Conduit

A RESEARCH AND ALUMNI NEWS MAGAZINE
Department of Computer Science, Brown University // Vol. 24

What Is The Yurt?

+ Celebrate With Andy:
  50 Years Of CS At Brown
+ Diversity At Brown CS: 2015

Notes From The Chair

BY UGUR CETINTEMEL

Last summer I started serving as the seventh Department Chair of Brown CS. I am honored and thrilled about the opportunity to help move the department forward. I would like thank Roberto Tamassia for his effective leadership and service for the last seven years, and also for his help in my transition to this new role.

It has been an exciting nine months for me and the department with many accomplishments, inaugural events, and even more memorable things on the horizon as we approach the end of the semester.

Our faculty, especially our junior colleagues, generated a lot of excitement last year. For example, just since the beginning of 2015, James Hays received a Sloan Award for his work in computational photography, joining past Brown CS recipients, Paul Valiant, Ben Raphael, Chad Jenkins and Amy Greenwald. Rodrigo Fonseca and Tim Kraska received NSF CAREER awards, bringing our total to 12. Tim also received an Air Force Young Investigator Award.

My CS colleagues have been working on two exciting programs. The Human-Centered Robotics Initiative (HCRI) was chosen as one of the two University Signature Initiatives two years ago and is going forward with continued support from the administration. We have also made significant progress towards an "Executive Masters Program in Cybersecurity" (now pending Corporation approval) together with the School of Professional Studies. Cybersecurity is one of the defining problems of our times and is also a strategic growth area for CS. This executive program will be a building block towards a multi-disciplinary cybersecurity ecosystem we plan to create at Brown.

We are very proud of our extraordinary alumni. To honor their accomplishments, we started two new lecture series, "IT Leaders Lecture Series" and "Life After Brown." Sridhar Ramaswamy PhD '95 and Adam Leventhal '01 came back for the inaugural lectures of these series and delivered inspiring talks. We are working on more alumni-oriented events to bring different generations of our alumni together and also engage with them more frequently and at a deeper level.

Space is one of our biggest challenges. Our home, the CIT, is now three decades old and has started showing signs of wearing down. Since last summer, we have been making an extensive renovation effort to refresh and modernize rooms across the building. The first stage of our renovations, which focused on the conference rooms, classrooms and student offices, is done; the second stage will take place in the summer of 2015. Concurrently, we have also been revising office assignments to achieve a better clustering of the students and faculty based on their research affinities to improve collaboration and synergies.

Also as part of the renovations, we have been repurposing rooms to create incremental office space. The lack of space has been severely limiting our research and teaching capabilities. We are working with the administration to acquire more space in the CIT and in nearby buildings (such as the Science Library) to accommodate near-term growth. Faculty growth is another major challenge for us. Recent years have seen "exploding" enrollments and interest in CS at Brown and elsewhere. The continuous growth of CS as its own discipline and the diffusion of computational tools and ideas into many other disciplines are exciting, yet the demand these trends create is beyond our capacity. It is difficult to remain competitive and ahead of the curve without commensurate growth of the department, especially during a period when many peer CS departments are growing fast. I am thankful to the Brown senior leadership in recognizing the importance of CS and starting to work with us toward a substantial growth plan, which I expect to materialize within the next six to eight months.

We are very much looking forward to a packed end-of-year schedule. The events include a multidisciplinary symposium ("The Next 250 Years"), which will bring to the CIT highly distinguished speakers across Computer Science, Economics, Physics, Neuroscience, and Mathematics. We will also see the opening of the Yurt, the successor to our cool virtual reality environment, the Cave. The Yurt represents a major leap in the visualization

CONTINUED ON PAGE 47

Conduit
Vol. 24

Published by the Department of Computer Science at Brown University, *Conduit* is distributed free to all computer science alumni, faculty, staff, students and industrial partners.

Queries about this publication can be directed to:
conduit@cs.brown.edu or
115 Waterman Street
Campus Box 1910
Providence, RI 02912

PUBLISHER
Industrial Partners Program,
Department of Computer Science

EDITOR-IN-CHIEF
Jesse C. Polhemus

GRAPHIC DESIGN
Brown Graphic Services

CONDUIT ON THE WEB
John Bazik
Kathy Kirman

PRINTING AND DISTRIBUTION
Brett Turner, Information Services
Brown Graphic Services

Table Of Contents

BROWN

MIX
Paper from responsible sources
FSC® C018792

Conduit is printed on Burgo's ChorusArt, an acid free and elemental chlorine free paper containing 50% recycled content and 15% post-consumer waste. You are the difference – reduce, reuse, recycle.

What Is The Yurt?

BY JESSE C. POLHEMUS

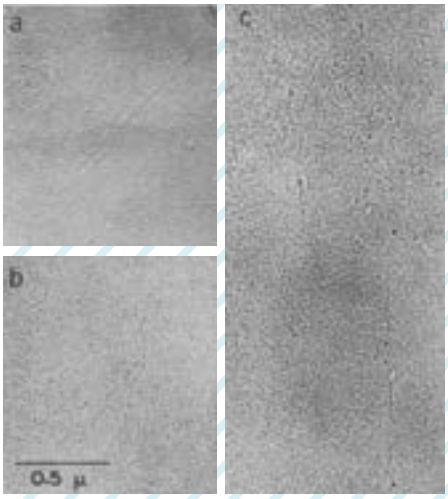
How often do we buy something, much less build it ourselves over a period of years, without fully understanding what it will achieve? Most objects, from a chair to a microscope, are designed to pursue predefined goals: offering a place for our arms to rest, supporting our back.

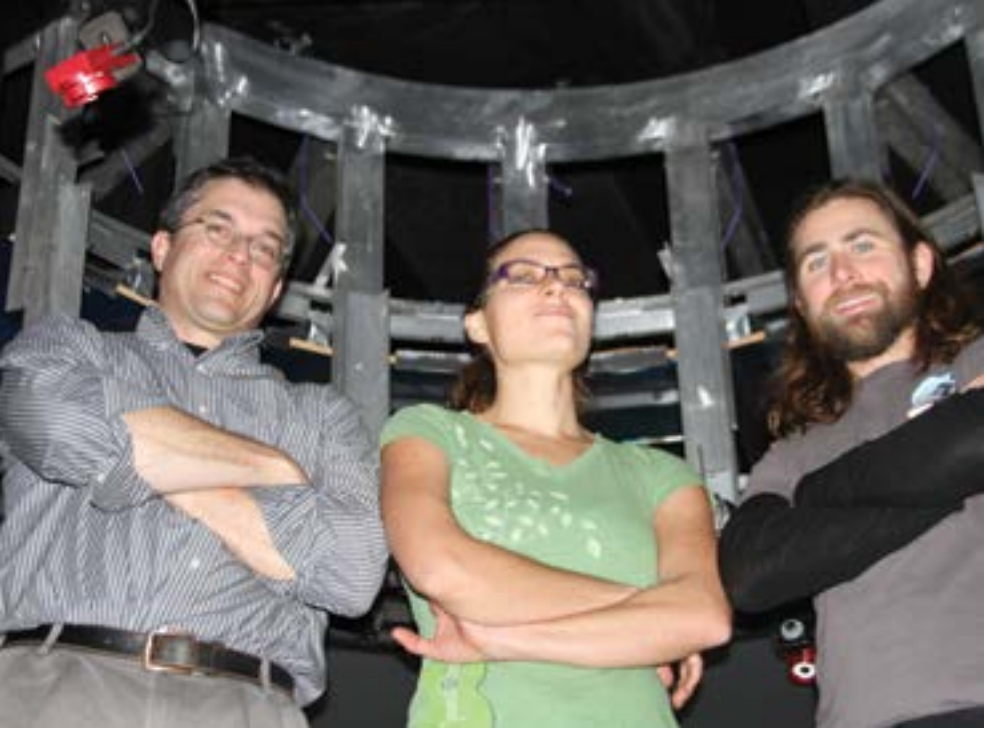
But this is exactly what's happening as Brown CS makes final preparations for the Yurt, the successor to the virtual reality display known as the Cave. "This is a landmark for visualization at Brown and a transformative leap for the field," says David Laidlaw, "but there's more to this moment in time. We've already used the Cave to explore Mars, paint in 3D, and navigate the human brain. Very soon, we'll have a world-class VR display in our hands to test the limits of what VR can be used for."

What is the Yurt? It's a question that David and his team have been asking themselves from the earliest days of its conception. Now that it's here, they're turning to experts and laypeople alike for the experiments that could someday benefit anyone working in the arts, sciences, or any other discipline. It's time to discover the essence of something that never existed before.

YURT TEAM MEMBER PROFILE: DAVID LAIDLAW, PROFESSOR OF COMPUTER SCIENCE

If one of the micrographs below contains gold atoms and the other doesn't, how would you know?





Tom Sgouros, Sarah Thomas, and Dallas Jamme

Fortunately, identifying the presence of gold numerically instead of visually is far easier. David Laidlaw first saw the value of visualization when he worked in a biophysics lab in high school: the task of finding gold atoms was completely transformed when he understood that the value of pixels could be shown as numbers, not colors.

"I started out by working in stereo and four dimensions when I came to Brown and studied under Tom Banchoff," David says. "I always liked how math was amenable to the extra visual cues that stereo provides, but I didn't get into virtual reality until I came back as a faculty member and we launched the Cave."

What was the secret of the Cave's success? "We spent a lot of time trying to figure out what makes it magic, but we couldn't. For certain tasks, like trying to locate a point on the surface of an object, a stereo desktop setup is actually faster. But something about VR is compelling: people work better, more efficiently when you completely fill their visual field and let them use their whole body to interact. It's a whole different scale, and as we worked with the Cave, we began to realize its limits and wonder what it would take to get us past them."

"We thought we'd have a new Cave ready in 2011," David says.

And now?

"2011!" he laughs.

His current team is composed of John Huffman, Dallas Jamme, Benjamin Knorlein, Wesley Miller, Johannes Novotny, Tom Sgouros, Sarah Thomas, and John van Rosendale. "I didn't set out to find a bunch of Renaissance people," David says, "but the goal I had in mind was that everybody would be able to latch onto a commitment of their own. We're dealing with mechanics, light, metallurgy, plastics, all challenging and interrelated. You have to be a polymath to feel the full sense of ownership and pride in all of it. All these guys are good thinkers, problem solvers — and they haven't run away yet! I haven't, either, so I guess I'm stubborn."

Laidlaw explains that one of the main goals of the Yurt is to take virtual reality beyond the accidental limits of technology. Updated hardware and software eliminate gaps, brighten colors, and increase resolution, providing 140 million pixels. That number is hard to grasp, so David gives an analogy: "Remember how different things looked when you first got a phone with a retina-quality display? Imagine standing in an entire room at that resolution, with pixels that are too small to see individually. If you improved on any of our specifications, the human eye would almost never be able to detect it."

Even for a layperson with no background in visualization or virtual reality, it's impossible not to start dreaming about the possibilities.

10/27/14: A SNAPSHOT

Take a quick look at the Yurt in autumn of last year. It's tucked away inside 180 George Street, a clay-colored building by Philip Johnson that once housed the IBM 7070, the most advanced mainframe on the East Coast at the time. Access is through the front door, then a set of double-doors at the left. Ordinary at first, with shelving and boxes and a small elevator, the room opens up dramatically when a visitor climbs a few steps.

Gray and blank, the Yurt's front wall and floor are in place, sixteen feet across. Stretching out from them, above and below and to the sides beyond, are the aluminum bones of the superstructure, wrapping the Yurt's edges and reaching upward to the open circle at the top that gives it its name. Just outside this skeleton, every inch of space seems to be filled with equipment: mirrors, boxy projectors, cameras, fishing line.

Even unfinished, the detail and the intricacy are so great that the Yurt gives the sense of always having been there, sprawling and revealingly open, but solid. Yet that isn't so. Construction began by opening a wall of the building, then lifting parts into place with cranes outside and chain hoists from beams in the ceiling.

"Think of a home renovation project, then multiply it by ten," David laughs.

Sarah Thomas

John Huffman and Wesley Miller

YURT TEAM MEMBER PROFILE: DALLAS JAMME, RESEARCH ASSISTANT

"You have to see this to understand." That was what David said to Dallas Jamme when they met through a mutual bicycling friend. Dallas is soft-spoken, smiles easily, and like his colleagues, his background is eclectic. He seems to be interested in everything at once:

"I've worked in ecobuilding, studied finance, worked as a bike mechanic and tour guide. I rode my bike around the country before coming to Brown, in hopes of riding it around the world. My background in finicky mechanical stuff has worked out well. We've had to draw on different areas of experience from everybody on the team, not just computer science or mechanical engineering or even virtual reality."

"At this point in construction, we'll take the victories," he says. On their first attempt, the mirrors warped in the summer heat due to expansion differences between the glass, mastic, and fiberboard backing. They had to be removed, the mounting method redesigned, and mastic reapplied. Now, there are four points of contact for each, with neoprene and clips to keep everything flat. "We're on the cusp. When all screens are up, it'll be the last big milestone. The rest is fine-tuning."

Dallas credits all the amazing teamwork to date: "It's humbling to work with such bright people. Everyone's amicable, reaching for the same goal. We have weekly meetings with John van Rosendale via Skype, and it shows me that people can work from anywhere. The world's getting smaller. I'm actually taking business classes in Costa Rica right now...when the Yurt is done, we just want people to use it! It's a tool, and I'd like to see it really capture people's imaginations."

He ends with a statement that seems to apply both to the Yurt and to himself: "Further studies in any field are interesting to me."

11/04/14: WALL AND FLOOR ALIGNMENT

On a late Tuesday afternoon a few weeks before Thanksgiving, the Yurt is quiet and smells of cut wood from some recent construction. In the area just outside what will be its back wall, there's a single desk, endless boxes and packaging and parts, a camera and tripod for pictures, tools of every kind, a framed shadow box of knots hanging on the wall, orange safety cones where a railing will one day be. When a roll of duct tape runs out and David flings it into a trash can, the vibration causes a dinner fork to clatter to the floor. It doesn't have the look of a dorm room, or even the feel, but there's the sense that people live here, at least part of the time. It's home.

Tom Sgouros is in khakis, with grey sneakers and a t-shirt from a local brass band festival. He explains that the floor has bubbled slightly, that it's no longer perfectly flat. Everything after that is a question. Was this the result of a temperature change? Did the wall push the floor upward? Will it go away?

There's the squeal of styrofoam as David lifts up the particle-board-and-foam protective layer, revealing a section of floor. He's in shorts, with a Block Island t-shirt. Underneath a blue tarp, the floor is a darker gray, as if a pool of liquid has welled into the Yurt. More than a dozen feet long, it's shaped like a right triangle with a curved hypotenuse, vaguely reminiscent of a church window.

The floor screen itself is polycarbonate, blended with dye and a proprietary "magic dust" with optical properties that facilitate projection. Just this past week, it went in on top of a layer of acrylic in two pieces, then was cleaned three times with alcohol and a microfiber cloth. (Shoes will

Dallas Jamme and Sarah Thomas

never be welcome in the Yurt.)

"Pull the tape away from the plastic, not the metal," David instructs, then adds for the bystander's benefit: "Look at this seam. It'll never see the light of day or oil of human bodies, but we'll clean it with alcohol later."

"Are you suggesting I stop drooling?" Tom teases. Then, squinting in concentration: "Is it meeting over here?" They're moving around the perimeter of the Yurt at the intersection of wall and floor. Holding up an iPhone as a light, they find a spot where it does, then another.

"If it meets in two places, we can't just move it to fit," David says. "Definitely a problem."

By now the rest of the team has arrived, and brainstorming begins: maybe they could trim the piece that doesn't fit well, laying one piece over another and planing it until they're identical.

"I'm a little dubious that it's as easy as it sounds," Tom admits. Other ideas are floated, some completely fanciful: someone suggests dabbling in chemistry to create transparent lead, which would be heavy yet clear.

Luckily, the Yurt itself is willing to lend a hand. David goes to the desk and types a command: there's a slight beep-whine, then a series of clicks as the projectors power up. The floor flickers and a uniform grid appears, offering a perfect tool to measure a fraction of an inch of misalignment. The team crouches carefully on the floor and begins to count squares.

YURT TEAM MEMBER PROFILE: TOM SGOUROS, PROJECT MANAGER

Massive progress has been made since Tom started working on the Yurt, when only the barest outlines of scaffolding were visible. A physics major with a minor in political science, he'd been doing software work for Brown CS when David began having problems with the Yurt's fishing lines. "Most people's journey from software to hardware isn't like this, but rigging is something I know something about!" Tom explains. "I used to put on a tent show called the Pan-Twilight Circus: puppets as animals, a slack rope, tightrope...Why have I worked in so many fields? I think there's a widely-overlooked value in breadth...I'm fascinated by how the world runs. I value work with a purpose, and the purpose of research is pretty compelling."

The phone rings, and Tom switches seamlessly into a detailed discussion of glue properties with a 3M supplier. Hanging up, he points to the door frames, which are now hung and close nicely. Motion capture cameras are working properly. Things are coming together.

"What I think is important," Tom says, "is that the Yurt's an open invitation: bring your data, bring your apps. It'll succeed when people imagine what tasks it could be useful for, then try them...I've learned from David that our senses are different from our brain. Some data sets out there are so vast that you can only grasp them when you're inside them — the understanding isn't available otherwise."

When Tom is asked if the time spent with David's team has changed anything about how he thinks or works, he has an immediate answer. He points a web browser at http://www.sgouros.com/pens/pig, and an animated piggybank that he created himself to visualize a pension system appears. A clock runs and the bank bubbles with activity as colored circles flow upward and downward, showing premium and benefit payments, investment income. In a

matter of seconds, numbers that were previously incomprehensible provide a conclusion: despite the media's apocalyptic rhetoric, an "underfunded" system may not be in immediate jeopardy for a hundred years or more, depending on the demographics. Without visualization, this communication task would have been endlessly more difficult.

"What complex visualization does best," Tom says, "is present systems in a way that's appropriate to how we really work as whole beings."

12/03/14: DOOR ARRIVAL

Three weeks before winter break, John van Rosendale, the Yurt's principal designer, pulls up from Virginia in a yellow Penske truck. The doors have arrived. A stack of two-by-fours appears in the lobby as the moving crew (John, David, Tom, and John Huffman) unpack pieces from their protective packaging, rolling the bigger items on a cart and carrying others by hand. Segments of screen are wrapped in blue and green blankets, but the rest, all gleaming, machined aluminum, looks like the innards of a giant's wristwatch: curved pieces that frame the doors, huge hinges, intricate axles.

Inside, it doesn't take long before people want to see how things work. Tom lifts a part of the frame and points: "Why this position for the rib assembly—"

"Just a second," says John, carefully navigating the boxes and packaging to look closer.

"—when the rib fastens to this?"

John grins. "I told you this was the complicated part. There are nine steps. First…"

A bit later, everyone is crouching on the floor again, comparing the profiles of two different screws. David looks closely. "There's a ¾-inch clearance on the floor."

"Why are we seeing any profile at all?" Tom asks.

"Look over here, it seams up properly."

"The floor is lit beyond the seam, I get it."

"It's tricky," John says. "There's nothing easy about this, it took the shop guys an hour to assemble and disassemble it. Are you busy tomorrow morning?"

"Yes," says Tom, perfectly deadpan. "Doing this."

NOT KNOWING IS THE BEST PART

As *Conduit* goes to press, David and his team are preparing for the Yurt's first major debut, the "Immersion at Brown" symposium being organized by Professor John Cayley of Brown's Literary Arts Program and John Huffman in his role as Manager of User Services for the Brown University Center for Computation and Visualization. The two-day event will begin with demonstrations in both the Cave and the Yurt. Afterward, major figures from the world of computer graphics, developers, scholars, and artists will give talks and presentations that will review the rise of immersive visualization and point toward its future.

The list of fields that have already benefited from the Cave is impressive: planetary geography, archaeology, fluid flow, applied mathematics, literary arts. All of them stand to gain even more from the Yurt, along with research already being planned in brain science,

biology, systems biology, genomics, and big data visualization.

In any of those fields, the gap between the art or science before and after virtual reality is vast. The painter and even the sculptor are limited by their materials, by physicality itself, but a CavePainter can step into her work, see it from all sides, shrink it down to the size of a pinhead or expand it to be as big as a room. Interactions that didn't exist before are creating an art form that's equally novel.

ARCHAVE, which visualizes archaeological data, lets the user walk the Great Temple of Petra, using gestures to pull information through time and space and have it made instantly comprehensible through shape and color. Even someone at the actual site would never be able to isolate the particular data needed (think of the micrograph images at the start of this article) in anywhere near the same amount of time. For the student or researcher at any level, it's superior to being there in person in any number of ways.

"We've just scratched the surface," David says. "Virtual reality lets you use your mental map of the world to find a new way of understanding and interacting and making discoveries in whatever field you work in. I have no idea what the Yurt's most interesting or most powerful uses will be yet. Not knowing is the best part!"

Please join us as we explore the Yurt's possibilities by visiting the Brown CS site (www.cs.brown.edu), Facebook page (https://www.facebook.com/groups/21496918775), or Twitter account (follow @browncsdept and look for the #YurtAtBrown hashtag).

Celebrate With Andy:
50 YEARS OF CS AT BROWN

BY JESSE C. POLHEMUS

THE SEMICENTENNIAL FESTIVITIES KNOWN AS *CELEBRATE WITH ANDY*, TO BE HELD ON MAY 22, MARK THREE GOLDEN ANNIVERSARIES FOR THE BROWN CS FAMILY: FIFTY YEARS OF THE UTA PROGRAM, UNDERGRADUATE INVOLVEMENT IN RESEARCH, AND ANDY VAN DAM AT BROWN.

Heather Claflin, Peter Relson, Douglas Dixon, Andy van Dam, the late David Notkin, and Henri Bulterman

A thousand words don't suffice to tell the history of those three "institutions," but one picture from our archives evokes something of their spirit. Believed to be taken at Commencement 1977, it shows van Dam and five others (Heather Claflin '77, Peter Relson '77, Douglas Dixon '77, the late David Notkin '77, and Henri Bulterman '71 '77 ScM), some in regalia and some not. Laughter and conversation are passing diagonally across the scene, and just for a moment, neither in the center of the composition nor at the Golden Mean, Andy has turned to the camera very casually: "Look at the great people we've got here!"

It's time for a toast. Romulus and Remus are fables: Brown CS doesn't require a founding myth because the true history of these three anniversaries is compelling enough. This article, however, will give only an abbreviated version of that story and tell just a fraction of the anecdotes. (We'd rather you join us in person or via livestream on May 22.) Instead, in preparation for all the fun of *Celebrate With Andy*, let's take a few moments now to go back in time to reflect, enjoy, and celebrate.

A RANDOM SEQUENCE

The story of CS at Brown begins, humbly enough, in a bathroom. In 1962, Andy's wife, Debbie, was teaching high school French, and one of her National Education Association magazines had ended up as his bathroom reading material. "I read an article," he remembers, "about teaching students at Bronx High School of Science to program and thought, 'That's ridiculous! I'm in grad school, just learning to do that!' But it kept bugging me, and I figured that it wasn't quantum physics, that they could certainly learn logical thinking."

So in 1962 he began a summer program of his own, showing Philadelphia area high school students and their teachers how to program, and even managed to obtain his first NSF grant, to support this novel project. "Running this course is how I fell in love with

teaching," van Dam says, noting that the program continued on after his tenure. Alumni of the pioneering effort include Elliot Perlman, a prominent local ophthalmologist who today counts Andy and Tom Doeppner among his clients; our own Steve Reiss was a later graduate.

"I was teaching programming," Andy says, "but in my own first course in grad school, I didn't actually get to use a computer because Penn's sole computer was too scarce a resource. We wrote machine code on paper and had our programs hand-corrected, but at least I got to see the mainframe!" He describes as "pseudo-religious" the experience of standing not just in the the machine room of UNIVAC 1, but inside its main memory, a little room consisting of a thousand words of memory implemented with mercury-filled acoustic delay lines.

"My arrival at Brown is based on a nearly random sequence of happenstance events," says Andy. "Reading the magazine article was the second one. The first was an unplanned conversation that got me into computer science to begin with. I was a hard-core electronics engineer, with an offer from Bell Labs to go design transistor circuits. But I went to grad school to learn more about the field, and my officemate mentioned that there was a new course on computers: 'We both have electives, so how about this new Computers and Automata course?' Up until that point, I'd only worked on analog computers, not digital ones, and I fell in love and switched my field. Over the years, and even now, as I interview new TAs, hundreds of people have shared similar experiences with me: taking a CS class at random, falling in love, and realizing for the first time what they want to do with their professional lives. It's many people's story, not just mine."

The third random event was the one that brought Andy to Brown. "Reading that magazine," he says, "led to teaching, and teaching led to a phone call three years later from a graduate of the summer program, James Castellan, who was then a student in Applied Math at Brown." Castellan called Andy after van Dam had all but accepted his first academic job elsewhere, asking if Andy knew that they were recruiting a CS person in what students called "Apple Math" at the time. "I don't know anything about Brown or Applied Math," Andy replied, adding that he'd essentially already made his decision. Jim persisted, saying that Brown was the perfect place because of its emphasis on undergraduate teaching.

"I spent one day here," Andy says, "and knew it was the right place because of their early history using computers in Applied Math and Engineering and especially because of the undergraduate emphasis." The clincher, he adds, was when the Chairman of Applied Mathematics excused himself in the middle of Andy's candidate interview to go teach a first-year course.

THINKING OF THEMSELVES AS COMPUTER SCIENTISTS

Understanding the genesis of undergraduate teaching assistants and undergraduate research is impossible without seeing the context of specialization and the department's formation. Future articles will address this issue in depth, and be narrated by others, but these new roles for undergraduates were were born in what van Dam calls those "workaholic, all-consuming, frantic" early days. "For some time," Andy says, "there had already been LISP and FORTRAN programming courses at Brown, but I was brought to Brown to create a formal computer science track within the Division of Applied Mathematics. Applied Math didn't see CS as something self-standing, but by the late '60s, after John Savage and Peter Wegner and several others came to Brown, undergraduates began thinking of themselves as computer scientists: your degree would say 'Applied Mathematics' on it, but effectively, you were a computer scientist."

Andy, John, and Peter initially proposed a Center for Computer Science, but — amazing in retrospect — the University's response to the proposal was negative, and so the three colleagues drafted a two-division program uniting CS-oriented faculty and courses from Applied Math and Engineering. In essence, it was a trial department, followed by the official establishment of the Brown CS Department. Andy was the Program Director and reported to both Division Chairs; in the final year of three, John served as Acting Director in his absence until Andy returned from his sabbatical at CERN and the University of Geneva in the summer of 1979 to become Chair of the new Department.

When the time came to start a computer science degree program at all three levels (undergraduate, Master's, and PhD), competing universities were anything but amenable to the idea of undergraduate CS education. "Here's the thing," van Dam explains. "Even if we didn't call it that, Brown almost exclusively pioneered the idea of an undergraduate CS program, which our competitors said was premature specialization -- they thought students should wait to specialize in CS at the few grad schools that offered programs at that time."

"The genesis of undergraduate participation in teaching and research has to be contextualized by the fact that in 1965, teaching computer science as a degree program, not just a few programming courses, to undergrads at all was novel. Teaching these various topics in computer science that were being taught at the graduate level elsewhere to undergraduates, even beginning undergraduates, worked at Brown because of the high quality of the students who were willing to be part of this 'total immersion' style of learning."

"Offering teaching and research assistant opportunities to undergrads," he says, "was even more unusual, indeed was viewed with everything from skepticism to outright hostility. Hardly anyone said, 'What a fantastic idea!' Everyone was used to four years of preparation as an undergraduate, then ***n*** years of graduate work before you could contribute to a science. But we're different. CS was and is young, experimental, and open for undergrads to contribute. And undergraduate participation in research in all fields has become commonplace, especially in the last decade."

BORN OF NECESSITY: THE UTA PROGRAM

In 1965, a single, intense full-year course could cover much of the breadth, if not the depth, of the systems-oriented portion of the discipline, not including theory, AI, numerical analysis, and a few other topics. Andy insisted that students couldn't learn to be good programmers by solving small "toy" problems; they had to write significantly-sized programs, each taking multiple weeks.

Not just checking for the right answer but giving useful feedback on structure, style, and efficiency required careful reading and one-on-one help with concepts and debugging. In a class with forty students, it was impossible for one graduate TA and a professor to provide this level of attention, no matter how little sleep they were getting, so van Dam asked for help from students who had taken a prior programming course. In that first cohort, he remembers Bill Adcock; Dan Bergeron, who also subsequently got his PhD with Andy and became Chairman of the CS Department at UNH and went with him and a group of six other of Andy's students for his first sabbatical in 1971 at the University of Nijmegen in Andy's country of origin; and Dennis Ruggles, among others.

"The undergraduate teaching assistants," Andy explains, "though they were initially called graders, didn't just grade programs — they not only provided one-on-one help to students but also became active participants in course design and in subsequent years read research papers and brought new ideas into the curriculum. In fact, they did everything graduate TAs did, becoming producers and not just consumers of education. We kept modifying the course as we went along, but the one constant was the highly-appreciated UTA system."

Few people appreciate it more than Ed Lazowska '72, who will lead the first ("Stone Age") panel for *Celebrate With Andy*. He says, "I'm a faculty member precisely because of the UTA program. I went to grad school because Andy told me to. In some way, everything I do professionally today is due to him."

To provide feedback for the course, students wrote detailed, multi-page evaluations, something that was almost unheard of in 1965. As Bob Munck recalls, "Also after every class, the graders would sit around on the floor of Andy's office (later my office) and critique the lecture and him. I'd never seen anything like it."

On his commute home from work, Andy would listen to tape recordings of his lectures, filling the empty minutes with self-critiques: "Boy, was that a clumsy explanation! Get rid of the 'um's and the 'you know's." Presentation skills are still something that van Dam is keenly interested in. "Today's equivalent of 'you know' is 'like', which I try to stamp out in all students who work with me. I've given up on 'awesome.'"

Andy van Dam at the Brown CS 2014 Holiday Party

An interesting aspect of the UTA program is that the system has essentially never been challenged by students due to the built-in checks and balances. "By having rotating TAs and detailed rubrics," Andy says, "you create fairness. It's a system that's at least as fair as having a single faculty member grading. Besides, a single faculty member, even assisted by a few graduate TAs, can't begin to read that many programs at the required level of detail, and students recognize that. Part of the checks and balances is that faculty members are responsible for assigning the final grades, and I personally review all borderline grades, hoping to find evidence for promotion to the next grade bin."

Originally something made up as they went along, the UTA program matured over a period of decades. Iteration and gradual regularization brought cross-course norms and standards that are used today by almost all Brown CS courses. "In my opinion," says Andy, "We have the most systemic TA program, and there's a well-defined appeal system in place to address any grading errors."
In some classes, van Dam explains, even PhD students are in a course with undergraduate TAs, but it works: for a particular topic, in a particular course, the younger student knows more. He drops his voice an octave to imitate a disbelieving critic. "Undergrads grading grad students? How can that work?"

His own warm bark of a laugh is flung out with the response:

"Just fine — in fifty years, I've never had a complaint from a grad student! They respect competence as much as I do."

FEARLESS, AMBITIOUS: UNDERGRADUATE RESEARCH

After undergraduates had successfully assisted with teaching, the logical next step was assisting with research; the logical choice of accommodation for a research team was a shared room. If these conclusions seem obvious, listen to Andy's description of what happened: "Applied Math had never seen anything like it! The biggest room in the building as this nerve center, six hundred square feet for me and an admin and four or five student researchers, going in and out at all hours of the night. They saw us as these unwashed hippie kids, loud adolescents — how could they possibly do research?"

"We occupied the entire basement, too," says Ed, "dozens of desks, cheek-to-jowl. What really drove the Applied Math faculty crazy is that we were constantly running from the basement to the third floor. We had weekly project meetings in Andy's office, lined with bookshelves and filing cabinets surrounding the desks, where several dozen students would cram in, with no room to breathe."

"The schleps, as we called them," Andy continues, "were a group of more than a dozen undergraduates apprenticing in the group who contributed in every capacity, from getting lunch to reading research papers and explaining them to me to see if they were usable in class. They worked with a few Master's and PhD students, including the late Charles Strauss, Dan Bergeron, and Jim Michener, among others. The bullpen was noisily chaotic, but we were young, and kids have powers of concentration that adults don't. The best part was the selective eavesdropping and peripheral conversations, learning by accident from the people around you. My graphics group still works that way: we strongly encourage everyone to be in the graphics lab together multiple nights per week."

> "...**ANDY ASKED US TO FIGURE OUT HOW TO DO THINGS THAT HADN'T BEEN DONE BEFORE.** IT WAS THE FIRST TIME THAT SOMEONE HAD TREATED ME AS AN INTELLECTUAL PEER AND SHOWED CONFIDENCE THAT I COULD DO THE TASKS THAT ADULTS COULD DO."

"Resulting in at least five geek-geek marriages," notes Bob Munck, crediting the fact that women were fully equal contributors in Andy's group from the beginning.

These were the days in which the IBM /360 Model 50, which started with 256KB of memory and no disks and was upgraded to 512KB and a disk array, served the entire university. Normally, users keypunched their programs on decks of "IBM cards" and submitted jobs that were processed in batches, many hours later. Andy's group, doing graphics research on their IBM 2250 display (courtesy of an IBM research grant), were allowed small chunks of time during third shift to debug their programs, where an occasional crash that brought down the mainframe was reluctantly tolerated by the operators.

Stories of how Andy and company were at times dilatory with food and candy wrapper disposal, how they allowed dogs (and therefore, without putting too fine a point on it, the things dogs do) into the machine room, and how they bought far more Girl Scout cookies than were strictly necessary from "Big Grace," the head operator, are better left for *Celebrate With Andy*.

At the time, these quarter-of-a-million-dollar displays (in 1967 dollars: close to two million in today's money) were rare indeed, and letting undergraduates have access to them was even rarer. With Brown's acquisition of the 360/67, Andy's group became one of the earliest users of virtual memory and virtual machine-based time-sharing. "Among the many firsts," Andy explains, "Bob Munck and other students built time-sharing systems to run in a partition of the OS on the 360/50. Even before his graduation, Bob took the highly unusual step of teaching portions of my courses, on assembly language and other systems topics."

"Steve Carmody was another student in my first course in 1965, and is still associated with CIS at Brown. He was a leader in the group project to design and implement the first hypertext system on commercial equipment in 1967, the Hypertext Editing System (HES). HES was co-designed with Ted Nelson, coiner of the term 'hypertext'. HES was followed by FRESS (File Retrieval and Editing System), which was an active project for more than a decade, starting in 1968. Many undergraduates contributed to its design and implementation, including the late Bob Wallace, who was one of the seven original founders of Microsoft and the inventor of shareware with his utility, PC-Write."

As part of the LSD (Language for Systems Development) project to define a systems programming language and create an optimizing compiler for it, led by Dan Bergeron as a PhD student, Andy recalls the thrill of having exclusive access to some highly sought-after IBM software. "We were using a proprietary systems dialect of the standard language, PL/I, called PL/S," he says. "It was never used by anyone else outside the company, and even years later, I'd get calls from people within IBM, wondering if I could tell them about this mysterious language that they'd heard about but weren't able to get a hold of."

"We were also among the very first to do simple distributed computing by attaching graphics mini-computers to a mainframe. The late George Stabler and Rick Harrington," Andy adds, "a PhD student and undergraduate, respectively, designed, implemented, and published the first remote procedure call (RPC) protocol to allow code modules on the graphics satellite and code modules on the mainframe to call each other, and even to let code migrate to do load balancing from one to the other, at least a decade before other organizations reinvented the idea of RPC. To make our microprogrammed multiprocessor graphics satellite even more real-time, undergraduate Hal Webber designed and built the first high-performance, microprogrammable 3D and 4D homogeneous coordinate transformation engine, SIMALE, now part of our

Andy van Dam and Brown CS faculty members at the 2013 Commencement

Computer Museum. PhD student Jack Stankovic, who became the Department Chair at UVA, and I ran the first workshops on distributed computing in the 1970's."

"The whole idea about being a research assistant," says Ed Lazowska, "was that Andy asked us to figure out how to do things that hadn't been done before. It was the first time that someone had treated me as an intellectual peer and showed confidence that I could do the tasks that adults could do. The whole group was remarkable, and Andy and Charles had an extraordinary impact on me. They totally captured my imagination."

Even the briefest look at Strauss's research gives a powerful sense of the time. For the first time, his work with a light pen and specially-designed stereoscope that fused left and right images on a split screen allowed the user to navigate a live, 3D stereo representation of the layout of pipes in an oil refinery, helping identify potential interference between pipes. For the computer user of today, the world in which mainframes rented for tens of thousands of dollars per month is scarcely thinkable. Looking that many decades into the past, we might be impressed to find graphics of any kind, even 2D. Yet in this case, 2D wasn't sufficient, and neither was static 3D: Brown had to pioneer not just 3D graphics but interactive 3D stereo motion graphics to provide the functionality required. Working with Professor Tom Banchoff of the Math Department, Charles was the first to provide real-time manipulation and visualization of Möbius strips and 4D geometry: hypercubes and hyper tori. "Banchoff-Straus Productions" continued for decades and produced impactful movies of manipulations of 4D geometry, which were greatly aided by Hal Webber's SIMALE.

"Up until this point, computers were used almost entirely for crunching numbers, and computers with graphics were for oil companies and car and airplane manufacturers," says Ed, whose Brown independent concentration was titled "Non-Numerical Computer Science." "With HES and FRESS, we were working with text! Not just text, but WYSIWYG hypertext. It wasn't until that point," says Ed, "that you could actually put the word 'personal' in front of the word 'computer,' although our PC was a multi-million dollar mainframe. That's all Andy."

Andy shrugs. "We were just fearless, we had ambitious ideas, didn't really know what was possible and what was not. I had all those smart and highly motivated kids available, so we took wild, crazy ideas and ran with them."

CREATIVE EXPRESSION

What's the common link between undergraduate teaching assistants and undergraduate researchers? "Creating knowledge," says Ed, "not absorbing knowledge. Creativity. Teaching and research both need this in spades."

Janete Perez '06, who will lead the third ("Machine Age") panel at *Celebrate With Andy*, says, "I wanted to be a UTA like high schoolers want to be on the varsity football team...To add to a class, make it more fun, be part of it all...Andy finds the kids that are really excited, not just the straight-A students. He teaches you to work hard and be disciplined, but really to be creative."

Interestingly, van Dam's thoughts move in a similar line when asked about the theme of his life's work: "From the time I saw Sutherland's mind-blowing Sketchpad movie in '64, I've loved human-computer interaction and the visual; I really value creative expression in various media."

"Watching the Sketchpad movie," he says, "was another random event that changed my life forever. At the time, computing was done by entering programs and data via punch cards or teletype tape. Programs were run in batches and dealt with numeric data. Sutherland showed the world interactivity, humans working with computers in real-time, and he showed us communicating through drawing and manipulating images directly. It was beyond revolutionary, and like the other random events, it ended up completely determining my career. When advisees come to me obsessed with making a commitment to one research area, I tell them to relax: 'You're going to experience ideas that'll change your point of view. Be open, experiment, try different things. You'll change your mind a half-dozen times.' It was true then and it's a hundred times more true now."

But back then or now, what could be a taller order than trying to foster creativity? After hundreds of thousands of years of human history, our understanding of our creative powers is still incomplete. But let's try. Ed shares a visual from the height of the late 60's hippie era that we'll return to later: driving in a Volkswagen bus in mid-winter to northern Virginia, where the group programmed a special version of FRESS for a 3-lettered federal agency while locked in a Faraday cage and monitored by armed guards when they went to the bathroom. "There was no working heater in the bus (of course)," adds Steve Carmody, "so for the entire trip people took turns sitting atop a multi-platter disk, trying to keep it warmer than the frigid air inside the bus."

Now let's try to press Andy again for the secret of bringing out

people's creativity. Asked for heroes of the recent past, he divides them into those outside his field (Einstein, Feynman, Gandhi, King, Mandela) and those inside: Engelbart, Turing, von Neumann, Maurice Wilkes. "Douglas Engelbart was just amazing, but he unfortunately never had the direct impact he should have had...he had trouble explaining his vision, and sadly is only remembered for inventing the mouse, probably the least important of his huge number of inventions in the oNLine System, NLS, from which so many of our modern ideas of word- and idea-processors derive."

Hearing that, anyone who has known van Dam for five minutes is going to think the same thing: *Andy doesn't have a problem explaining or sharing his vision*. Whether it was inspiring Janete and her peer UTAs to create elaborate skits for CS15 class with classically-trained musicians playing instruments, or getting a bunch of tie-dyed rebels to bring peace and love into the fortress of unsmiling agents, Andy van Dam fosters creativity through personal connection. "Students relate to him," Janete says. "More than fifty years younger, they relate to him because he relates to who *they* are."

"Andy believes in the power of young students," adds Ed. "He taught me that impact and excellence are a multidimensional quantity...we can't hire or admit people or motivate them to do great work through just one lens."

When we ask Andy about a common theme for both undergraduate teaching assistants and researchers, there's a long pause. "The idea that you can do serious work before the PhD is almost unique to CS," he says. "We did it fifty years ago, and it's true to a fare-thee-well today...it's about skilled and creative analysis and synthesis; I try to create a productive, challenging but nurturing environment for creatives to make things that are, to use the Jobs phrase, *insanely* great."

RESPONSIBILITY, THEN AND NOW

Norm Meyrowitz '81, who will lead the second ("Iron Age") panel at *Celebrate With Andy*, also believes that giving responsibility to young students was (and is) key. "We were seventeen, eighteen, nineteen, creating all the assignments for an entire class. I was a junior, writing a windows manager program, a twenty-year-old with other twenty-year-olds presenting our research to the NSF."

Did this seem strange at the time? "It just felt like something we were supposed to do!" Norm replies. "Remember, the only PC then was the Apple II: there were no mice, no graphics, no hypertext in general use. There were thousands of areas that nobody had started researching yet, so it was exciting. So Andy, Bill Shipp [then Vice-Provost of Computing and a professor of biology], and I — at the ripe old age of 23! — raised 17 million dollars to put hundreds of graphical workstations on campus. The workstation effort led to the development of the Intermedia hypermedia system —which looked like the Web and worked on a LAN in 1985 — by me along with many of Andy's former students. Andy gave us incredible responsibility as undergrads, and that bred confidence in future endeavors."

Their confidence was clearly justified: the third extant HTML message ever created, by Tim Berners-Lee for his own research team, was about Intermedia.

Responsibility and confidence are both in full view at a January, 2015 meeting of Andy's group in the CIT Library. Students and researchers sit at a long table with their laptops, tablets, and smartphones; their mentor is leaning back in a chair, dressed in familiar sweater-over-the-shoulders style with arms crossed. His laptop (a ThinkPad touch tablet) is closed, and his smartphone only emerges for a momentary calendar check.

"The batch inputter is going pretty well," says a student.

Andy's eyes narrow a little as he grins. "Did I hear 'pretty well' or 'very well' in there?"

"We're working on the user interface, but we haven't caught the edge cases yet. We'll be done by end of day, then test."

"No more guesswork," says Andy on another feature. "We may have to take over these transactions ourselves."

The atmosphere in the room is immediately recognizable to anyone who has worked in a production environment, in the technology sector, or in any setting where efficiency matters. The students are obstacle-oriented, focused, going back and forth seamlessly. Andy lets them converse, answering each other's questions and asking for clarification when necessary.

The sophistication of the students could be envied by professionals twice their age, and it's mirrored in the vocabulary that van Dam uses in his comments: *bona fides, rubric, interregnum, kibbitz*. Later, he'll credit this to "growing up surrounded by people who use language well" and not being a native speaker of English, but the fact remains: this is the way that someone addresses responsible peers, not children. For the hearer, confidence follows naturally.

After an impromptu test of a new feature on an Android tablet works better than expected, the table explodes in cheers: "Yay!... Wow!...Show that again!"

"See you next week," Andy says at the end. "Same bat time, same bat station."

GETTING IT DONE

"Fifty years later," Ed says, "every generation tells the same stories."

"Andy always said that we're here to make the future happen," Norm adds. "Research is a byproduct of having a vision of the future and sharing it through teaching, instilling it in generation after generation. Research is just those people making the vision happen, getting it done...As teaching assistants or researchers, everyone from first-years to PhD students, Andy had us think of ourselves as a collaborative troupe spanning the generations. Every day, we put on a show and did our best. After you leave Brown, the troupe still exists for you in the community, the camaraderie."

Celebrate With Andy is only one night, but it carries a thank-you that doesn't end to Andy and everybody else for our past half-century. The troupe goes on, making the future happen.

Google's SVP Of Advertising And Commerce, Sridhar Ramaswamy PhD '95, Inaugurates IT Leaders Lecture Series

BY JESSE C. POLHEMUS

As committed and motivated architects of ideas, Brown CS alumni contribute in the widest scope possible to science, learning, culture, and their community. Some make their careers in academia, and others in industry and research, but a few are so independent in their thought and innovative in their accomplishments that their work serves as a touchstone and a landmark for computer scientists of any kind.

Sridhar Ramaswamy PhD '95 is one of these.

An honored guest, he returned to Brown in September to deliver a lecture ("F1: A Distributed Database That Scales") that inaugurated Brown Computer Science's new Information Technology Leaders Lecture Series at a time of exciting growth for the field, the university, and the department.

WILDLY DIFFERENT

Arriving at Brown CS in the early 1990's, Sridhar found an environment that was "wildly different" from his previous schooling at Indian Institute of Technology (IIT) Madras, where the approach to learning was highly structured: "Brown offered a number of areas that I was interested in at the time, like databases and graphics, and the enormous amount of intellectual freedom to do what you wanted."

Like many others, he gladly seized the many opportunities of the open curriculum. "I used it," he says, "to learn many wonderful things. I took lots and lots of courses on literature and music. Brown was amazing in that respect. It really opened the rest of the world to me, things that I didn't get from a super-technical education."

> **"BROWN WAS AMAZING IN THAT RESPECT. IT REALLY OPENED THE REST OF THE WORLD TO ME**, THINGS THAT I DIDN'T GET FROM A SUPER-TECHNICAL EDUCATION."

Sridhar's observations about the size of an earlier Brown CS ("It was small at the time, about fifteen professors. Whatever area you wanted to study, you had one choice of advisor.") anticipate the growth that occurred in subsequent years as the Department of Computer Science doubled the size of its faculty. Small or not, Sridhar remembers the years fondly, even recalling the course number of a legendary class: "I loved Stan Zdonik and Tom Doeppner, how open they were. You could talk to any professor, any of the grad students. It was quite cool. I still remember CS 169!"

THRIVING MADNESS

A single sentence from a letter that Sridhar sent to *Conduit* in 1999 nicely frames the two sides of the career that immediately followed his graduation: "I am leaving the comfortable and laid-back environment of Bell Labs for the thriving madness of Silicon Valley."

The seeds of this desire for "thriving madness" were sown with his early research work: "At Brown, I discovered all these amazing problems to be solved, and wonderful, inspiring people like Paris Kanellakis, who was my advisor. That desire to solve problems built on itself and kept growing. I'm a bit of a stubborn person; I didn't want to start something and leave it half done."

"Part of Paris's advice to me," Sridhar says, "was that I needed to become more of a systems person, which was what I had done as an undergraduate at IIT with things like graphics device drivers. I started doing more database systems research, first at Bellcore, then Bell Labs." This blend of theory and practice continued with Ramaswamy's work on a revolutionary system called AQUA (Approximate QUery Answering)

Roberto Tamassia, Sridhar Ramaswamy, and attendees of the inaugural lecture

that was aimed at providing provable guarantees for fast answers on massive datasets. "It was a collaboration with a wonderful group of people," he remembers.

But this was the Internet Age. As Sridhar explains, "My thinking was that I wanted to change direction, and if I was really going to do so, I had to make a drastic change. I decided that I'd head out to the Valley to try my hand at software engineering." After four years as the Director of Engineering at a startup called E.piphany, a slightly larger company beckoned in 2003. It was Google. "Well, it was obviously a place that was full of opportunities, and I thought it was humongous when I first joined," he laughs. "I think there were all of three hundred engineers!"

PLANET-SCALE

Sridhar pauses for a moment, mentally reviewing the past decade, which has brought him to the position of Google's Senior Vice President of Advertising and Commerce, where he oversees the design, innovation, and engineering of the company's advertising and commerce products. Leader of the engineering teams that helped define the vision and direction of AdWords, he now also leads Google's efforts in Display advertising, Analytics, Shopping, and Payments. Additionally, Sridhar is part of a group of senior executives who report directly to CEO Larry Page. "Gosh, I've had a wonderful time at Google."

At length, he explains that much of his success comes from "being part of an amazing team" in an equally incredible environment. "None of this," he insists, "is mine alone, but one thing I'm very proud of is the Advertising teams' emphasis on building amazing infrastructure. We believe that creative systems engineering goes a long way toward solving problems that are otherwise considered unsolvable."

Interestingly for someone who transitioned from researcher to software engineer, some of Ramaswamy's favorite achievements are process-related, systems-oriented, even theoretical. "We've developed an entire science," he says, "around how we think about experiments and how we deploy them. All the changes on the site, big or small, can have a huge impact in areas such as monetization. To be on a team that helped develop a whole framework to ask how one considers change, how one develops experiments and conducts them in massive numbers while making sure they don't interact with each other, that's a signature accomplishment for me. It's a cool thing."

Sridhar also mentions his love of auctions, saying that he's been privileged to be a part of the "considerable amount of innovation" in this area. One of the greatest challenges for Google or any of its competitors, he says, is striking a balance between the long-term value of auctions and their current value while trying to optimize for the long term.

"PEOPLE DON'T EVEN REALIZE WHAT WE CAN DO WITH SIMPLE MODELS AND MASSIVE AMOUNTS OF DATA..."

But the accomplishment that Ramaswamy actually mentions first is the one that served as the subject of his inaugural Information Technology Leaders lecture. F1 (the name is derived from the nomenclature in Mendel's famous genetic experiments, not the type of racecar) is a hybrid between an object store and a relational database. "We wanted a system," Sridhar says, "that could be what we call planet-scale but also answer very difficult queries for the purpose of, say, building reports. We wanted both things, and we did it. It's in in production now. The conventional wisdom was that you could build scalable object stores or relational databases, but not both together."

Circling backward in the conversation to give a precise definition of what "planet-scale" might refer to, there's a soft but unmistakable satisfaction in his voice. "We mean a system that will keep working beautifully even if California becomes an island."

A VERY DIFFERENT FUTURE

"There is a world we're already living in that I think will become even bigger and more important." Asked about Brown and the digital society of the future, Sridhar's answer is immediate. "That's the world of cloud computing and amazing devices and interfaces."

He begins with a bit of history: "When the first Internet companies started, people were literally running services from their garages. Then computers got better, people put them into racks, but there was always this sense that you had to own big machines, big data centers. In my mind, what's been remarkable about the last few years, as evinced by many companies like Netflix and Dropbox, is that cloud computing is such a commodity and can run at such a vast scale."

The opportunities for the next wave of computer scientists and the next generation in general are omnipresent. "Four people with exactly four laptops can build global-scale applications," says Sridhar. "That was unimaginable ten years ago. Things get more and more refined, and people have mobile phones in their hands, these wonderful interfaces. Behind them, a back-end is running at an incredible scale. It's pretty amazing. People don't quite appreciate it, but it's breathtaking."

He's also very excited about the connected Internet (webcams, thermostats, and even house locks that can be operated remotely from a phone) and the "very different future" it foretells. On a more narrow technical front, advances in machine learning and artificial intelligence have tremendous untapped potential.

"People don't even realize," says Sridhar, "what we can do with simple models and massive amounts of data. You might think that spelling correction uses fancy logic about sentence structure or phonemes, but it's purely a statistical algorithm based on a dataset of errors and corrections. The whole field of deep learning is young, and it'll solve problems that look quite beyond our capacity right now."

UNCONVENTIONAL WISDOM

A statistical algorithm to analyze Sridhar Ramaswamy in conversation would provide equally interesting insights. Three times in a half-hour, he's used the term "conventional wisdom" to point out the conclusions that many people readily jump to, the dead end offered by cynicism, a failure of vision. Inspired by mentors such as Paris Kanellakis, Tom Doeppner, and Stan Zdonik, drawn to collaboration and to lead teams of people that he respects so highly, one challenge has echoed throughout Sridhar's responses. "It's about solving," as he puts it, "the unsolvable."

It's a system that can operate if California becomes an island.

It's four people with four computers making global-scale applications.

It's a world in which anything is possible.

"Computer science is what's really exciting," says Sridhar. "I say to my children, you can be a physicist. It's an honorable profession. But every smart person for the past five hundred years has been trying to solve the hardest problems of physics. What excites me is that computing itself is very young. It's only begun to touch numerous aspects of our life. I can point kids to so many different areas and tell them that there are thousands of possible futures there, just waiting!"

At a time when the field's prospects and Brown University's have seldom looked brighter, Brown CS thanks Sridhar Ramaswamy for his inaugural lecture, his unconventional wisdom, and the opportunities that those futures offer.

You can watch a recording of Sridhar's lecture at http://cs.brown.edu/events/talks/ramaswamy.html.

Delphix CTO Adam Leventhal '01 Inaugurates Life After Brown Lecture Series

Adam Leventhal at his inaugural lecture

BY JESSE C. POLHEMUS

Investigations into that hazy realm known as "life after Brown" continue, with Adam Leventhal '01 sending back the latest report from the field. He's the Chief Technology Officer of Delphix, a company that builds products that virtualize data, making it faster and easier to build and test applications, execute business reports, modernize systems, and migrate between data centers.

Adam returned to Brown CS as an honored guest on November 5, 2014 to deliver a lecture to our undergraduates on what he describes as the lessons learned of entrepreneurship, the undervalued aspects of a computer science education, and making the educated choices that can help build a successful life after graduation. For anyone unable to attend the event, we asked Adam a few questions to trace some of the outlines of his unique perspective:

BROWN CS: I WAS INTERESTED IN THE "HOLISTIC ENGINEER" CONCEPT THAT YOU MENTION ON YOUR BLOG. COULD YOU TELL US MORE ABOUT THAT?

"Sure. This is the idea that an engineer needs to consider the whole system, the whole body of work that makes a product successful. You can see examples of this in classes like CS 32, where you're building software, but the who, what, and why are important. Another source is the UTA program, where you're taking ownership of what you're teaching at an early stage, thinking about pedagogy. Brown as a whole is about owning your education, and that's part of what I mean about the holistic engineer: putting broad responsibility on the individual."

BROWN CS: YOU ALSO TALK ABOUT THE IMPORTANCE OF COMPANIES HIRING GREAT PEOPLE, GREAT ENGINEERS. HOW CAN OUR STUDENTS WORK TOWARD BECOMING THOSE PEOPLE?

"They're probably already doing this, formally and informally. I think the biggest thing is to wrap your head around the way that other people understand. Other people don't think the way you do, and being able to explain sophisticated concepts is a huge skill. I also want to stress the importance of finding the right time and the right place when you're first going out into the workplace. You have options, so find your moment and take a chance. You should be excited to work with your future colleagues, and they should be excited to work with you."

BROWN CS: FINALLY, HOW ARE THINGS DIFFERENT NOW THAN WHEN YOU STARTED LIFE AFTER BROWN, AND WHAT DOES THAT TELL YOU ABOUT THE FUTURE FOR OUR GRADUATES?

"This is a great question. The key thing for me is that the barrier of entry for startups and independents is so much lower. When I graduated, the Internet was the 'go west, young man' of my generation. We remember that time as this exciting bubble, but the way you'd build everything now is easier and cheaper: databases, colocation, Linux, open source software. Developers can easily buy computing time and storage, and collaborate through resources like GitHub. Even things like recruiting are easier due to social networking advancements. We really stand on the shoulders of giants, but not in a passive way. We can get right into their work, extend it, and get new benefits from it."

Big Grammar

BY PROFESSOR EUGENE CHARNIAK

When I was in grammar school one assignment we were given was sentence diagraming. We wrote down a sentence like "Alice fed the dog" and underlined it. Then we were to draw a vertical line between the subject ("alice") and the predicate "fed the dog" followed by a half line between the verb ("fed") and the direct object "the dog."

I have no memory if we were told the point of this exercise. In retrospect I think that it was suppose to improve our grammar. In fact, I (and everyone else) found it completely useless. Nevertheless, I now find myself a world expert in syntactic parsing, getting a computer to do this sort of thing, but writ large — in effect diagramming every sentence in today's New York Times.

This is not useless for a computer because computers do not (yet) understand English, and the point of syntax is not to improve your grammar, but to understand sentences in the first place. Every day we have conversations with others and they use sentences we never heard before. If they are using a language we know we understand them because we are able to build up the meaning of the entire (novel) sentence from the meanings of the pieces. Syntax tells us what these pieces are, and in what order they should be combined. So we first put "the" and "dog" together to get the meaning of "the dog" (presumably we are referring to some animal Alice knows) and then combine the meaning of "the dog" with that of "fed," etc. The sentence may be novel, the words from which it is composed are not. If a computer is to do this same thing it too must understand syntax, and be able to "parse" a sentence — figure out that it should first combine, say, "the" and "dog," and not "fed" and "the."

The standard approach to this is to first write down a set of grammar rules that specify the way words combine, and then use well-known algorithms for working out how they apply to a particular sentence. So for about 40 years people endeavored to write down a grammar for English, and failed. The first thing they found was that English (and all other natural languages) can be pretty free-wheeling, and when they applied their grammar to real-world sentences there were always new things they had not considered. Just as bad, when they expanded the grammar to include these less used constructions, they found that the sentence had not just one analysis, but thousands trending to millions.

Today there are several syntactic parses available on the web that can, in fact, assign a pretty accurate parse to every sentence in today's Times, and if you are translating English to Chinese, Google uses syntactic parsers to help. What changed?

Modern computational linguistics (of which syntactic parsing is a part) is dominated by machine learning techniques, and machine learning is dominated by probabilistic and statistical techniques. So the first thing that changed is that we no longer expect to find a single answer to a question, rather we ask, what is the most probable parse. Furthermore in many situations there are ways to find this without enumerating all of the possibilities first. Most can be rejected without even spelling them out.

Secondly, even if we cannot write down a complete grammar for English, if you give trained linguists a sentence, and ask for the correct parse for that one sentence they have no problem producing it. So rather than try to write down a succinct grammar, we simple write down the correct parse for tens of thousands of sentences and then use machine learning to produce a grammar. Of course, the result is not a succinct grammar with, say, hundreds of rules, but rather a huge (or at least, very large) grammar, with hundreds of thousands. In other words, twenty years ago when this approach took hold, computational linguistics had already entered the modern world of "big data."

So there is a larger moral to this story. The phrase "big data" is everywhere these days, and many of us, use to distrusting things that look like the latest fad, may assume that it too will head off to the dustbin of academia. I am not one of these people. We in computational linguistics were not trying to be trendy. We simply had a problem and we were forced into the modern era. Over and over we are finding that problems that previously fought us to a standstill are now succumbing to the combination of machine learning, and the data to feed its techniques.

Faculty Notes

SORIN ISTRAIL

Sorin gave two invited lectures; started teaching a new graduate course, *Advanced Algorithms in Computational Biology*; received a new grant on computational genomics of autism as co-PI and professor Eric Morrow MD, PhD of Brown Medical School as PI; published two conference papers in RECOMB and Pacific Symposium on Biocomputing; had a working visit with his collaborator and mentor of 15 years, the leading experimental molecular biologist of the area of developmental gene regulatory networks, professor Eric Davidson of California Institute of Technology; was an invited participant at the U.C. Berkeley Simons Institute for Theoretical Computer Science "Algorithmic Spectral Graph Theory" Program; and together with Brown colleagues worked and provided leadership and coordination for the computer science component of the interdepartmental T32 "Transdisciplinary Predoctoral Training Program in HIV Data Science" (PI Joe Hogan) that was submitted to NIH in J anuary, 2015.

Derek Aguiar, his second PhD student at Brown, defended his PhD thesis in May 2014. Sorin introduced Derek at his thesis defense with these words: "...Derek has been, in my view, the quintessential all-around strong PhD student. There is something special about him, a quiet state of balance: I call it a 'state of Derek.' Unpretentious, modest, quiet, very generous with his time to help others, totally absent at self-promotion, his main focus has been always on his algorithms, papers and software...Derek is like his native state of Rhode Island: from a distance it appears small, but it is very big on hope." Derek is now a postdoctoral student in the Department of Computer Science at Princeton University.

Henri Luchian (Professor and Vice-President for International Affairs, University "Al. I. Cuza" Iasi), Vasile Isan (Professor and President, University "Al. I. Cuza" Iasi), John Conway (John von Neumann Professor, Princeton University) and Sorin Istrail (Julie Nguyen Brown Professor of Computational and Mathematical Sciences and Professor of Computer Science, Brown University)

Sorin Istrail and Derek Aguiar

John Conway, the John von Neumann Professor at Princeton, was accompanied by Sorin when he traveled to Iasi, Romania in June, 2014. He was given the Doctor Honoris Causa award from University "Al. I. Cuza" Iasi, Romania by the President of the University, Professor Vasile Isan; Sorin was honored to be part of the committee of the award. Professor Conway also delivered the keynote lecture at the opening conference of the "Grigore Moisil" Institute for Computer Science and Applications.

Sorin gave a "Grigore Moisil" Lecture entitled "Computer Science Through Urn Games: A Unified Framework for a Hierarchy of Solvable and Unsolvable Problems" at the "Grigore Moisil" Institute conference. His lecture and associated paper use a silly game of Dijkstra and its generalizations (see his article in *Conduit's* Fall/Winter 2008 issue, "Criticizing Professor Dijskstra Considered Harmless") and is similar in its popularizing spirit to Alan Turing's last published paper, "Solvable and Unsolvable Problems." He also gave a keynote lecture at COCOON 2014 (the 20th International Computing and Combinatorics Conference), "On Humans, Plants and Disease: Algorithmic Strategies for Haplotype Assembly Problems."

The "von Neumann professors cluster" at Brown, chaired by Sorin, together with the Office of the President, are organizing a symposium in May, 2015: "Brown University: The Next 250 Years." A most distinguished list of speakers, including 3 Nobel Laureates, will each give a von Neumann Lecture on their respective fields: computer science, economics, physics, and mathematics.

MICHAEL LITTMAN

After a year of being a conference organizer (ICML 2013, AAAI 2013), Michael was pleased to make a transition to keynote speaker (UAI 2014, ICAPS 2014, NASEC 2014, IJCAI 2015) and distinguished lecturer (Virginia Tech) this year.

BARBARA MEIER

We sent our first-born off to college this year. Helping him navigate the cascade of choices he is facing, I am reminded what a great advising program we have at Brown. As you probably know, all incoming first-year students get a faculty advisor and a peer advisor. Students meet with their advisors at least five times their first year, and continue this relationship throughout their entire Brown career, switching advisors as their needs change. Brown students are fortunate to have this program in place, but as a first-year, sophomore, and concentration advisor, I consider myself equally lucky. It is a privilege to get to know these talented and thoughtful folks beyond the classroom and to follow them through the process of settling into Brown. Their candid opinions about courses they are shopping encourage me to reflect on my own teaching. Indeed, their dreams and ambitions are inspiring, and the advice doesn't always flow in only one direction! The reality of having my own kid out in the world has reminded me that each advisee is someone else's kid who worked really hard to get to Brown and I need to do my best for them.

JOHN SAVAGE

John Savage continues to be active in cybersecurity policy. Last fall he was appointed a Faculty Fellow at the EastWest Institute in this area. Last June he was a discussion leader in two areas at the EastWest Institute's working roundtable on *Pathways to Improve Global Cooperation in Cyberspace*. The meeting brought 50 thought leaders on cyber policy from 13 countries together to prepare for the much larger (more 250 attendees) December EWI Cyberspace Cooperation Summit in Berlin hosted by the German Foreign Ministry. John presented a paper at this meeting written with Bruce McConnell entitled *Exploring Multi-Stakeholder Internet Governance* that has been published by EWI. This paper also served as the basis for a presentation as a panelist at the AAAS 2015 Annual Meeting in February. Last July John gave two other talks both in the State Department. The first, invited by the Bureau of Intelligence and Research and the National Intelligence Council, dealt with Internet governance. The second was as a panelist at the 10th anniversary celebration of the Jefferson Science Fellows Program and concerned the course *Cybersecurity and International Relations* that he introduced to expand his knowledge of this area acquired as a Jefferson Science Fellow in the State Department.

Last fall, although he was on sabbatical leave at Brown, in October he served on an NSF site visit review committee for an Engineering Research Center at Stanford University in the area of nanotechnology and in November served on a NEASC Accreditation Committee for the University of Bridgeport.

In the spring semester he was a member of the departmental faculty search committee and served as Secretary of the Faculty Forum. In addition he taught CSCI 1800 *Cybersecurity and International Relations* to 80 students and CSCI 1951E *Computer Systems Security: Principles and Practices* to 73 students. In November 2014 he was awarded the patent *Method Providing Radial Addressing of Nanowires* with co-authors.

John Savage and his Brown Secure team: Celina Stewart, Luke Camery, Sam Brebner, and Jared Schober

Department Awards and Honors

UGUR CETINTEMEL WINS IEEE DATA ENGINEERING (ICDE) 2015 INFLUENTIAL PAPER AWARD

EUGENE CHARNIAK WINS 2015 AAAI CLASSIC PAPER AWARD

THOMAS DICKERSON AND CEMETECH WIN TWO AWARDS AT WORLD MAKER FAIRE 2014

PEDRO FELZENSZWALB WINS ACM'S GRACE MURRAY HOPPER AWARD

RODRIGO FONSECA WINS NSF CAREER AWARD

AARON GOKASLAN WINS HACKPRINCETON BEST IOS APP AWARD

JAMES HAYS RECEIVES SLOAN RESEARCH FELLOWSHIP

MAURICE HERLIHY ELECTED NATIONAL ACADEMY OF INVENTORS FELLOW

ACM HONORS MAURICE HERLIHY ON HIS 60TH BIRTHDAY

HERLIHY'S DISTRIBUTED COMPUTING THROUGH COMBINATORIAL TOPOLOGY NAMED A NOTABLE BOOK

SORIN ISTRAIL RECEIVES NSF GRANT FOR HAPLOTYPE RECONSTRUCTION ALGORITHMS

PHILIP KLEIN WINS RADCLIFFE INSTITUTE FELLOWSHIP

TIM KRASKA WINS AIR FORCE OFFICE OF SCIENTIFIC RESEARCH YOUNG INVESTIGATOR AWARD

MOLLY LONG AND LAYLA OESPER WIN GOOGLE ANITA BORG MEMORIAL SCHOLARSHIP

DANAË METAXA-KAKAVOULI SELECTED AS RUNNER-UP FOR CRA AWARD

LAYLA OESPER WINS ISMB WORKSHOP BEST PRESENTATION AWARD

JOHN SAVAGE APPOINTED AN EASTWEST INSTITUTE PROFESSORIAL FELLOW

JOHN SAVAGE CHOSEN FOR "DIGITAL LIFE IN 2025" SURVEY

STEFANIE TELLEX WINS BEST PAPER AWARD

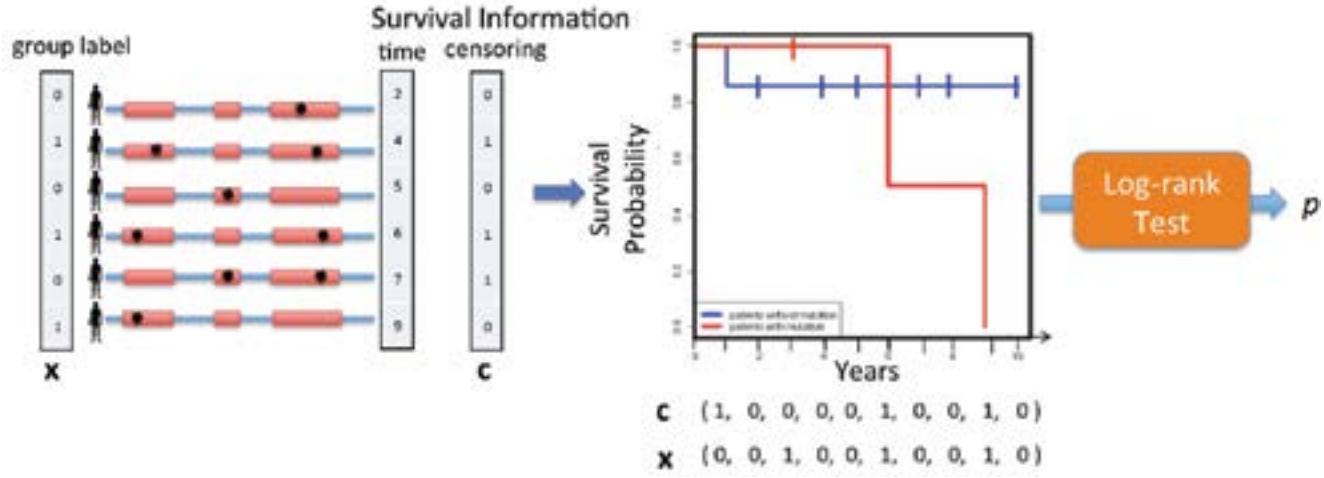
SIX BROWN CS FACULTY MEMBERS WIN OVPR SEED AWARDS

BROWN CS TAKES FIRST AND NINTH PLACE AT CYBERSEED CYBERSECURITY COMPETITION

For full versions of all stories above, please visit www.cs.brown.edu, where they're featured at either CS News or CS Blog.

Opening The Black Box: A Novel Algorithm Reduces False Positives In Genomic Testing

BY JESSE C. POLHEMUS



Sometimes, breaking new ground starts with words like these: "Fabio, you must have a bug."

Adjunct Assistant Professor of Computer Science (Research) Fabio Vandin, along with professors Eli Upfal and Ben Raphael and PhD candidate Alexandra Papoutsaki, had set out to correlate gene mutation with survival, one of Fabio, Ben, and Eli's longtime interests. They ended up doing something quite different.

For some context, begin with the fact that clinical trials involve certain populations. In some cases, such as the testing of a drug, the populations are perfectly equal in size, with 50% of the patients given the drug and 50% given a placebo. In genomics, however, the difference in population sizes can vary considerably. For example, for a single instance of a mutation that's being looked for, there could be a hundred instances where it occurs differently or not at all.

"To explain it very simply," Eli says, "we look for correlations between patterns of mutation in the cell's DNA and the disease, with the goal of distinguishing between significant patterns associated with cancer, and random mutations that are the result of the cancer."

One of the key aspects of genomics is identifying mutations that distinguish patients with different survival times following a diagnosis (for example, cancer) or treatment (perhaps a drug regimen). Setting out to correlate gene mutation with survival, Fabio began working with a standard tool known as the log-rank survival test. He was using the standard subroutines, but with one crucial factor: unequal population sizes.

Right away, the results were off. Not only that, they were off by up to seven orders of magnitude, meaning that a huge number of false discoveries were being reported. That was when Eli e-mailed Fabio, suspecting an error in the program. "When the results came back," Fabio says, "That was my reaction as well: it's a bug." Taking Ben's class, he had been drawn to computational biology due to what he considered to be its numerous interesting problems, the enormous potential impact from new discoveries.

But when Upfal ran the test himself, the results were perfectly and strangely identical. "My initial conjecture was wrong," Eli says. "The problem was somewhere else." It turned out that the problem that the log-rank survival test relies on a normal approximation of the true distribution, and in the genomics applications it had been used for circumstances in which the approximation no longer applied. "We demonstrated not that the tool was wrong but that it was used in a regime that was wrong for it."

Next was a phase of extensive research. "We spent many, many weeks getting up to speed on the literature on the biostatistics side," says Alexandra. "We knew it can be hard to convince experts from another discipline...they can be defensive. But between Ben, Eli, and Fabio, we had tremendous experience with cancer biology...We saw that most of the literature contained statistics that had been inspired by medical research, not derived algorithmically."

"I'M PROUD OF THE IMPACT WE MADE BECAUSE IT PLAYS AT THE STRENGTHS OF TWO FIELDS. THE ALGORITHM WAS DESIRABLE FOR US, AND THE APPLICATION WAS USEFUL FOR BIOLOGISTS."

Unexpectedly, but happily, the interdisciplinary aspect became one of the most interesting challenges of the project. Biologists, of course, aren't mathematicians, and they don't always have the expertise to evaluate the accuracy of their statistics. Upfal says, "We were drawn to this. It goes to one of the general problems of our work. In computing, we create programs for people in the experimental sciences, but they're black boxes to them."

They spent a year evaluating the problem, then created a a new algorithm called ExaLT (Exact Log-rank Test, now available on the web at http://compbio.cs.brown.edu/projects/survival/). "It's an approximation algorithm," Eli explains, "but fully analyzed, tight. It's useful and works efficiently. There is non-trivial math in there, which is very satisfying."

"To be useful to biologists," Fabio says, "I like practical algorithms that give guarantees. Otherwise, the results may be only interesting as theory, or they may not reflect the correct answer. When I gave our presentation at RECOMB 2013, I showed the problem with the results from the standard log-rank procedure, and then I demonstrated our method. Everyone in the audience had their heads up. It was wonderful to see the community appreciating our work."

Given that reducing false positives could prevent potentially massive amounts of research time and money from being wasted, the appreciation and the recognition that followed should come as no surprise: the research ("Accurate Computation of Survival Statistics in Genome-wide Studies") won a Best Paper Award. Since then, Alexandra explains, Fabio has been working continuously to get more exposure for their results, culminating in recent publication by *PLOS Computational Biology*.

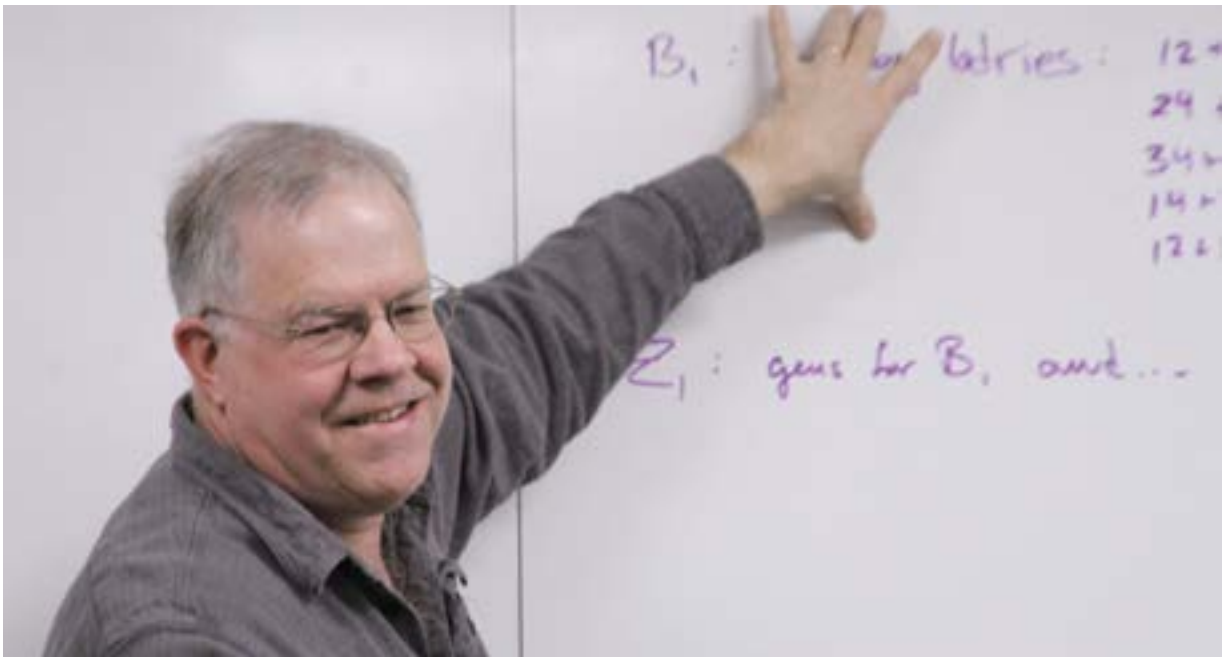
Fabio says, "I really liked working with people with different expertise and different amounts of expertise on this project. Eli has been in academia a long time, Ben has drawn me to computational biology, and together we talk about problems and how to do things better. It has been great to work with Eli and Ben as mentors, and I enjoyed being a mentor for Alexandra on her first project at Brown, watching her understanding and contributions grow."

"I'm proud of the impact we made," adds Alexandra, "because it plays at the strengths of two fields. The algorithm was desirable for us, and the application was useful for biologists. On top of that, we raised their awareness that they need to know more about the computational tools they use so they can apply them properly."

Even if it was just for a moment, biologists saw inside the black box, to the benefit of scientists from both disciplines.

Excellence In Teaching

BY JESSE C. POLHEMUS



John Hughes

Does a higher number of mental health professionals reduce suicide rates?

Are lexical differences correlated with book classification?

Who uses a larger vocabulary, politicians or musicians?

"I like to show off," John "Spike" Hughes says as he heats water in his office for his morning cup of Lipton tea. He's talking (and probably teasing) about his motivation for going into teaching, but the same holds true when he's given a chance to talk about the student projects above. They all owe a debt to a course (CSCI0931: *Introduction to Computation for the Humanities and Social Sciences*) that he co-founded and has been teaching for more than a half-decade.

According to colleagues, students, and Spike himself, CSCI0931 is unique. We'll examine its value through the eyes of former students, focusing on their wide-ranging and surprising work. Along the way, they'll tell us about learning as much from homework as lectures and about a professor who foils helicopter parents, whose office opens for six hours at a stretch when final projects are due and students seek the expertise of someone they describe as insightful, fear-dispelling, exceptional, and insistent upon big ideas.

CSCI0931 began as a joint project with Tom Doeppner, Shriram Krishnamurthi, and Steve Reiss. Spike explains that at the same time that the National Science Foundation was focusing on broadened participation in computer science, "We were saying that computing is happening everywhere at Brown, but few people are being trained in it. They're reinventing old ideas, and not always well. At that time, students couldn't learn algorithms from us without first learning about transistors, so we asked ourselves whether we could change that."

But if a course is open to everyone, who ends up enrolling? "It's hard to generalize," Spike says. "Last semester, we had a remarkable gender mix for a CS course — 82% female — but backgrounds always vary. On the first day, when we have students give their name and concentration, we get fifteen different answers by the time we hit the second row. That's a challenge, because we can't go deep into the subtleties of, say, political science: only a fraction of the students will have the background for that."

The first few weeks of the class begin with spreadsheet work to analyze voting patterns in the United States Senate. "The course moves from spreadsheets to using Python for textual analysis," says Spike. "By using voting as an example, we demonstrate two things about the usefulness of computer science. First, students learn to frame a pattern problem as a computational problem. Second, they see that computing can provide an answer so quickly that they probably have time to evaluate and go back and ask a different question. There's always the possibility of a better thing to ask."

"That's what happened to me," says Madeline DiGiovanni, currently a sophomore. "I wanted to find out whether having more

Excellence In Teaching *continued*

mental health professionals would decrease a country's suicide rate, but it was harder than I'd expected. Not all countries provide this data, and then there were problems with statistical analysis and even the fact that mental health professionals might have a variety of job titles."

"**SPIKE IS SO INVESTED IN PEOPLE DOING THEIR BEST**, AND WHAT MAKES THE COURSE GREAT IS THAT HE GIVES YOU TOOLS."

Madeline's second project (analyzing vocabulary to determine whether individual psychology texts were written before or after Freud) was much more successful, and she credits Spike's pedagogical approach: "He won't let you be afraid, but he also insists that you think big. People should take this course in their first or second year, because he doesn't coddle students or put up with the 'helicopter parent' high-school mentality. He works hands-on with you, but you need to show the initiative, which is wonderful."

Originally taught in rotation by Spike, Tom, and Steve, with Shriram sitting in the rear of the classroom and offering feedback, the course evolved further when the faculty members made the decision to bring in graduate students (Hughes mentions Anna Ritz '08 PhD '12, Jadrian Miles '08 PhD '13, Steven Gomez '11, and Hammurabi Mendes as some of the contributors) who would first audit the course, then instruct it.

"I jumped at the opportunity to step into a wildly popular class," Anna remembers. "It was a great course for helping TAs learn how to teach. I wanted to show students how to form a hypothesis, test it, and get an answer, no matter what their backgrounds were, and we did. Sometimes that meant adjusting on the fly, like when we decided to have a code review and none of us, including me, had ever done one before! But that freedom was very useful."

"CSCI0931 is so open-ended that it's amazing. There should be more courses like this." For her first project, Lee-Sien Kao looked at whether there was a causal link between performing a Google search on a particular country and then traveling to it. (Interestingly, there didn't seem to be.) "Spike is so invested in people doing their best, and what makes the course great is that he gives you tools. I can't imagine how much time he and the TAs put into the assignments, because they always added new elements and went beyond the lectures, so you actually learn from the homework."

Lainie Rowland agrees. "The learning curve trains your brain perfectly. Spike is so responsive, and the support system in the class is really unique and helpful. Brown students want to be on the cutting edge, and the skills that CSCI0931 provides are powerful...in so many areas of study, the analysis and evaluations are similar to the CS approach….For my final project, I wanted people to be able to enter the name of a politician or musician and then see the results of scraping his or her tweets for word length and sentence length. It was very cool to push a button and see the answer pop up in graph form."

"I love these ideas!" says Spike. "Sometimes students come up with things that are completely insane or too trivial, but I'm constantly impressed by the variety and quality of their ideas." When we ask him to anticipate where graduates of CSCI0931 might go next, he starts small: "I'm cautiously optimistic that many of them are much better with spreadsheets, with understanding that we're talking about the relationship between cells, not the data."

But then he warms to the subject: "It's just a powerful thing to be required to describe what you're doing in repeatable terms. If someone doesn't like your results, just give them your code and tell them to prove you wrong. Or if someone looks at the world and says, 'Isn't it obvious that...?,' you can scrape the data and show that the reality might be totally different."

On the subject of things that might have turned out differently, Halie Rando '11 took the class in 2009. Now doing graduate work, she wrote to Spike a few weeks ago. She says, "It was my coding skills (developed through CSCI0931 and subsequent self-study) that got me short-listed for every life sciences PhD position I applied for...I'm aiming for a career in biotech -- but I would very likely have been just another interested woman who didn't end up in a computational field if it weren't for CSCI0931 giving me a push in the right direction."

Today, Halie is researching stress resistance in domesticated silver foxes; Madeline used her newfound skills to analyze academic possibilities for her college-bound siblings. Lainie is planning to attend her first hackathon.

"For me," says Anna, "the most notable thing about the class is the vibrancy that the students bring from their varied backgrounds. In return, as computer scientists, we suddenly realize that we've actually done it: they're thinking differently. We can thank Spike for that."

Barbara Meier

Sitting under her own oil painting of an Irish landscape, the recent winner of the Philip J. Bray Award for Excellence in Undergraduate Teaching in the Physical Sciences has just made an unusual comparison. Teaching beginning animation students, she explains, is no different from teaching beginning readers.

"If we meet students where they are instead of telling them what they're doing wrong," says Barbara Meier, "they'll surprise themselves with the next step." It's an educational assessment of the challenges of artistic creation, and not a surprising one from someone whose structured teaching has been called ultimately practical, a remover of obstacles for students whose redefinition of success has allowed them to learn alongside her and even laugh at themselves along the way.

Teaching was an unexpected choice for Barb after years in California as a visual effects animator, but after the birth of her second child and a cyclical downturn in the movie industry, the glamorous Hollywood career lost its appeal. Random chance (one faculty member's leave and another's sabbatical) opened an opportunity, pragmatism required a common-sense look at her options (career-planning exercises in a book called **Pathfinder** that Meier recommends), and she took Brown CS up on the offer to teach a course. Barb remembers that Andy van Dam's "of course you have to do this" also helped.

"Being new to teaching," she says, "I was freaking out on a daily basis as I looked ahead to each new topic in the syllabus." The core of her solution was to have her class incorporate not just the chronological sequence of industry-style production (modeling, shading, lighting, animation) but also the collaborative critiques common among industry peers.

In this "create-critique-revise" process, Meier explains, students project their work on a screen while the class goes through each person's work individually, randomizing the order each time. There are two critiques, first an in-progress one (not graded) and then a final one, and each time, students analyze their classmates from both a technical perspective ("the too-bright lighting is blowing out the details of the texture and the shadow is too sharp for that time of day") and an artistic one ("the surface really feels like burlap because the threads stick out just the right amount — any more would be the wrong scale").

Marianna Neubauer '12, who took multiple classes and an independent study with Meier, says of the approach, "We followed the industry sequence, but it felt like an art course with critiques in front of the class. I really appreciated the tutorials." Now a graduate student in computer graphics at Stanford, she explains that at times she "feels like an expert" among many frustrated classmates whose previous training was more academic and less hands-on.

Another of Meier's early innovations was something that became almost an unofficial motto: *do your best work*. "It seems obvious," Barb says, "but it sets a high bar, doesn't allow people to drift around, and it isn't about their skill or level of exposure to the software." Of course, this necessitates a follow-up question: if someone's best is the rule, the daily standard, how do you possibly keep students working at that level? There's no hesitation in the response.

"Be enthusiastic!" Meier says. "Be passionate about animation, from Disney and Pixar to shorts at international festivals. It's a super-cool art form: the visual can be anything, and people respond to stories, so it gives you a framework to get them involved and rooting for a character — it's universal. And I just like animation!"

But she admits that enthusiasm in itself isn't enough and that her pedagogy is also represented in the many tutorials she's created, the painstaking design of resources to best help students. "Animation is a new skill when you're starting out," says Barb, "no different from literacy. How could you ever tell a kid that they were doing something wrong if they were trying to read and not succeeding? I want students to be creative, not worry about getting 100 instead of 98. Brown is unique that way. We can set students up to succeed instead of trying to trip them up."

> "TEACHING IS HARDER THAN I THOUGHT IT WOULD BE, BUT **BEING A STUDENT IS HARD, TOO. THEY'RE HUMAN**..."

Paul DiPierro '06, who first studied under Meier in 2004 (he came to Brown with no mathematical or programming background and now works as a 3D production artist), understands that challenge. "It's extremely tough to be someone in her position. Students come in with big expectations, and she sometimes has to tell them that their idea is unfeasible while still encouraging them to achieve big things, point them in a productive direction. It could be such a negative process, so I credit her diplomacy: Barb builds a team of peers who thrive on interacting with each other. People fail less and accomplish more."

As we come to the big questions (why make art, why teach, why do it here), Meier pauses for a long time. "Art is about

Excellence In Teaching *continued*

self-expression, the best way for some people — and I'm one of them — to get their ideas out. Brown attracts kids like that: by the time you get here, you're self-selected for interdisciplinary work, you're not just a brilliant, laser-focused person. I loved working for Hollywood, but now I love being here, mentoring kids who often want to get into the industry themselves. I can tell them what to look for, what their individual challenges will be."

Multiple generations of students have seen the results. Marianna tells the story of a job fair at Stanford where a Pixar recruiter lit up the moment she mentioned undergraduate work at Brown: "Oh, you must know Barb!" Paul has had similar experiences. "I think it's tremendous," he says, "that Brown CS is renowned for the full spectrum of computer graphics, from the mathematical and technical through visualization and animation, the artistic side."

Barb realizes that a student's life can be difficult. "Teaching is harder than I thought it would be," she admits, "but being a student is hard, too. They're human: I can't help seeing them as inherently good. 80 to 90 percent of the reports that students hand in with their assignments have some sort of apology in them because they wanted to do something and didn't have enough expertise yet or ran out of time. But there's no need to apologize! I know how much they have to juggle."

"I'm in the same boat," she claims. (Students like Paul who say that they "wouldn't have the career I have today without her" may disagree.) "Even a class that I've taught five times has flaws, so I could apologize, too — but I don't! We'll never be perfect, so forgive yourself, revise, and do your best work."

Paul Valiant

In August of last year, Brown CS reported that Assistant Professor Paul Valiant had received a Sheridan Junior Faculty Teaching Fellowship, a year-long program run by the Harriet W. Sheridan Center for Teaching and Learning to develop the teaching potential of promising new faculty. Over the course of this year, through lectures, workshops, and teaching observations, faculty refine their teaching and assessment strategies, give and receive peer feedback, and explore their own practices and beliefs about teaching. The end goal is to enable participants to improve the learning of their students and their own experiences as teachers.

Coming to Brown, Paul had big shoes to fill: he had taken over teaching CS157, the popular undergraduate algorithms class that had previously been taught, he says, in an incredibly dynamic and engaging fashion by Claire Mathieu. "Each of her classes looked like a magic trick," says Paul. "She would ask a question, write down student responses, and by the end of class have a complete description of a novel algorithm along with its formal proof, written on the board using nothing but student words." For Paul, arriving at Brown — like many new science faculty — with little to no classroom teaching experience, this was a tough act to follow.

Since joining Brown CS two years ago, Paul's efforts as a new professor have been marked by close attention to his own methods as well as careful analysis of feedback from students and colleagues. "Working with students has to change your worldview," he says. "If it doesn't, you're doing it wrong! People ask why I have so many chairs in my office, and it's for meetings with students, and my undergraduate teaching assistants, who inform and shape the course through their unique insights into the student learning process."

Even as he began testing new techniques and adjusting his teaching, Paul saw value in the rigor and interactivity of a formal certificate program. "I like that Brown faculty members are known for continually refining their teaching methods," says Paul, "and when I came here I was often asking colleagues for their advice. Among other things, they recommended the Sheridan Center."

Part of the attraction of the program, for Paul, was the possibility of drawing on teaching techniques from disciplines well beyond computer science, benefiting from the breadth of different perspectives at Brown. "Any computer science curriculum should

include writing," he says. "Think back to eighth grade, when your work for Math class is just a series of equations, but in History or English, you're expected to use language to address complex ideas with sophisticated arguments. We can gain from asking students to apply that same sophistication here."

For Paul, developing student communication skills goes hand in hand with learning sophisticated algorithmic tools. Students in his class write a lot, turning in homework problems in the form of mathematical proofs which look a lot like English essays, but with symbols and diagrams mixed in. For Paul, asking his students to communicate their homework in this level of detail is a necessary step towards developing the kind of clear thinking that he regards as necessary for the study of advanced algorithms. "Students acquire a rich toolbox of algorithmic techniques, which they instinctively combine in rich and magical ways," says Paul. "And the first time they really let the genie out of the bottle, and construct something whose behavior they do not understand, it's a wakeup call — that to move to the next level, they need to develop new ways of thinking and talking about algorithms."

"WORKING WITH STUDENTS HAS TO CHANGE YOUR WORLDVIEW. IF IT DOESN'T, YOU'RE DOING IT WRONG!"

Paul explains that during his Sheridan experience, as a Junior Faculty Fellow, he received an expanded version of the Certificate 1 program: five lectures, and accompanying workshops spread out over the academic year. As part of the training, one of his classes was videotaped for review and critique; he was also partnered with three peers, who visited each other's lectures to offer support and advice. A colleague specializing in theatre arts had some unexpected words of wisdom when Paul mentioned the challenge of getting students to ask questions: "You need an actor in the classroom!"

Only a few months later, Paul thinks he has changed significantly as an educator. He recounts how observing other classrooms in comparison to his own allowed him to contrast perspectives from both sides of the podium. "Students used to call my lectures disorganized," he admits, "and I now know exactly what they meant." He goes on to explain, "a class's organization is something which may exist only in the mind of the professor — connections binding the many parts of the narrative together — and I now appreciate how much effort it takes to ensure an audience of a hundred shares all these connections."

One tangible example of how Paul put his Sheridan training into practice is a new formulation for "group office hours." During stereotypical office hours, Paul explains, a student spends an hour or more in line for five minutes of solo time with a TA. The window is so short that any sort of Socratic method is impossible, with both sides impatient to "get to the point." In place of this, Paul has his CS157 TAs manage office hours with typically twenty students in the room, organized into groups working together on different homework problems while the TAs rotate through the room. "A group of students is much more effective than a single student at figuring out a hint," Paul explains. "This gives our TAs much more latitude in how to provoke interesting thoughts from a room full of students."

Another instance of using a variety of pedagogical methods is Paul's inclusion of an oral exam that replaces a week of homework. It's a "try until you succeed" instead of a "try until the deadline" method, he explains. The first round is between a student and a TA, and further optional rounds are with the professor, which gives Paul a chance to focus on those students most in need of individual attention. Grades go up with each new attempt, and students can try as long as desired.

One of the most interesting parts of the oral exam is Paul's use of coaching to prepare the TAs for the task ahead instead of just setting them loose. He asks them to think of themselves as children being told a beloved bedtime story by the students. "The student is telling the story, I explain, and you need to guide them to your favorite parts. I want the students to know that you are on their side, you want them to succeed, even if you cannot tell the story for them." The response from both students and TAs has been very positive, and Paul credits the supportive atmosphere for "amazing turnaround stories" in the performance of many students.

Of course, even with these innovations, there are always new challenges: due to positive word of mouth, the course tripled in size this past year. "With so many students in the class, everything takes more time, even things you wouldn't expect to change — the amount of time students are spending on homework seems to be increasing!"

One of the key concepts of the Sheridan program is the emphasis on reflection, on close examination of methods and their effectiveness. (Paul mentions writing up lecture notes after class, and realizing that he shouldn't have explained verbally in ten seconds something that took him a page to write.) But it's clear that even long before the program, Paul was already thinking carefully about his role as scientist, researcher, and educator.

"As a scientist," he said last August, "your experiments and practice give you an intuition that allows you to theorize. This mindset underpins my research, and it unites my research and teaching. When trying to understand complicated phenomena in science, such as protein folding, evolution, or fluid dynamics, I write programs to teach myself what's going on...Computers have great powers to teach you; you should ask them to teach you things and then learn from them. In this sense, my research gives its own distinct perspective on teaching."

A Busy Semester For Kanellakis Fellows

BY ALEXANDRA PAPOUTSAKI

Hammurabi Mendes, Alexandra Papoutsaki, Esha Ghosh, Daniel Spielman, Eugenios Kornaropoulos, and Irina Calciu

The fall semester was particularly eventful for the Kanellakis fellows, the proud recipients of the annual award that has been established by Brown University in memory of Paris Kanellakis. Paris was a beloved Brown Computer Science faculty member who died with his wife and two children in a tragic plane accident on December 20, 1995. PhD candidates Esha Ghosh and Hammurabi Mendes were awarded the fellowship for the 2014-2015 academic year and joined the growing family of more than 25 Kanellakis fellows.

In November, the Brown and MIT Kanellakis fellows met in Boston for the annual Kanellakis Fellows Dinner, a meeting that brings current and former recipients together. Aristidis Karalis, the second-ever recipient of the fellowship at MIT, was a great host who amazed everyone with the vast amount of Greek food that he had cooked. Everyone was thrilled to welcome new faces and learn exciting news from old friends.

On December 11, Brown Computer Science hosted the Fourteenth Annual Paris C. Kanellakis Memorial Lecture. Daniel Spielman of Yale University delivered a talk on Laplacian Matrices of Graphs: Algorithms and Applications. After the well-attended lecture, he met with the current Brown fellows.

Over the past few years the fellows have visited Mrs. Argyroula Kanellaki, Paris's mother, every January in Athens, Greece. This year, due to her frail health, she moved to the countryside. Nevertheless, many fellows called her individually to wish her well for the New Year, and everyone signed a Christmas card with good wishes and small thank-you notes. Mrs. Argyroula always shares stories from Paris's life and reminds her guests that the fellowship was established to keep his memory alive and to create an ever-growing academic family which spans the years.

Kanellakis fellows at the home of Aristidis Karalis

Recent PhDs

CLOCKWISE FROM TOP LEFT

Derek Aguiar

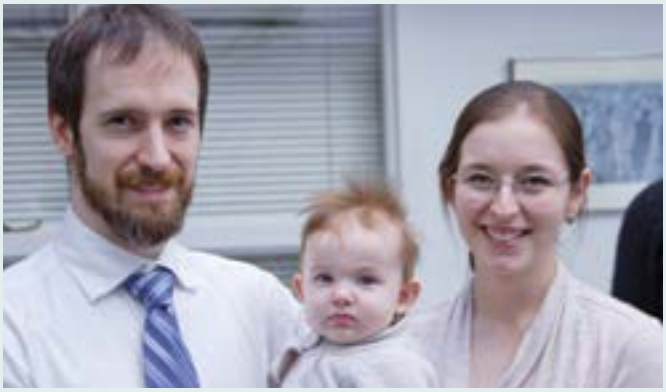
Foteini Baldimtsi

James Kelley

Ben Swanson

Alex Tarvo

Silvia Zuffi



Around The Department

Former PhDs Stefan Roth and Matt Lease are reunited in at WACV 2015 (IEEE Winter Conference on Applications of Computer Vision) and celebrate the reunion with a digital chicken

The CS 15 Lab Dream Team (as they jokingly refer to themselves): Samuel Angelo Crisanto, Daniel Rothman and Tushar Bhargava

Tara Shriram Fisler, Thomas Dickerson, and Betsy Hilliard at the 2014 Brown CS Halloween Party

Students competing at the 2014 Brown CS Orientation prepare to drop an object made of straws and tape over the fifth floor railing

Attendees at the 2014 Brown CS Town Hall Meeting

The GWiCS 2014 Holiday Cookie Swap

Hack@Brown 2015: At A Glance

BY SHARON LO '16

The student organization Hack@Brown began last year as the organizers of the university's first annual hackathon. Their mission was to focus on inclusion by removing the intimidation factor usually associated with hackathons and instead focus on collaboration and mentorship. The event proved to be a huge success for Brown CS: over 250 people attended, with one commenting, "Hack@Brown was a really friendly, encouraging, and accommodating environment for people who had never been to a hackathon before."

Participants at Hack@Brown 2015

This year, the Hack@Brown team decided to expand their efforts while keeping their mission to heart. Registration for the hackathon opened in December 2014, and more than 2250 students around the globe responded. Hack@Brown 2015 was held this past February, welcoming 350 students from over 71 schools and as far away as Mexico and Canada. In its commitment to reduce barriers of entry and promote diversity, all applicants were chosen at random, removing selection based on merit, and all student travel was completely reimbursed.

"With everything the team did this year, we really wanted to spread the message that hackathons are so much more than programming," says Sharon Lo '16, the event's Co-Director and a computer science concentrator. "It's about having the confidence to learn something new and thriving on the collaborative synergy and excitement from all the other students and really just building something amazing together."

The result was a focus on learning and collaboration as students gained experience working side-by-side with industry mentors, many of which were returning Brown alumni. This year, nearly 60% of participants were first-time hackers and 40% were female (in comparison to 10-15% female attendees at most hackathons).

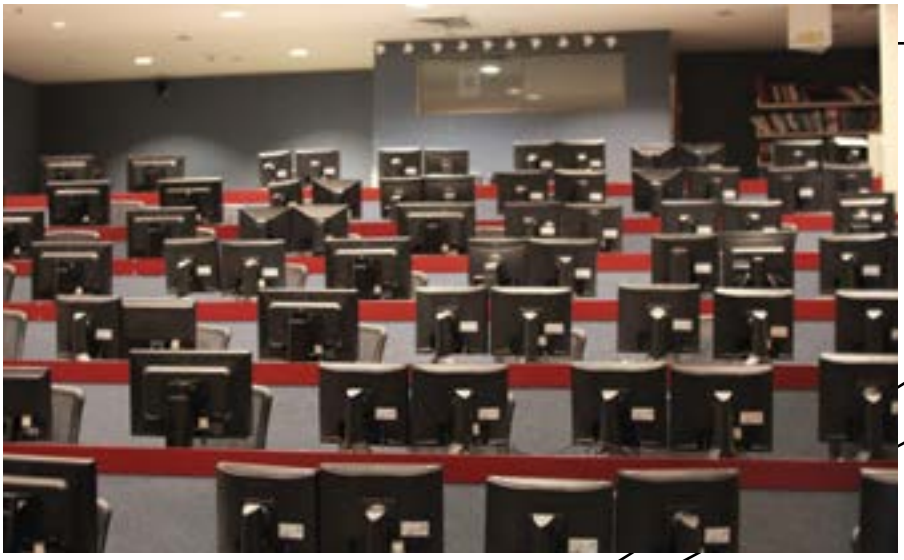
Over 24 companies, such as Oracle, Two Sigma, and Microsoft sponsored the event, and Professors Jeff Huang and Michael Littman served on the judging panel.

In addition, Hack@Brown has expanded their efforts into a year-long series of events that continue to foster peer-to-peer learning beyond the weekend event. Over the course of this past school year, Hack@Brown has hosted over 15 workshops in topics ranging from HTML, Javascript, and Git, as well as hardware such as the Microsoft Kinect. The HTML/CSS workshop was attended by over 150 students, with most students coming from a non-CS background. The team has also worked to spread education beyond Brown by collecting a host of learning resources to help students jump-start any of their technological endeavors. As Wilson Cusack '16, Hack@Brown's Director of Workshops and a CS concentrator, says, "Why even wait for a hackathon? You are the only thing standing between your idea and its execution."

Renovations Present And Future Enhance The CIT

If you haven't visited the CIT recently, you may not know that renovation has been occurring in almost every corner: the entryway, staircases, the back hallway on the first floor, 368, 506, and numerous other spots.

New furniture is in, more is coming, and other improvements are already complete, from whiteboards in the first floor atrium to the bricks outside the main entrance. We all owe a debt of thanks to Tom Doeppner, who has ably and patiently overseen the effort. He says, "We've had work being done throughout the building, with really significant changes in rooms like 368. In addition, other rooms have a lot in store for them in the next year or two. You always wish that you could do more, but I think things have turned out very well."



before

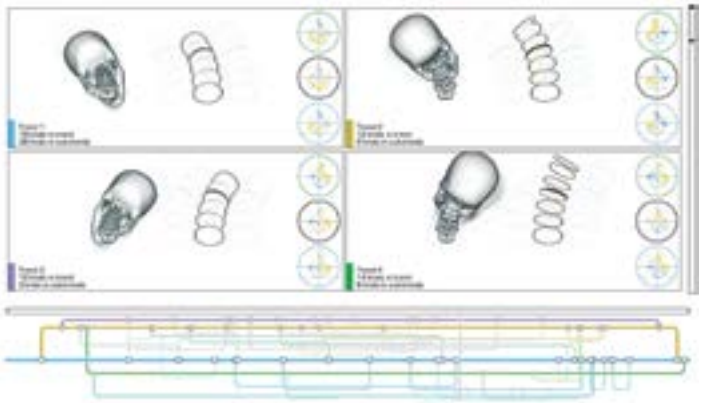
during

after

Alumni Update

DANIEL KEEFE '07

by Jesse C. Polhemus



An interactive subway map for visualizing trends in human spinal kinematics studies

Picture the map of a transit system, maybe not very different from that modern icon of information design, the London Underground Map. (You'll find out why later.) Faced with a complex dataset (geography, landmarks, distances, transit modes), the graphic designer must make conscious decisions to make the data as readable as possible: creative human insight tailoring data displays to work at a human scale.

Now, get on the Brown line at Scientific Visualization. Travel through the Art/Science interchange, pass through Virtual Reality, then transfer to the Big Data line to step outside (just for now) at Trend-Centric Motion Visualization. You've traced the barest outlines of a career path that Daniel Keefe '07 (now on the faculty at the University of Minnesota) has followed in pursuit of "understanding the complex relationships between humans and computers."

Daniel is laughingly forthcoming with his earliest motivation for the academic life: "With my father teaching in the medical school at Duke, I grew up in one of those parts of the country where colleges are everything — admittedly, this was probably as much a result of college basketball as it was academics — but, nevertheless, I knew at an early age that I enjoyed the university atmosphere." As childhood ended and the need for professional direction became more clear, Keefe kept his sights on academia but repeatedly questioned himself: "Do I really want to do this? Yes, I do want to be a professor, but what do I want to profess?"

The answer was computer science, but with a unique emphasis on art. After graduating from Tufts University in 1999, what brought Daniel to Brown CS for doctoral work was a desire to combine the technical aspects of computer graphics with the visual arts. "Other schools said they were interested in art-science collaborations, but at Brown they were doing it. David [Laidlaw] had a new NSF grant to develop visualization techniques using ideas from oil painting. And when I visited the Graphics Lab, the first thing I saw was a poster of Dr. Seuss's Truffula trees, created using a non-photorealistic rendering algorithm developed at Brown. I knew right away, this was the place for me."

"It was just what I needed," Daniel says. "David [Laidlaw] was brilliant at letting everyone in his group sample different ideas."

As he worked on virtual reality user interfaces, the proximity to RISD and interdisciplinary possibilities were a key part of Keefe's education as he developed expertise of his own. "Art had always been important, personally important, to me," he says, "and I worked in art-based rendering and painterly visualization. Supporting artists with visualization tools eventually became part of my dissertation."

Interdisciplinary ties didn't end there. After graduating, at his advisor's invitation, Daniel teamed up with Bruce Campbell of RISD to host an art show as part of the important VIS conference, inviting Maxwell Roberts of the University of Essex to exhibit his groundbreaking cartographic work. The great designer and psychologist responded by sending boxes and boxes: fifty maps, all mounted on foamcore.

"If that aspect of graphic design hadn't already won my heart," Daniel says, "that sealed the deal. It's aimed at one of the greatest modern challenges: in any science, our ability to collect data has outpaced our ability to understand it. We can't use the statistical models of the past, but if we combine data processing with visualization, then we might have an answer."

Daniel's recent work with analyzing animations of the human spine is a perfect example. "We know," he explains, "that we can use computer graphics to help orthopedists and physical therapists by showing them the human spine in motion so they can look at correct and incorrect movement. But if we have a study of two hundred patients and we look at multiple spinal movements pre-treatment, post-treatment, and during a follow-up, there can be thousands of instances. You can't compare them individually, and if you lay them all on top of each other, you just end up with noise."

Visualization (and Maxwell's cartography and that London Underground map) were key to Daniel's solution. He says, "We started using subway-inspired lines to look at motions aligned to a common time axis and find trends. Everyone starts on the same line, but as people's motions vary, branches start to form: someone can diverge from the main line, or come back to it. A group of patients (say, healthy patients) can branch off and follow a similar motion pattern, while other groups may cluster into other trends. If we click on a particular branch, we get a 3D visualization of that motion trend. While comparing hundreds of individual *motions* side by side is too confusing, we can compare a small number (say, two to four) of motion *trends* side by side, and if we do a good job picking the trends, then we still see all the important variation within the whole dataset."

There are clear ramifications for our understanding of human vision and even cognition. "If you are trained in data visualization," says Keefe, "then you probably have a strong belief in the power of the human visual system, but we get roadblocked when the dataset is so huge. There's no way I can look at an animation of 1000 neck circumduction exercises and then answer the question, how is #3 different than #703? On the other hand, an automated algorithmic analysis doesn't work either. These data are new enough that nobody quite knows what to look for, so we need some hybrid approach that automatically clusters or helps organize the data but also allows us to investigate the motions visually. That's the only way we can figure out what normality looks like, what abnormality looks like."

On the subject of normality, he also credits Brown for helping him form a somewhat unorthodox view of how various disciplines interact: "We met with a writing fellow constantly, something which was very unusual. David insisted that we have a broad understanding of the world, not just a technical one." When asked to look into the future after being recently appointed a tenured associate professor, Daniel pauses. "I feel very optimistic about what's ahead. If we embrace other disciplines and lead, then computer science is in a wonderful position."

With tenure secured and his first art exhibition since graduate school behind him (VISAP 2014 in Paris), Keefe is eager to get back to creating more of his own artwork as well as continuing his academic research on art-inspired computer graphics: "I'm excited about new design tools, 3D printing, very hands-on and physical computing with pens and gestures and 3D tracking. Using computers to enable the human creative process."

And that's just the first item on his list. Continuing, he returns to that same human angle, the anthropocentric impulse that's guided so much of his work. "I'm interested," he says, "in the psychology of creativity." In other words: in the era of big data, what does creativity in design really mean? If a supercomputer is doing all the work, how do we avoid giving up control?

"How do we use human insight?" Daniel asks, a pointed question for any field. "Let's keep the human in the loop!"

ADAM KENNEY '04

by Adam Kenney '04

Sometimes it's good to go back to your roots. When slinging code in the world of private industry, it's easy to feel distanced from the thoughtfulness, idealism, and teaching of academe. Yet these qualities are essential to success in any industry, and students also benefit from the dialogue as they prepare for the world beyond the university's boundaries.

I graduated from Brown University in 2004, which makes me ancient in the eyes of college students. But my visits to Brown on behalf of pMD, a company that makes mobile software for doctors, have been rejuvenating. Over the past few years I've given technical talks, helped students polish their resumes, and reconnected with some of the faculty members whom I admired most.

Each visit, I've been inspired by the insights and diverse perspectives of the students. They haven't shied away from asking tough questions during my talks — or from putting themselves out there. When I asked a large audience to name their favorite mobile apps, one student immediately shouted, "Tinder!" Perhaps the movie **The Social Network** was right, and college students only care about one thing. But more to the point, this is an incredibly successful app that came into existence only two years ago. The students have their fingers on the pulse, and they've kept me on my toes.

More satisfying still has been the experience of giving back. Through resume review sessions, I've met one-on-one with dozens of students to talk about their career goals and to help them fine-tune their resumes. As a hiring manager at pMD I've had the dubious pleasure of reading more than a thousand resumes, so I know what makes a resume scannable and readable, and what's attractive to an employer. Many students hesitate to trim and focus their resumes, and they've told me that it's helpful to hear my "less is often more" perspective.

Finally, I've found the most joy in giving tech talks at the computer science department. Working at pMD, I've had the opportunity to observe hundreds of physicians and their staff as they learn to use our software for the first time. So most recently I spoke about "How to Build Learnable Apps that Users Love at First Sight." User experience design is rarely taught in the classroom, yet the students showed a remarkable aptitude and passion for creating truly love-worthy apps.

"I'm in the early design stages of an app with a few friends and we've been debating the issue of borrowing UI patterns from common apps vs. coming up with something novel (which might require more investment from users to learn). Your talk certainly helped me think about that."
– Jonathan Schear '15

"I found it particularly interesting that large, well-known companies seem to think they can get away with neglecting new users in their UI design. A team of freshmen (myself included) won Hack@Brown with a voice-messaging app called 'Squawk', and we tried to simplify the design as much as possible."
– Joe Engelman '17

I returned from Brown feeling invigorated and with renewed enthusiasm to move the dial on great software design. Even more importantly, I met and spoke with another generation of computer scientists committed to building great, learnable software that users love. I can imagine nothing more rewarding.

SUNIL MALLYA '11

by Jesse C. Polhemus

Like the company that he co-founded, Neon Labs, Sunil Mallya '11 sees himself as rooted in science and invigorated by its potential for discovery, transforming what had previously been uninteresting or impassable. He says, "I grew up at just the right moment in time to be constantly amazed by the ubiquity of computers. I was interested in being able to express problems, model them, and leverage computation instead of just throwing more humans at our challenges. Empowering people through technology is exciting."

After attaining a Bachelor of Engineering in Computer Science from PES Institute of Technology in 2008, Sunil went to work in the field, but something was lacking. "I wasn't solving problems," he explains, "and that made me unhappy, not doing what I loved. I wanted to contribute to science, and I knew Brown would be a wonderful place to do that. Sure enough, everything I'd heard about students and faculty interacting without silos turned out to be true."

Research for his Master's degree led Sunil to work in systems, combining interests in energy management and machine learning. Brown also provided an introduction to fellow student Sophie Lebrecht, whose PhD work in cognitive neuroscience had produced an unusual finding: humans tend to perceive certain images negatively (for example, a gun) or positively (a baby), but no image will be perceived as entirely neutral.

The discovery raised a question: now that we understand this, how can we share it?

Inspiration came from the ubiquity of YouTube and the endless thumbnail images that form an essential part of its interface. Sunil and Sophie were struck by the realization that a more appealing thumbnail would mean more views for a video, which would mean more advertising dollars for video publishers. They began developing prototypes for a product that automatically selects images based on subconscious human visual preference, working intensely over a period of five months to acquire a first round of venture capital and the NSF's Small Business Innovation Research grant.

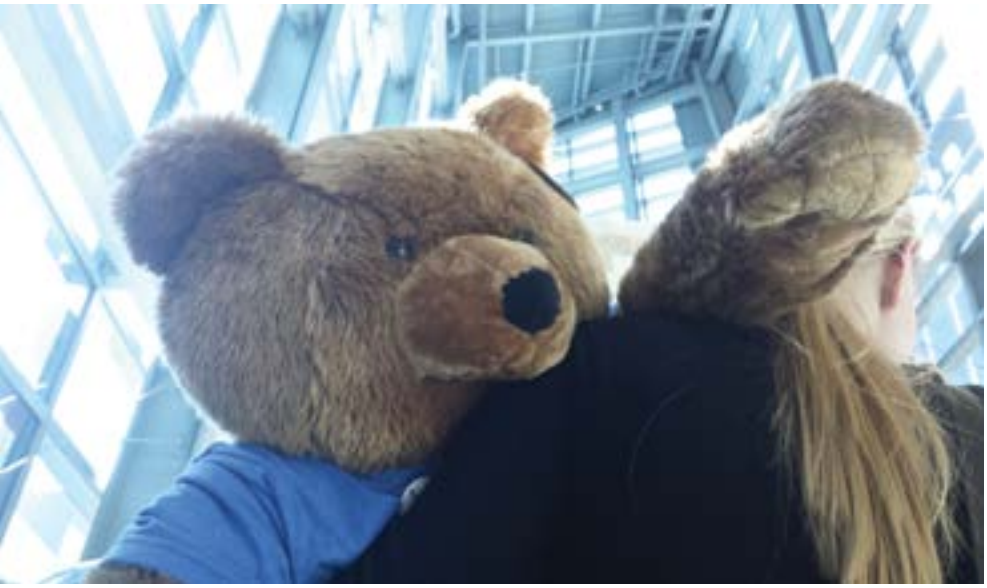
Neon Labs was born. Sunil describes the organization as an enterprise company whose customers are often publishers and content creators with financial models based on advertising revenue from videos. Currently, Brown alumni comprise 30% of their staff: Sunil, Sophie, and Nicole Halmi '10.

"What's exciting right now," Sunil says, "is our potential to provide services to numerous markets, from still images to e-commerce. Our existing product, Neon for Video, addresses the huge pain point in video where content creators either choose a thumbnail at random, likely with poor results, or hire an editor who could spend hours pausing the video again and again to find an appropriate image. We get publishers past that problem by using science to automatically find and surface the most engaging still images from a video — the images that people want to click on."

Neon Labs is currently live and providing services to customers like IGN, a large-scale gaming and entertainment site. Neon is also using their mid-2014 round of venture funding to expand the team, allowing them to serve more customers.

Sunil's summary of the situation highlights the parallels between his own beliefs, the core values of his beloved Neon Labs, and those of his alma mater. "As we add customers," he says, "we're hiring accordingly. We'd love to have more Brown graduates work with us, because we find they innately understand our approach and how we build our product. They're rooted in science, and they hold themselves to high standards. We want to emulate Brown CS, constantly growing while maintaining an academic edge. For me and for Neon Labs, that's staying true to our roots."

Diversity Committee Scholarships Enable A Growing Grace Hopper Conference Presence



Brunetta hugs a GHC attendee

BY NEDIYANA DASKALOVA

In October of last year, Phoenix, AZ became the meeting ground of more than 8,000 attendees at the Grace Hopper Celebration of Women in Computing. The conference has been growing since its 1994 inaugural year, and last year it included a record-breaking number of attendees. The keynote speakers included various prominent leaders from the world of computing technology, such as Shafi Goldwasser, a professor at MIT and Turing Award winner, and Satya Nadella, CEO of Microsoft.

"I have never attended GHC before, and I've heard so many good things about it from virtually all my female tech friends. So I thought I should go when I have the chance," says Hua Guo, a fourth-year PhD candidate in Visualization.

Some students from Brown received funding from the Brown Computer Science Diversity Committee to attend. They had great experiences and met other women in tech not only from the US but also from all over the world. The best things about this conference is that it introduces you to all the amazing things that people are doing in both academia and industry, or as one of the Master's students, Ning Hou, exclaimed, "We've got so many cool women in CS! It really made me feel proud and special about what we are doing!"

"GHC is not a one-time thing," Hua added. "It provides a great opportunity for one to find and join a community. For me, for example, I learned about the existence of and joined Chinese Women in Computing, a sub-community of Systers, which probably wouldn't happen otherwise."

For the second consecutive year, Brown hosted a booth at the career fair at the conference. Current graduate students handed out information about the university and answered questions from visitors. This was also a great place to meet up with Brown alumni who stopped by. Potential students who wanted to apply to graduate school could also submit their resume and be entered in a raffle to win Brunetta the Brown Bear. When a twin of this bear was raffled off in 2013, it ended up returning to Brown because the woman who won it is now a PhD student at the Computer Science department. Hopefully, the 2014 one will make its way back, too.

This year was also special because one of our own PhD students, Layla Oesper, won the Google Anita Borg Memorial Scholarship. This award was created to honor the memory of Anita Borg, who revolutionized the technology world and challenged the impediments posed to women in computing. Layla says, "[As] part of the scholarship, I was able to go to GHC last year. While I was there I got the chance to meet other Anita Borg scholars from both this year and previous years. Being able to interact with such a dynamic and energized group of female computer scientists was really energizing."

Grace Hopper 2015 will be held from October 14–16 in Houston, Texas. The Diversity Committee will again be offering scholarships to students, hoping to give the opportunity to even more people to experience it.

Diversity At Brown CS: 2015

The challenge of achieving diversity in computer science pervades the field's history, spans academia and industry, and touches every part of the globe. In 1961, a concern for inclusion was already present: Alan Perlis lectured at the MIT Sloan School, proposing that all children should learn to program. A half-century later, Laszlo Bock, Google's Senior Vice President of People Operations, said, "Put simply, Google is not where we want to be when it comes to diversity." Promoting diversity of all kinds here at Brown CS and beyond our walls has been a perennial concern for our community, and this article will examine where we've been, where we are today, and where we're going.

Last year, the Brown CS Diversity Committee was reminded yet again of the urgency of the task at hand by a letter that Karen Smith Catlin '85 sent to *Conduit*, available at https://cs.brown.edu/about/conduit/IFeltLikeIBelonged.pdf. "Looking forward to the 2014 Commencement," she writes, "the Brown CS Department will award degrees to 120 undergrads: 26 to women (22%), 94 to men (78%). That's roughly the same number of women as in my graduating class, but more than twice as many men."

Karen's analysis has galvanized the Committee to expand our efforts, which go beyond gender disparity and include diversity of all kinds. We've launched a long-term initiative that begins with an analytical phase of gathering quantitative and qualitative data. This article is a small portion of that phase.

As you'll see below, there are some powerful limiting factors, but in the face of incomplete data, we've attempted to highlight previous practices that have either proven successful here or elsewhere or seem to be correlated with success (shown underlined) and suggest future actions that we believe will contribute to a successful outcome (shown in **bold**).

As our Department Chair, Uğur Çetintemel, has said, "Just saying diversity is a priority doesn't solve the problem. Brown as a whole needs to develop a firm position reflected in policies, recruitment, and retention. Otherwise, we can't be effective. But I believe that society is making progress, even if too slowly, that we're changing the view of computer science as a discipline."

THE PAST

As we begin our review in the earliest days of Brown CS, the most immediate challenge is the lack of quantitative data. For example, although the current four-year trend in gender disparity is positive (8.3% of concentrating graduates were women in 2009–2010 and 22.6% were in 2013–2014), records, which are available at https://cs.brown.edu/about/conduit/ConcentratorGenderData.pdf, only go back to 1996–1997. Analyzing other dimensions of diversity is even more difficult, because Brown CS is prevented from sharing undergraduate demographic information such as race and ethnicity. (A limited amount of graduate data is available at https://cs.brown.edu/about/conduit/GraduateStudentDemographicData.pdf.)

Other metrics are more challenging still. It seems reasonable to assume that if Brown CS is attracting diverse applicants for faculty positions, this can help attract diverse students, but there's a seemingly insurmountable obstacle to proper measurement: applicants are not required to report any diversity-related information whatsoever. Faced with this quantitative deficit, we turned to Karen and other graduates, faculty members, and current students to begin to assemble a qualitative picture.

Karen describes herself (all interviews below have been heavily condensed) as someone who came from a modest background where handmade clothes were the norm:

"We were makers, but I hadn't seen a computer until I saw a story about a female computer scientist in *Money* magazine when I was a junior in high school...My father pushed me toward the field, reminding me that I was good at math and science and I liked experimenting. I came to Brown with my major already declared, and found that CS was a combination of everything I enjoyed.... Anecdotally, I remember a lot of women. CS 11 had a huge group of TAs, a third of whom were women, and they were all role models. There were no female faculty members, but that wasn't a problem: Andy [van Dam]'s TA interviews were gender-blind from the get-go, so I felt like I belonged."

Overall, Karen describes her gender as "mostly a non-issue" at Brown CS, but there were exceptions. Later, when she became a TA herself, grading a male student's program, she found that he'd chosen a different counter variable than the default, removing the first vowel from "count" to embed hate speech in his code. Karen remembers asking herself: "Why do I have to put up with this? What could he possibly be thinking?" She conferred with her fellow TAs and Andy and the student dropped a letter grade on an otherwise perfect project.

Far from being discouraged by that incident or others, Karen has taken a strong position of advocacy, urging the use of "proven practices" that other universities (and Brown CS at various points in the past) have put to good use: "Are we attracting accepted students to the CS department with 'A Day on College Hill' activities? Are we **tracking when women and other underrepresented minorities drop out of the CS curriculum and exploring making changes**

to keep them? Are we evaluating what other universities such as Carnegie Mellon and Harvey Mudd have done to reconfigure their introductory courses, reach out to high school teachers, and mentor students? Even something like paired programming projects where a student is deliberately matched with someone from a different background [Editor's Note: Among others, Amy Greenwald has used a different version of paired programming in CS017 to maximize the number of people that a student is partnered with] could make a difference."

We also spoke with Elisabeth Waymire '85, one of Karen's peers who had done no computing in high school ("it just wasn't a concept") and wrote her application to Brown on a typewriter:

"The state of diversity at Brown CS never occurred to me. If we weren't really that diverse, I didn't notice it. Coming from an all-girl's high school, it never occurred to me that I couldn't do computer science. I don't mean that in a defiant way: for me it wasn't positive or negative. When I got to Brown, I never felt like I couldn't start learning CS or that I couldn't keep doing it...I had females all around me as friends and roommates and TAs; I'm not sure what it would have been like otherwise….Brown's open curriculum helped, because I was able to get a BA and not a BS. I was also one hundred percent supported by the Brown CS leadership: the department treated me as a person, not a female, and it flowed down from the top."

"AS DIRECTORS, WE HAVE **LEARNED LIFE LESSONS AND GLEANED INSPIRATION FROM OUR YOUNG STUDENTS.**"

Elisabeth emphasizes the importance of keeping the field broad enough to include people with varying interests: "Not everyone is a Sergey Brin or working on rocket science algorithms or artificial intelligence. I'm a UI designer: I haven't programmed in twenty years, and I was very free to take that path...I give great credit to Norm Meyrowitz, Andy van Dam, and Bill Shipp, who spun the Institute for Research in Information and Scholarship (IRIS) out of Andy's graphic group."

Andy notes that IRIS was largely populated by Brown CS graduates: "It kept the departmental values," he says, "particularly a concern about diversity."

"IRIS made it easy for me to continue my social-science CS research during the summer at Brown," says Elisabeth. We need to **keep finding opportunities like that for the kids of today**!"

As we continue through the past and toward the present, we see multiple attempts to create the opportunities that Elisabeth mentions. Brown CS has become an active contributor to the Grace Hopper Conference (Betsy Hilliard and Layla Oesper wrote a recent blog post on attending); groups such as Women in Theory, Women in Machine Learning, and Women in Computer Science; the Richard Tapia Celebration of Diversity in Computing; and most recently, Hack@Brown, a hackathon purposefully designed to be welcoming to women and minorities.

We asked Andy van Dam to speak from his experience across the department's history and particularly about one of our most significant and successful attempts to promote diversity, the Artemis project:

"The idea that girls can't do math or can't program is bullshit. From the beginning, we were acutely aware of a lack of diversity and the need to create role model researchers, TAs, head TAs... Speaking just for myself, my approach has always been merit-based but proactive about diversity. If two candidates are equal across all fronts, from skill to experience to personality to ambition, I'll choose the diversity candidate....Despite our best efforts, there have been moments of machismo, a 'boot camp' mentality, even cyberbullying, but we always swat it down as soon as we learn about it."

"There are societal problems, too," van Dam says. "Karen remembers the days before computers were widely available and girls were just excited about them as boys. Then the marketing campaigns aimed at boys started, and that changed everything...On the whole, are we doing better now? I can't tell for sure. But for CS015, 40 percent of my 34 TAs are female, two-thirds of my head TAs are female, numerous nationalities are represented — it's a diverse group. CS123, my graphics course, has three female and three male TAs, admittedly unusual. My biggest research project has more female undergraduate researchers than male and a female co-lead."

Brown was one of five sites for an NSF-sponsored Science and Technology Center in Computer Graphics and Scientific Visualization that had an 11-year run. Part of the grant was for creating an outreach program that went beyond the obvious student population of the sites. Brown CS hired Anne Morgan Spalter, who had degrees from Brown and RISD, as the STC's educational outreach coordinator, and she and Andy created the five-week summer program in computer science for middle school girls called Project Artemis in 1996 at the Brown site. "This was our chance to reach girls before they lost interest in math and science," van Dam says. "We did everything we could to make a splash, be useful, be interesting. It was a powerful step in working toward diversity and also in teaching fun concepts in computer science to non- or not-yet scientists."

Now just a year short of its twentieth anniversary, Project Artemis is one of the longest-running programs of its type anywhere in the world, and is hugely beneficial to the Brown

women who participate, not only the inner-city girls. "As directors," Karishma Bhatia writes in our last issue of *Conduit*, "we have learned life lessons and gleaned inspiration from our young students."

"What's most under our control," Andy concludes, "is the environment here and how it supports diversity. Opinions vary: I've been told by some women that it's fine and by others that they feel at a disadvantage, even here. But I think we've always taken an active role, we've spent huge numbers of cycles on this. Am I encouraged by the results? Yes and no. As always, there's some success but a long way to go. And of course, that situation isn't just at Brown or in the Physical Sciences, it's the story nationwide, with rare exceptions."

THE PRESENT

Debjani Mitra, currently a CS concentrator, was surprised by the "dichotomy between observed and actual" when doing research for a scientific writing class: "I went to the same all-girls school in India for fifteen years. It was a meritocracy, and we came from the same socioeconomic group, so I was never aware of diversity issues in computer science until I heard people speak of them here... When I took CS 15, the gender balance wasn't half-and-half, but there were enough women and female TAs that people didn't treat anyone differently...When I had to create an infographic for a scientific writing class, I decided to look at growth in the number of female CS concentrators. Based on what I'd seen in CS 15 and what I'd heard about the department's outreach, I expected to see close to 40 percent female participation. Instead, I saw that enrollment of women had gone up, but the percentage of female concentrators was only between 18 and 24 percent."

Debjani's optimism is clearly visible in her recommendations: "Our TA program adds a real sense of humanity to this department. I've benefited from being on the other side — we need **more TAs and more diverse TAs! Discussions, panels**, anything we can do to **dispel myths** are all good. We're one of the most fun and community-oriented departments on campus: I fell into CS because of a comment that a friend made on Facebook about CS 15 being a 'must-take' course. We need to **get to people early and make explicit what we can offer them**."

The fact that Nediyana Daskalova, a current PhD candidate, chose Brown CS is a testament to the strength of several best practices: "As an undergrad, I knew about Brown but hadn't applied

to the PhD program. When I went to the Grace Hopper Conference, I saw that Brown had a strong presence, with a huge stuffed bear and some really friendly people. It wasn't generic, either: [PhD candidate] Connor Gramazio was there, and he mentioned Jeff Huang and HCI, and I went home and Googled the department because I was really interested. I left my resume at the booth to try and win the raffle for the bear, and I was really surprised when Shriram [Krishnamurthi] reached out to me based on what he'd read. Even more amazing, after I wrote him a really long response, he wrote back again less than five minutes later!"

The story didn't end when Nediyana won the stuffed animal. She had the additional challenge of trying to ensure that she and her boyfriend, Alejandro, stayed in the same geographic area for their doctoral work. She reports that Jeff, Shriram, and Ben Raphael did everything they could to inform him about his options in the area and assist with the Brown interviewing process. Eventually, he was accepted into Brown's PhD program in Molecular Pharmacology and Physiology. "I don't know what I could complain about!" she laughs. "I love the GWiCS events, all the fun of that, but I like being able to be friendly with everybody — I don't feel like being a woman has changed my experience at Brown CS. I'd like to see **more icebreakers during orientation** and other **ways to help people get to know fellow students**. There's a lot of diversity here, and social events help bring that out."

Joey Genfi, a current concentrator in computer science engineering, addressed the Diversity Committee at a recent meeting: For diverse students, majoring in computer science can be quite alienating. Other than required group projects, there's not so much collaboration, and different people have their own preferences in regard to who they work with — familiarity surely plays a role here. There's a sort of community in the CIT or the Sun Lab, although as an underrepresented student you could still feel ignored."

Inspired by his praise for two advocacy organizations, Women in Computer Science (WiCS) and the National Society of Black Engineers (NSBE), the Committee and Joey considered the

possibility of **creating an umbrella affinity group, tentatively titled Underrepresented People in Computer Science (UPiCS), that could work on behalf of any students in Brown CS who feel underserved**.

"It could prove as effective as these other organizations," Joey said. "UPiCS could make an impact, even with something like helping new students become more acquainted with the Linux environment and commands, which I found somewhat of a barrier early in my path to CS. They could **hold a shell programming introduction**... Personally, there were times I felt discouraged. Becoming a SunLab consultant was a helpful step for me in this regard, and it demystified many things. An increase in minority staff recruitment as such, can also help attract more diverse students to Brown CS and maybe UPiCS could provide some insight into this and other issues."

Another opportunity for UPiCS that the Diversity Committee proposed would be to **create diversity-related content for use during Student Orientation** on issues such as body language sensitivity, avoiding misattribution of ideas during group discussions, and other topics. These would accompany several other Diversity Committee efforts that were new this year: an exhibit on microaggressions, the inauguration of a series of diversity lectures and diversity CS Blog posts, and investigation into **possible curriculum changes** to provide different entry paths into computer science.

"I'm confident our department will improve," says Betsy Hilliard, a PhD candidate and member of the Diversity Committee, "because we are taking the problem seriously. I've seen incidents of 'brogrammer' culture and microaggressions occur, but every time someone points it out, the faculty responds...We need to recognize that our efforts will take a few years. Until we see balance and diversity at all levels, we can't let up on taking an active role in welcoming everyone."

THE FUTURE

Both the quantitative and qualitative data above, the statistics as well as the underlined practices, represent the beginning of the Diversity Committee's large-scale analysis of diversity at Brown CS:

- The items underlined above indicate what we and others are doing well and point to where we can improve in every aspect of communicating, teaching, advising, and providing opportunities, particularly in problem areas of the past. It's vital that we understand what progress has been made in other universities and even other fields. For example, has diversity improved in biology but not physics? How is the way computer science is taught or not taught in high school affecting diversity here at Brown CS?
- Following the analysis, the Diversity Committee will provide recommendations (some seen in rudimentary form in the **bold** items above) to the Department Chair, some of which will go beyond our walls.

The challenge of promoting diversity in computer science has been a real one throughout the history of the field: Brown CS has been aware of it since our inception, and we've worked hard to achieve results. Progress has been made, but it's not enough, which is why the Diversity Committee has begun this analytical phase of quantitative and qualitative data.

"There's an old adage," Karen explains, "that we can't change what we don't measure. We need to survey people and get every data point we can. Right here at Brown CS is where we can make the biggest change if we focus on our charter, then reach out into industry and schools. But we need to train people here and now in social dynamics alongside scholarship. We can't let 'if I really should apply to be a TA, someone will tell me' be the way women think. We can't solve diversity for the world at large...yet! But we will."

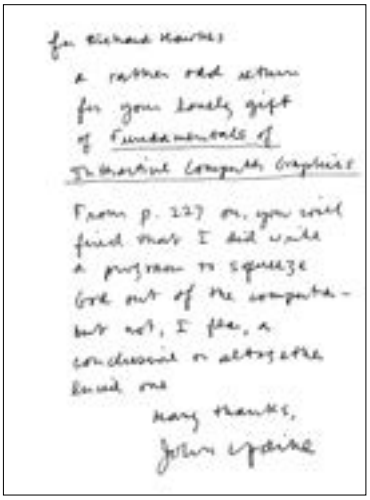
In addition to the people named above, we want to thank Emma Catlin, Lauren Clarke, Amy Greenwald, Michael Littman, Layla Oesper, and Stefanie Tellex, all of whom contributed to this piece.

Letters To The Editor

RICH HAWKES '84

Hi Conduit,

In 1984, Pulitzer Prize-winning novelist John Updike visited my family and the CS Foxboro Auditorium to learn about computers for an upcoming novel. I gave him a demonstration of the Differential Curves Package that Timothy Kay, Eddie Grove, and I had written for Prof. Banchoff's class in Differential Geometry, and presented him with my favorite textbook. He later sent me a copy of the final novel, **Roger's Version**, with the attached warm inscription.



My wife, Claudia, and I recently attended "Beyond the Box" — a celebration of Tom Banchoff's 50 years of teaching, as well as my 30th Brown reunion. It was great to see how much Brown and technology have changed, and how little my friends have changed...both very positive!

I am now engineering operations lead for the Netezza brand at IBM.

Regards,
Rich Hawkes, class of 1984

NELL ELLIOT '11 AND BEN COHEN '10

Nell Elliott ('11) and Ben Cohen ('10) met in the spring semester of 2010, when they were both TAing CS 16 with Spike. On February 5th, they were married in a small ceremony in Seattle. The two official witnesses to the ceremony were CS alums Doug Kirschner ('10), and Benjamin Simon ('10.5). Doug was also one of the Head TAs for CS 16 the semester that Ben and Nell met, and takes credit for introducing them.

Nell & Ben
267-909-6086 (Ben)

Notes From The Chair

CONTINUED FROM PAGE 2

technologies, rendering, for the first time, human visual capabilities as the bottleneck. The biggest event of the year will no doubt be our celebration party for the fifty years of undergraduate teaching and research and Andy van Dam at Brown. Already, more than 450 of you have signed up to come back for this event, which is a testament to your deep loyalty and support as well as the remarkable impact Andy had on our community and discipline. This event is now combined with the CS reunion and will immediately precede the graduation weekend.

To our graduating students: we are very proud of all your accomplishments and contributions to the department. We know that you will continue to push the boundaries and do even more amazing things.

Department of Computer Science
Brown University
Box 1910
Providence, RI 02912
USA

Industrial Partners Program

The IPP provides a formal mechanism for interactions between companies and students in the CS Department. Member companies benefit from superior visibility in the Department, exclusive access to event/interview space in the CIT Building and assistance with recruiting events; students benefit from specific information about opportunities for summer internships and permanent employment.

The department wishes to thank our Industrial Partners for their support:

Premier Partner
Adobe

Affiliates
DropBox
Facebook
Google
GTECH
Jane Street
Microsoft
MongoDB
Oracle
RetailMeNot, Inc.
SIG
TripAdvisor
TwoSigma
Yelp
Zynga

Advertising
OpenDNS
PureStorage
Remilon, LLC

Start-Up/Small Company
Cloudera
GreenBytes, Inc
Joyent
pMDsoft
ThumbTack
Vision Systems
VoltDB

Individuals
Paul Edelman,
Edelman & Associates

Rob Khoury, World Wide Financial Industry Recruiting Services, LLC

For more information about the Industrial Partners Program, contact:

Lauren Clarke
Program Manager
Tel: (401) 863-7655
lkc@cs.brown.edu

Ugur Çetintemel
Professor and IPP Director
Tel: (401) 863-7600
ugur@cs.brown.edu

To learn more about the IPP visit:
http://www.cs.brown.edu/industry

Connect with the CS Department:
Join the 'Brown University Computer Science' group on Facebook.

Brown University – Computer Science
LinkedIn

@browncsdept

Ping!

Where are you and what are you doing?

Let us know what's happening in your life! New job? Received an award? Recently engaged or married? Submit your news by e-mail to **conduit@cs.brown.edu** or by mail to:

Conduit
Department of Computer Science
Brown University
Box 1910
Providence, RI 02912

BROWN