning's Ph.D. students, Brian Ferris, along with Kari Watkins in Civil & Environmental Engineering. Borning saw the potential to build something bigger.

"OneBusAway originated as a system written by transit enthusiasts, for transit enthusiasts," Borning explained. "Brian didn't initially view it as a research project worthy of a Ph.D., but I thought it was worth pursuing. So we did, and both Brian and Kari wound up writing their dissertations on it."

Working with local transit agencies, the team set about building an app and back end servers that would provide real-time arrival and departure information for buses — and eventually, rail — and assist riders in locating transit routes and stops. The success of OneBusAway attracted



Alan Borning and Larry Ruzzo in Siegel Hall in the '80s



Alan Borning in his office in Sieg Hall

the attention of other transit agencies, including New York's Metropolitan Transportation Authority. To date, OneBusAway has been deployed in eight localities in the U.S.A. and Canada, with beta implementation in several more.

Borning, who presently serves on the OneBusAway board of directors, noted that at the time the project began, real-time transit information systems were not new — some of the pioneering work in the area was done by Dan Dailey and others at UW, among others. But OneBusAway was unique in that it was open source and widely adopted by users. The team put considerable time and thought into accessibility, including adding a high-contrast mode for people who are low vision as well as supporting voice-over mode for people who are blind. They also built in an SMS texting feature to enable people without smartphones to access transit information. Borning and his colleagues fought to maintain those features as OneBusAway evolved, so that no one dependent on public transit would be left behind.

Borning credits fellow CSE professor Richard Ladner with sparking his interest in accessibility issues. This led him to work with another team of students on StopInfo, a system to provide useful information about the location and layout of bus stops to people who are blind or low vision that was built on top of the OneBusAway platform. Although the service is currently on hold, Borning hopes that the project will soon be resurrected through the Taskar Center for Accessible Technology.

StopInfo and OneBusAway employed value sensitive design, a framework that places human values at the center of technology design. UW iSchool professor Batya Friedman is a leading proponent of this approach and heads the Value Sensitive Design Lab on campus.

"Alan has been an inspiration to me for decades," said Friedman. "Collaborating with him, a privilege. We have shared research and design projects, graduate students, and pipe dreams about nascent intellectual ideas. His

commitment to computing in support of societal good is surpassed only by his integrity, kindness, and wisdom. Alan's is the rare intellect that can see through to the essence of a problem or bottleneck. Among his many contributions to Value Sensitive Design, he untangled complexity around the source of human values in a technical design — a large scale urban simulation — to identify the categories of explicitly supported project values, designer values, and other stakeholder values. Those categories are now standard in analyses of human values in computational systems. Like exemplar scholars from a gentler age, Alan is willing to engage in heartfelt, sustained intellectual discourse — placing human well-being at the forefront. A conversation with him is a pleasure. Alan's contributions will long be valued and built upon by future scientists and engineers."

"Value sensitive design is good for helping develop solutions that people will actually use and that at the same time support important values," explained Borning. "It urges researchers to ask themselves, 'Who are the stakeholders in the system, both the ones actually using the system and others who don't use it themselves but are strongly affected by it? What are the important values at stake with this system?'"

The framework has figured prominently in Borning's recent work, including projects aimed at improving civic engagement and decision-making that he undertook with members of Engage, a cross-campus collaboration among faculty and students in communications, computer science and human-centered design. One of Borning's students, Travis Kriplean, conceived of ConsiderIt in response to the character of political discourse he encountered in online comment sections.

"ConsiderIt was a response to the fact that people seemed to be doing a lot of shouting and not enough listening when it came to politics online," Borning recalled. "We looked for ways to build in structural



Travis Kriplean and Alan Borning

Continued on page 12

CSE celebrates Borning

nudges that encouraged people to listen more and to deliberate on the issues that affect them and their fellow citizens."

ConsiderIt was the basis for the Living Voters Guide, a partnership between Engage and a local civic organization, Seattle CityClub. The intent behind the Living Voters Guide was to provide an online tool to help voters make more informed decisions and to foster a sense of shared responsibility for making democracy work. One of the particularly interesting features of the guide was a fact-checking service provided in partnership with the Seattle Public Library.

"People could ask a reference librarian to fact-check a claim put forward by one of the users of the guide," Borning said. "We made it easy for citizens to connect with a trusted institution and cut through the noise in the public square."

The Living Voters Guide lived for six political campaigns before being discontinued. Meanwhile, Kriplean built ConsiderIt into a startup company to help organizations engage effectively with stakeholders and provide a constructive environment for online discussion.

"Alan's research follows his heart. He works on what he feels is important, spanning constraint-based programming all the way to decade-plus cross-departmental collaborations on simulating contentious land use and transportation planning decisions," said Kriplean. "I feel much gratitude to Alan for his patience in supporting me as I searched and searched again for what was in me to learn, express, and create. I'm sure Alan will find new ways to make contributions to the world in his 'retirement.'"

When Borning first decided to shift his focus away from constraint-based systems and programming languages, he was interested in how technology could impact the public square in a more literal sense. Casting around

for a project that would address an urgent societal need, he found UrbanSim through his colleague Paul Waddell, then with UW's Evans School of Public Affairs. The project, which Borning characterized as "SimCity professional edition," simulated the impact of major development and transportation projects. It was designed to assist communities to make informed decisions about urban planning that would impact them — and the environment — for decades to come.

Borning is a Fellow of the Association for Computing Machinery and a recipient of the Fulbright Senior Scholar Award. Over the years, he has taught undergraduate courses in programming languages and human-computer interaction, as well as UW CSE's accessible technology capstone. Sixteen students have completed or will complete their Ph.D.s working with him: Jeffrey Scofield ('85), Robert Duisberg ('86), Bjorn Freeman-Benson ('91), John Maloney ('91), Molly Wilson ('93), Michael Sannella ('94), Gustavo Lopez ('97), Greg Badros ('00), L. Denise Pinnel Salisbury ('01), A.J. Bernheim Brush ('02), Michael Noth ('03), Janet Davis ('06), Kate Deibel ('11), Brian Ferris ('11), Travis Kriplean ('11), and Justin Bare.

"I learned so much from Alan, both about research and also how to be a great collaborator," said A.J. Bernheim Brush, now a Principal Researcher at Microsoft. "Alan has this way of helping groups get out of arguments by calmly identifying options, writing them down on the board — to dodge the 'it's mine so it must be good' problem — and then working through the pros and cons to arrive at the best decision. I use this tactic often in meetings, and the memory of Alan working his magic always makes me smile. Of course, Alan's dedication to bicycle commuting was another inspiration!"

Borning spent sabbaticals at institutions in England, Germany, Ghana and Australia. Greg Badros was one of the students who reaped the benefits of Borning's connections overseas and his determination to provide his students with the best possible research experience.

"Through Alan's connections, I had the great fortune of collaborating in Melbourne, Australia with some researchers there," Badros recalled. "Alan visited for part of that study abroad, too, and without a doubt, working through a bunch of ideas with Alan and our fellow researchers was an absolute highlight of my years in grad school. Alan's insight and thoughtfulness around context of the applications were second to none!"

Borning's work has recently come full circle. He has been designing a new constraint reactive programming language in collaboration with professor Emina Torlak. He also plans to spend the summer working with a student at the Hasso Plattner Institute in Potsdam,



Borning with his human computer interaction class at Ashesi University in Ghana, where he taught while on sabbatical, 2004.

Germany — one of the institutions where he spent a sabbatical — on programming language research.

"One of the benefits of being retired is I have time to write programs again," Borning remarked. "I was pleasantly surprised to discover I can still do it."

Borning has been easing into retirement, and he continues to spend time in the Allen Center.

"Thankfully, Alan is only 'sort of' retiring," said professor Ed Lazowska. "As a UW CSE faculty member for 35 years (and counting!), he's managed to combine research in constraint-based languages and systems with research that scratches his admirable social values itch: systems that make public transportation more usable, systems that support civic deliberation, systems that inform urban policy."

"Alan's career shows us all that we can be computer scientists while also directly pursuing the challenges

we see in the world around us. He's got the chops to do low-level and difficult things, but also the passion to do big and difficult things," said professor James Fogarty. "Best of all, he's always happy and pragmatic about it all — a reminder that these pursuits of ours are a pleasure and privilege."

He may have devoted a significant portion of his research career to constraints, but at UW CSE he did not feel bound by any.

"This job provided me with unfettered opportunity to do really interesting work," said Borning. "I was able to tackle technical problems, but even more gratifying was the ability to tackle societal problems — and to work with a terrific bunch of students and colleagues along the way."

UW CSE will hold a special dinner in the fall to celebrate Borning's many contributions to our department and to the field of computing.

Continued from page 5

Alum Achievement Awards

As he was winding up his doctorate, that new focus brought faculty offers from MIT, Stanford, Berkeley, CMU, Cornell, Princeton, UCSD, and several others. "Choosing San Diego was kind of iconoclastic, but it was the right culture for me, the same as at UW, and people I wanted to spend time with." (UCSD has a large number of UW CSE Ph.D. alums on the faculty, including Stefan's close collaborator and close friend Geoff Voelker.)

Challenging Cyber Crime

After first focusing on business network security at UCSD, the underworld of cyber drug crime sparked Savage's interest. He studied the business models and financial channels, identifying the point most vulnerable to shutdown — credit card transactions through merchant banks. He gained permission for his researchers to pose online as drug buyers, with specially assigned credit cards for tracing transactions. He also worked with Microsoft on a pilot program to curb the sale of counterfeit software by tracking the flow of money. Collaborating banks shut down the entire system in 18 months.

In a 2011 *New York Times* essay, Savage noted that criminal profit-seeking is a major force in transforming the computer security landscape and that new threats will directly reflect technical innovations in how money is used, moved, and stored. He argued that anticipating new threats requires an understanding of human nature and the drive for profit, warning about the potential rise of "social bots" that seek to build trusting

relationships to enable manipulation of scam targets. "The threat is not of humans controlling or monitoring our computers, but precisely the converse," he wrote. Savage also drew attention for work with CSE professor Yoshi Kohno (a UCSD Ph.D. alum) to expose how hackers could remotely break into a car's computer system and take control of critical functions such as engine acceleration and braking. He co-founded the Center for Automotive Embedded Systems Security, a joint effort between UW and UCSD, and also established the Center for Evidence Based Security Research in partnership with the International Computer Science Institute at Berkeley.

Among his honors, Savage emulated his UW mentors Bershad and Anderson in winning the SIGOPS Mark Weiser Award in 2013. The SIGOPS award nomination cited Savage as by far "the most creative person working in the hugely important fields of network security, privacy and reliability. He has the uncanny ability to ask exactly the right question, propose exactly the right solution, and see that solution through to impact."

One reason, Bershad says, is that "Stefan always had spark and a super power ability to take a complex subject and tell a simple and compelling story anyone could relate to. He's brought a lot of weird concepts into the mainstream."

"The alumni achievement award is a big honor," Savage says. "I'm very fond of my time at CSE and stay in close contact with the people who have been so influential in becoming who I am."

Datagrams

Irene Zhang runner up 2016 NCWIT Collegiate Award

CSE Ph.D. candidate Irene Zhang was recognized as runner up for the 2016 NCWIT Collegiate Award. The award honors the outstanding technical accomplishments of college women of any year of study and recognizes technical projects that demonstrate a high level of creativity and potential societal impact. Zhang works with Hank Levy and Arvind Krishnamurthy in the Computer Systems Lab. Her research focuses on systems for large-scale, distributed applications, including distributed runtime systems and transactional storage systems.



ACM SIGMOD recognizes Ph.D. alum Paris Koutris, professor Alvin Cheung



Each year the ACM's Special Interest Group on the Management of Data (SIGMOD) awards the Jim Gray Doctoral Dissertation Award, which recognizes outstanding Ph.D. dissertations in the data management field. In 2016 CSE alum Paris Koutris (Ph.D., '15) was recognized with the Jim Gray Doctoral Dissertation Award. Koutris — who joined the faculty of University of Wisconsin-Madison last fall — received the award for his dissertation titled "Query Processing for Massively Parallel Systems." CSE professor Alvin Cheung earned an Honorable Mention for his



MIT dissertation "Rethinking the Application-Database Interface." Learn more about this year's recipients at tinyurl.com/SIGMODJimGray2016.

Supasorn Suwajanakorn collects GeekWire Innovation of the Year Award

Ph.D. student Supasorn Suwajanakorn of CSE's GRAIL group took home the coveted Innovation of the Year Award at GeekWire's annual awards bash — a.k.a. "the Oscars of Northwest tech." He collected the award, which was voted on by members of the local tech community, for his work with professors Ira Kemelmacher-Shlizerman and Steve Seitz on "What Makes Tom Hanks

Look Like Tom Hanks?," which combines 3-D face reconstruction, tracking, alignment, and multi-texture modeling to create a digital persona from photos mined from the internet. Learn more about the project by reading the team's research paper at grail.cs.washington.edu/projects/3DPersona/.



Rajalakshmi Nandakumar wins CoMotion Graduate Innovator Award



CSE Ph.D. candidate Rajalakshmi Nandakumar was recognized with the 2016 CoMotion Graduate Innovator Award. The award honors a graduate student or postdoctoral researcher "who best demonstrates creative problem-solving on the road to moving innovative ideas to real-world impact." Nandakumar works with CSE professor

Shyam Gollakota in the Networks & Mobile Systems Lab on the development of applications in mobile health and human-computer interaction. She leads the research efforts for ApneaApp and FingerIO. More information on FingerIO is available in the article on page 20 of this issue of MSB.

Aleesha Wiest receives College of Engineering Staff Award

Aleesha Wiest, a program operations specialist in CSE, was recognized with a UW College of Engineering Professional Staff Award. Each year, the College honors faculty, students and staff who go above and beyond — be it through teaching, research, or, in Wiest's case, their vital work behind the scenes that makes faculty, students and fellow staff members look good. Wiest provides top-notch administrative and grants support to no fewer than nine individual CSE faculty members, as well as supporting UW-hosted Intel Science and Technology Center for Pervasive Computing (ISTC-PC) with its 10 UW faculty members from various departments and nearly two dozen postdocs, students and staff.



UW researchers shine at CHI 2016

UW had a large and quality presence at CHI 2016, the annual conference for human-computer interaction research, contributing to 39 papers. Three UW papers were selected for Best Paper recognition (top 1% of submissions) and nine were selected for Honorable Mention (top 5% of submissions). Of these, one Best Paper and five Honorable Mention papers were co-authored by CSE faculty and/or students. An overview of CSE's contributions to the conference may be viewed at tinyurl.com/CHI2016UWCSE. CSE professor



Katharina Reinecke co-authored one of the winning papers, "Enabling Designers to Foresee Which Colors Users Cannot See," with professors David Flatla of University of Dundee and Christopher Brooks of the University of Michigan. Read the paper at tinyurl.com/ReineckeCHI2016.

Alvin Cheung receives U.S. Department of Energy Early Career Research Award

Professor Alvin Cheung received an Early Career Research Award from the U.S. Department of Energy's Office of Science. His winning proposal, "Using Verified Lifting to Optimize Legacy Stencil Codes," was one of 49 projects selected for funding by DOE out of 720 proposals submitted. Cheung's proposal describes how verified lifting can enable legacy stencil computations to leverage domain-specific languages (DSLs) and frameworks to improve performance. For stencil computations, his proposal offers an alternative to the rewriting of existing applications or developing custom compilers to transform such code while leveraging the latest developments in high-performance DSLs and domain-specific compilers to improve speed, maintainability, and portability.



Hanchuan Li, Alex Mariakakis win Qualcomm Innovation Fellowship



CSE Ph.D. students Hanchuan Li and Alex Mariakakis are one of eight teams selected to receive a 2016 Qualcomm Innovation Fellowship. They won one of these coveted awards with their proposal for IDCam, a hybrid RFID-computer vision system that enables simultaneous

localization and identification for individuals and objects that will increase our understanding of how people interact with the physical world. IDCam observes how RFID tags instrumented on everyday objects are disturbed by their motion, and then correlates that information with visual motion information.

Austin Stromme wins Goldwater Scholarship



UW sophomore Austin Stromme, who is pursuing a double major in computer science and mathematics, has been selected as a 2016 Goldwater Scholar. Stromme worked with professor James Lee of UW CSE's Theory group last year on graph theoretic methods in computational linear algebra. Currently, he is

working with math professor Jim Morrow on the use of discrete harmonic cohomology modules to understand the geometry of boundary graphs, and with Ph.D. student Matthew Junge to analyze the frog model and related random models on graphs.

Rajesh Rao wins 2016 Guggenheim Fellowship

CSE professor Rajesh Rao, an expert in brain-computer interfaces, has been recognized with a 2016 John Simon Guggenheim Memorial Foundation Fellowship. Rao, who leads the National Science Foundation's Center for Sensorimotor Neural Engineering, was chosen based on his past achievements and exceptional potential to make future contributions in the field of neuroscience. The fellowship will support Rao's work on a project titled "The Computational Brain: Understanding and Interfacing with Neuronal Networks."



Krittika D'Silva named Gates Cambridge Scholar



Krittika D'Silva has been named a 2016 Gates Cambridge Scholar, one of the most prestigious international scholarships in the world. D'Silva, who graduates from the UW this June with a degree in CE and bioengineering, will pursue her Ph.D. in computer science at the University of Cambridge's Jesus College

Continued on page 22

UW CSE faculty and alums earn major honors

Tom Anderson, Albert Greenberg elected to the National Academy of Engineering

In February, UW CSE professor and alum Tom Anderson (Ph.D., '91) and alum Albert Greenberg (Ph.D., '83) were elected to the National Academy of Engineering — one of the highest professional honors accorded an engineer. They were among eight distinguished computer scientists and computer engineers who were included in the NAE's Class of 2016.



Tom Anderson is the Warren Francis and Wilma Kolm Bradley Chair in Computer Science & Engineering at the UW. His research interests span all aspects of building practical, robust, and efficient computer systems. As someone who is drawn to, in his own words, "the biggest

problem he can find," Anderson has made fundamental contributions to operating systems, distributed systems, and computer networks. Recently, Anderson and his students have focused on high performance operating systems to better support network intensive data center applications. His students and postdocs have taken faculty positions at Carnegie Mellon, Princeton, University of California San Diego, and the University of Texas, among others.

Anderson did not start out as a computer scientist, obtaining his Bachelor's in Philosophy from Harvard. After seeing the light, he earned his Ph.D. working with CSE professors Ed Lazowska and Hank Levy on operating system support for high-performance multiprocessing. He joined the faculty at the University of California, Berkeley in 1991, but returned to UW CSE six years later.

Anderson has been recognized with the USENIX Lifetime Achievement Award, the IEEE Koji Kobayashi Computers and Communications Award, the ACM SIGOPS Mark Weiser Award, and several others. He is a Fellow of the Association for Computing Machinery and has co-authored more than 20 award-winning papers. He was elected to the NAE in acknowledgment of his "contributions to the design of resilient and efficient distributed computer systems."

Albert Greenberg is Distinguished Engineer and Director of Development for Microsoft's Azure Networking, the company's cloud computing infrastructure platform for coordinating data centers around the world. He arrived at Microsoft Research in 2007, after spending 13

years focused on network measurement and network engineering research at Bell Labs/AT&T.

After obtaining his Bachelor's in Mathematics from Dartmouth College, Greenberg earned his Ph.D. at UW CSE working on the development of efficient algorithms for multiple access channels alongside professors Richard Ladner and Martin Tompa. A Fellow of the Association for Computing Machinery, he received the SIGCOMM Award for his lifetime contribution to the field of communications networks, the IEEE Koji Kobayashi Computers and Communications Award, and multiple "Test of Time" awards for his research.



He was elected to the NAE in recognition of his "contributions to the theory and practice of operating large carrier and data center networks."

Learn more at www.nae.edu.

Anna Karlin, Jeff Dean elected to the American Academy of Arts & Sciences

UW CSE professor Anna Karlin and alum Jeff Dean (Ph.D., '96) were elected Fellows of the American Academy of Arts & Sciences in April. They are among only six computer scientists selected for the honor out of 212 new members elected this year. The American Academy, established in 1780, is one of the nation's oldest and most revered learned societies. Its Fellows are among the most accomplished individuals in their disciplines, which span mathematics, the biological and physical sciences, medicine, the social sciences, business, government, humanities, and the arts.

Anna Karlin is the Microsoft Professor of Computer Science & Engineering and a member of UW CSE's Theory group. Her research focuses on the design



and analysis of algorithms, particularly probabilistic and online algorithms. She co-authored the paper that coined the now-standard terminology in online algorithms, "competitive analysis of online algorithms" and the "competitive ratio." Karlin is perhaps most well known for her result with Azar, Broder and

Upfal that has come to be referred to as "the power of two choices." This result considers the problem of assigning n jobs to n machines. If each job is assigned to a random machine, a classic result in probability shows that the maximum load on any machine is $\log(n)/\log\log(n)$. Karlin's result shows that if each job is considered for assignment to two random machines instead of one, and is then assigned to the less heavily loaded of the two, the maximum load on any machine drops exponentially, to roughly $\log\log(n)$. This result is useful in a variety of settings, including load balancing, hashing, and scheduling.

Karlin also works at the interface of theory and other areas, such as economics and game theory, data mining, operating systems, networks, and distributed systems. She is co-author of the forthcoming book *Game Theory, Alive* with Yuval Peres, to be published in 2016 by the American Mathematical Society. In addition to her research and teaching within CSE, Karlin has designed and taught a course for non-majors that examined the intellectual underpinnings and societal impacts of computer science.

Before her arrival at the UW, Karlin spent five years as a researcher at Digital Equipment Corporation's Systems Research Center. Karlin earned her Ph.D. from Stanford in 1987 and is a Fellow of the Association for Computing Machinery. As a founding member of the rock band Severe Tire Damage she has the distinction of having participated in the first-ever live music broadcast on the internet, back in 1993.

Jeff Dean is a Google Senior Fellow and leads the Google Brain project. Since joining the company in 1999, Dean has contributed to a number of significant developments, including five generations of crawling, indexing and query serving systems; the initial development of Google's AdSense for Content product; MapReduce, which simplifies the development of large-scale data processing applications; and BigTable, a large-scale, semi-structured storage system that underpins a number of Google products. He also worked on the system design for Google Translate as well as the design of DistBelief and TensorFlow for large-scale training and deployment of deep learning models — to name only a few.



Dean earned his Ph.D. working with Craig Chambers on whole-program optimization techniques for object oriented languages. He is a Fellow of the Association for Computing Machinery and the American Association for the Advancement of Science, and a Member of the National Academy of Engineering.

Karlin, Dean and their colleagues will be inducted at a ceremony in Cambridge, Massachusetts in October.

Learn more at www.amacad.org.

Four CSE students in the inaugural class of Husky 100



CSE undergraduates Karolina Pyszkiewicz, Krittika D'Silva, Sarah Yu, and Victor Farkas have been selected as members of the inaugural class of the Husky 100.

This new award recognizes 100 students from across the three UW campuses who are making the most of their time as Huskies. Pyszkiewicz is a junior CS major and CSE endowed scholarship recipient who has also been named a Washington State Opportunity Scholar and a NASA Space Grant Scholar. D'Silva is a senior in CE and Bioengineering who will pursue her Ph.D. at Cambridge University, where she has been named a Gates Cambridge Scholar. Yu is a senior majoring in CS, Economics and International Studies who is active with the American Red Cross. Farkas is a senior CS major and athletic scholarship recipient from Slovakia who will extend his time at the UW to complete CSE's fifth-year master's program. All four students have made a difference, both in and out of the classroom, as members of the UW community.

Learn more at www.washington.edu/husky100.

Professors Shwetak Patel, Luke Zettlemoyer receive Presidential Early Career Awards

The Presidential Early Career Award for Scientists and Engineers (PECASE) is one of the highest honors bestowed by the U.S. government on scientists and engineers in the early stages of their research careers. In February, the White House selected joint CSE and EE professor Shwetak Patel and CSE professor Luke Zettlemoyer to each receive one of these prestigious awards in recognition of their exceptional potential to advance the frontiers of knowledge and our nation's leadership in science and technology.

Patel leads UW CSE's UbiComp Lab and is a recognized expert in low-power sensing, mobile health and novel interaction technologies. He was nominated for a PECASE by the National Science Foundation for "inventing low-cost, easy-to-deploy sensor systems that leverage existing infrastructures to enable users to track household energy consumption and make the buildings we live in more responsive to our needs."

Zettlemoyer is a member of UW CSE's world class Natural Language Processing group whose research focuses on the intersection of natural language processing, machine learning, and decision-making under uncertainty. He was nominated for a PECASE by the Department of Defense for "his outstanding research accomplishments in computational semantics, in particular for innovative new machine learning approaches for problems in natural language understanding."

PECASE recipients are selected from among the most promising early career researchers across the nation, as

nominated by the federal agencies that have funded their research. The awards, which were established 20 years ago by President Bill Clinton, are coordinated by the White House Office of Science & Technology Policy.

Patel, Zettlemoyer and their fellow winners gathered in Washington, D.C. last month to be recognized at ceremonies hosted by the National Science Foundation and the Office of Science & Technology Policy, followed by a meeting with President Barack Obama at the White House.

For an academic department to have one faculty member awarded a PECASE in a given year is cause for celebration; it is virtually unheard of for an academic department to celebrate two winners in the same year. Patel and Zettlemoyer are among 105 scientists and engineers selected for the honor in 2016.

Learn more at tinyurl.com/white-house-pecase-2016.



Front row: Shwetak and Luke.
Back row: Eleanor Roosevelt.



2016 PECASE award winners at the ceremony with President Obama.

Passive Wi-Fi named a top 10 breakthrough technology of 2016

Wi-Fi is virtually everywhere these days, making it a convenient way for us to connect our devices and, by extension, to connect with each other. But every convenience has a cost — and in the case of Wi-Fi, that usually takes the form of a drained battery.

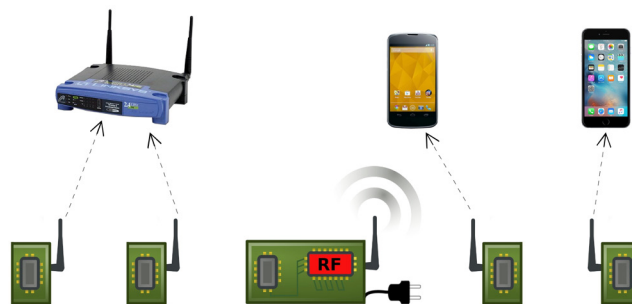
A team of researchers led by professor Shyam Gollakota of UW CSE's Networks & Mobile Systems Lab aims to change that. They have developed a new system, called Passive Wi-Fi, that is capable of communicating while consuming 1,000x less power than the most efficient technology commercially available today.

"We wanted to see if we could achieve Wi-Fi transmissions using almost no power at all, and that's basically what Passive Wi-Fi delivers," said Gollakota. "The conventional wisdom is that Wi-Fi is too power-hungry to be a factor in the Internet of Things, but our work suggests that it could, in fact, help IoT realize its full potential."

That prospect caused *MIT Technology Review* to select Passive Wi-Fi as one of its "Top 10 Breakthrough Technologies" of 2016.

The team, which includes UW Electrical Engineering Ph.D. student Bryce Kellogg, EE Ph.D. alum and current CSE postdoc Vamsi Talla, and joint CSE and EE professor Joshua Smith, is building on previous work experimenting with backscatter communication. Unlike that earlier work — in which an additional data stream was created to ride on top of existing Wi-Fi signals — the new system is capable of generating Wi-Fi transmissions that can be decoded by the billions of existing devices containing Wi-Fi chipsets.

"Our sensors can talk to any router, smartphone, tablet or other electronic device with a Wi-Fi chipset," said Kellogg. "The cool thing is that all these devices can



With Passive Wi-Fi, power-hungry RF functions are delegated to a single device plugged into the wall, while the passive Wi-Fi devices perform digital baseband operations like coding and modulation.

decode the Wi-Fi packets we create, using reflections, so you don't need specialized equipment."

Using off-the-shelf smartphones and Wi-Fi chipsets, the team has generated Wi-Fi transmissions at distances up to 100 feet. The system has achieved transmission speeds of up to 11 megabits per second — that's 11x higher than Bluetooth. Better yet, it consumed several orders of magnitude less power while doing it.

Passive Wi-Fi works by decoupling the power-intensive analog functions from the more energy-efficient digital ones. "All the networking, heavy-lifting and power-consuming pieces are done by the one plugged-in device," explained Talla. "The passive devices are only reflecting to generate the Wi-Fi packets, which is a really energy-efficient way to communicate."

Because Wi-Fi is so ubiquitous in people's homes and public spaces, Passive Wi-Fi opens up a host of new possibilities for energy-efficient sensing and communication while taking advantage of existing infrastructure.

"Even though so many homes already have Wi-Fi, it hasn't been the best choice for that," Smith noted. "Now that we can achieve Wi-Fi for tens of microwatts of power and can do much better than both Bluetooth and ZigBee, you could imagine using Wi-Fi for everything."

The team's research paper presenting Passive Wi-Fi earned the Best Paper Award at the NSDI 2016 conference in March.

To learn more, visit passivewifi.cs.washington.edu.



Passive Wi-Fi team, left to right: Joshua Smith, Shyam Gollakota, Vamsi Talla, Bryce Kellogg. Photo: Daniel Berman/Seattle Times

Research roundup: The cure for fat-finger syndrome, a robot hand that learns from experience, and more from the CSE labs

FingerIO: Sonar-based finger tracking for mobile devices

For those who struggle to interact with the tiny screens of their smartphones and smartwatches, help is at hand. A team of researchers in the Networks & Mobile Systems Lab have developed a new system that uses sonar for fine-grained finger tracking. Called FingerIO, the technology enables users to interact with their devices by writing or gesturing on a nearby surface or even in mid-air — freeing our fingers from the narrow confines of those itchy bitsy screens.

FingerIO uses the speaker built into the device to emit an inaudible sound wave, which bounces off the user's finger and is recorded using the device's own microphone. That signal enables FingerIO to calculate the location of the finger in space. By employing Orthogonal Frequency Division Multiplexing — a modulation technique common in wireless communication — FingerIO is capable of delivering sub-centimeter tracking accuracy with off-the-shelf devices.

"I don't need to instrument my fingers with any other sensors," explained CSE Ph.D. student and lead author Rajalakshmi Nandakumar. "I just use my finger to write

something on a desk or any other surface and the device can track it with high resolution."

It's a modern version of active sonar. Unlike camera-based systems, sonar does not require a direct line of sight — meaning it will work through the fabric of a pocket or sleeve. Sonar also does not require as much computing power as other approaches.

Nandakumar's collaborators include Electrical Engineering Ph.D. student Vikram Iyer, CSE professor Shyam Gollakota, and CSE affiliate professor Desney Tan of Microsoft Research. The team earned an Honorable Mention for its paper on FingerIO at the CHI 2016 conference in May.

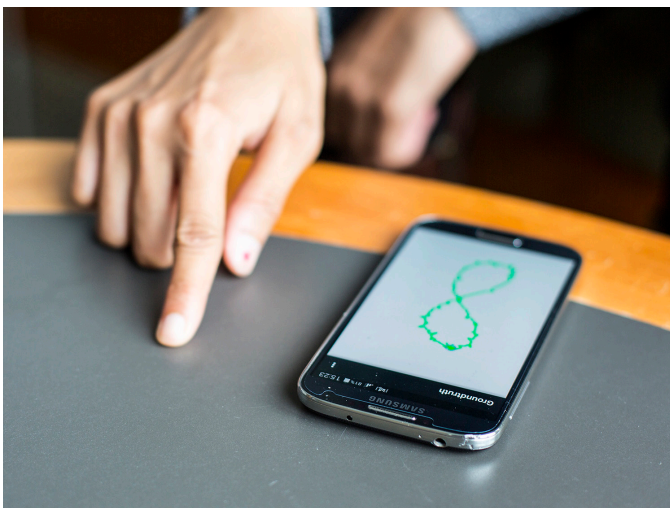
Learn more at fingerio.cs.washington.edu.

Adroit: The robot hand for which practice makes perfect

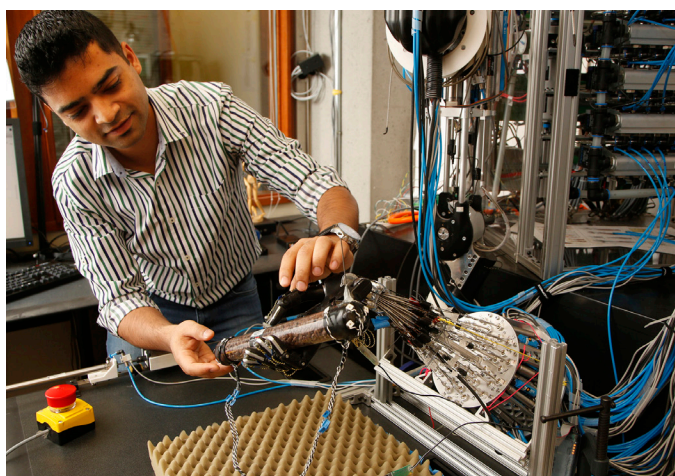
Of all the tasks robots have been shown to be capable of performing — from cooking breakfast to flying missions to space — they haven't been able to grasp the finer points of dexterous in-hand manipulation. Not, that is, until a team of researchers in the UW Movement Control Lab developed the Adroit manipulation platform.

The team paired one of the most sophisticated five-fingered robot hands in the world — built at UW CSE — with an optimization-based framework that uses a model of the system for synthesizing full details of the dexterous movements in real time. That overall framework is appended with a learning module, which learns the model of the system as the robot performs the task. On each repetition, the module uses a model learned from prior data to decide what the most promising action is, performs that action, collects more data, improves the model, and repeats.

"It's like sitting through a lesson, going home and doing your homework to understand things better, and then coming back to school a little more intelligent the next day," said UW CSE graduate student and lead author Vikash Kumar, who worked with CSE and Applied Mathematics professor Emo Todorov and CSE professor Sergey Levine on the project.



CSE Ph.D. candidate Rajalakshmi Nandakumar demonstrates how FingerIO enables users to interact with smart devices by gesturing on a nearby surface.



CSE Ph.D. candidate Vikash Kumar with the custom-built robot hand that learns by doing.

This autonomous learning approach is very different from that of other robot demonstrations. "Usually people look at a motion and try to determine what needs to happen. It's almost like making an animated film," noted Todorov. "What we are using is a universal approach that enables the robot to learn from its own movements and requires no tweaking from us."

The UW CSE robot hand demonstrated the ability to learn at a significantly faster rate compared to previous approaches. It was also able to handle challenging problems with surprisingly little data. To demonstrate, the team had the robot practice rotating a cylinder filled with coffee beans. On each subsequent attempt, the robot was able to improve its performance based what it had learned from previous tries.

The team's work earned it the Best Robotic Manipulation Paper Award at the recent ICRA 2016 conference. Having successfully demonstrated local learning — whereby the robot hand improves by repetition of the same manipulation task — the next challenge is to attain global learning, meaning the robot hand will figure out how to respond to objects or scenarios which it has not previously encountered.

Learn more at homes.cs.washington.edu/~vikash.

SpiroCall: Measure lung function from any phone

People who are living with chronic lung conditions may breathe a little easier thanks to a new health sensing tool, SpiroCall, developed by researchers in UW CSE's UbiComp Lab. With SpiroCall, at-home monitoring of lung function in patients suffering from asthma, chronic obstructive pulmonary disease and cystic fibrosis is just

a phone call away — using any phone, from anywhere in the world.

Four years ago, UbiComp researchers introduced SpiroSmart, an app that uses a smartphone's built-in microphone to measure lung function based on the sound and pressure produced by the user's exhalation. More than 4,000 patients have had their lung function measured using both SpiroSmart and a commercial spirometer at clinics in the USA, India, and Bangladesh. The comparative data collected from those trials has enabled researchers to refine the app and lay the groundwork for the U.S. Food & Drug Administration clearance process. But there was a problem. SpiroSmart was designed to provide patients with an at-home alternative to repeated visits to a clinic. However, based on their surveys of patients in India and Bangladesh, researchers realized that the low rate of smartphone ownership in low and middle-income communities would preclude widespread use of the app as intended.

SpiroSmart sends data on the user's exhalation to a central server, where machine learning algorithms are used to convert them into standard measurements of lung function. Because every phone has a microphone, the researchers determined that they could adapt their approach to work with any phone by relying on a call-in service to record and analyze the data.

"We wanted to be able to measure lung function on any type of phone you might encounter around the world — smartphones, dumb phones, landlines, pay phones," said joint CSE and EE professor Shwetak Patel. "With SpiroCall, you can call a 1-800 number, blow into the phone, and use the telephone network to test your lung function."



CSE Ph.D. candidate Mayank Goel demonstrates SpiroCall using a feature phone and 3-D printed whistle.

Continued on page 23

Datagrams (continued)

this fall. Most recently, D'Silva has worked with UW CSE professor Luis Ceze in the Molecular Information Systems Lab on the DNA data storage project. Previously, she collaborated with the late CSE professor Gaetano Borriello and CSE Ph.D. alum Nicki Dell on the development of mobile health apps for use in low-resource settings. D'Silva also spent more than two years as a researcher in the Department of Bioengineering, where she focused on improving the design of prosthetic devices used by people living with lower limb amputations. Check out her new Gates Cambridge scholar profile at tinyurl.com/GatesCambridgeDSilva.

Shayan Oveis Gharan, Su-In Lee receive NSF CAREER Awards



CSE professor Shayan Oveis Gharan and joint CSE & Genome Sciences professor Su-In Lee have received NSF CAREER Awards — the 29th and 30th faculty members to be recognized through this program and its predecessors.

Oveis Gharan is one of the most recent additions to CSE's Theory group. His research focuses on the design and analysis of algorithms. In addition to his work in approximation algorithms, he is well-known for fundamental contributions in algorithmic spectral graph theory.

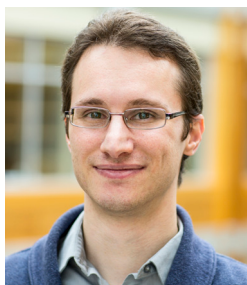


Lee's research focuses on the intersection of computer science and biology. This award

will support her efforts to develop a computational framework for identifying how the human genome interacts with hundreds of regulatory molecules — research that will answer fundamental questions to advance our understanding of how the human genome works.

Sergey Levine wins ONR Young Investigator Award

CSE professor Sergey Levine has been recognized with a Young Investigator Award from the Office of Naval Research. Levine's research focuses on the intersection between control and machine learning, with the aim of developing algorithms and



techniques that can endow machines with the ability to autonomously acquire the skills for executing complex tasks. In particular, he is interested in how learning can be used to acquire complex behavioral skills, in order to endow machines with greater autonomy and intelligence. Read more about his work on pages 20-21 of this issue of MSB.

Noah Smith receives UW Innovation Award to map the "perspectives landscape"



CSE professor Noah Smith received a 2016 Innovation Award from the UW's Office of Research to create a large-scale visualization of people's perspectives on current events and issues based on the vast amounts of text data available online. The UW Innovation Awards program supports potentially

transformational research for which other funding sources are limited. By developing tools to map the "perspectives landscape," Smith will advance the state of the art in natural language processing while enabling researchers, policy makers, and citizens to gain a better understanding of the public discourse.

Emina Torlak wins Sloan Research Fellowship, 2016 AITO Dahl-Nygaard Prize

CSE professor Emina Torlak was recognized by the Alfred P. Sloan Foundation with Sloan Research Fellowship. Recipients of these prestigious awards are nominated by their peers and selected by the foundation based on their early-career research accomplishments and for showing outstanding promise of making fundamental contributions to their fields.



Torlak is a member of CSE's Programming Languages & Software Engineering (PLSE) group and develops tools and programming models for computer-aided design, verification and synthesis of software. She was recently named the winner of the 2016 junior AITO Dahl-Nygaard Prize, an award that recognizes an early-career researcher who demonstrates exceptional potential in the area of programming and simulation.

Research roundup (continued)

Instead of transferring a sound file over the internet, SpiroCall transmits the audio over a standard phone channel and uses multiple regression algorithms to provide reliable estimates of lung function despite variations in audio quality. The system delivers results with a 6.2 percent margin of error — well within the industry standard of between 5 and 10 percent for clinical spirometry. The team also developed a 3-D printed whistle that changes pitch when the user exhales, which is useful for patient training and for testing patients whose vocal cords are unable to produce sufficient sound due to the severity of their illness.

"Our research area is not just about sensing, but human-centered sensing," said CSE Ph.D. student and lead author Mayank Goel. "Because this project has been around for four years, we've been able to talk to a lot of patients about how they're able to use the technology, and that feedback has really helped us make smart improvements."

The team earned an Honorable Mention for its work at last month's CHI 2016 conference. Co-authors include EE Ph.D. students Elliot Saba and Josh Fromm, CSE Ph.D. student Eric Whitmire, former high school intern and current Caltech student Maia Stiber, UW EE alum and Southern Methodist University professor Eric Larson, and the late CSE professor Gaetano Borriello.

Learn more at ubicomplab.cs.washington.edu/projects/SpiroSmart.

PaperID: Turn any surface into a smart interface

Health sensing is not the only frontier being explored by researchers in UW CSE's UbiComp Lab. Working with colleagues at Disney Research and Carnegie Mellon University, a team that includes professor Shwetak Patel, CSE Ph.D. student Hanchuan Li and EE Ph.D. student Josh Fromm has developed a system that leverages inexpensive RFID sensors to integrate real-world items — even a humble piece of paper — into the Internet of Things.

PaperID relies on simple RFID tags that can be stuck on, printed on or even drawn with conductive ink on everyday objects to give them sensing capabilities. Each RFID tag has a unique identification that can be picked

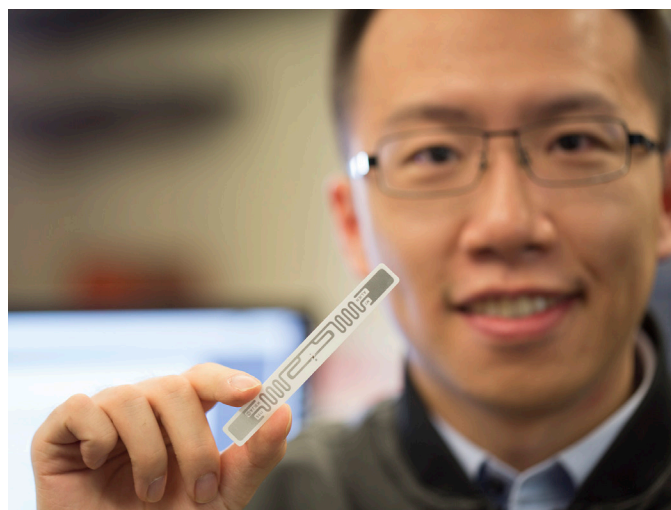
out by a reader device. When a person disrupts the signal between tag and reader by touching, swiping or performing another interaction, algorithms recognize specific movements and interpret the resulting signal interruption as a command.

The researchers demonstrated a variety of potential applications, from selecting the answers to an interactive multiple-choice poll, to switching lights on and off in a dollhouse. The system can also track a tagged object's velocity to enable gesture-based sensing and control, such as waving a wand in mid-air to control music.

"If RFID tags can make interfaces as simple, flexible and cheap as paper, it makes good sense to deploy those tags anywhere," said Li. "These little tags, by applying our signal processing and machine learning algorithms, can be turned into a multi-gesture sensor. Our research is pushing the boundaries of using commodity hardware to do something it wasn't able to do before."

The research team — which also includes Eric Brockmeyer, Liz Carter, and former UW CSE postdoc and EE Ph.D. alum Alanson Sample of Disney Research and professor Scott Hudson of CMU — presented PaperID at the CHI 2016 conference last month.

Learn more at www.disneyresearch.com/publication/paperid/.



CSE Ph.D. candidate Hanchuan Li holds up a PaperID sensor tag.



most significant bits

newsletter of uw computer science & engineering

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UW CSE alum Bay Area meetup: Join us at the Computer History Museum!

This year's UW CSE Bay Area alumni meetup will be hosted at the [Computer History Museum](#) in Mountain View.

Please plan to join us on

Wednesday, June 29th.

Eat! ... drink! ... connect with CSE faculty, alumni, and friends!

For more information, please contact Kay Beck-Benton (kbeck@cs.washington.edu).

RSVP is requested:

tinyurl.com/UWCSE2016CHM

