Conduit

A RESEARCH AND ALUMNI NEWS MAGAZINE
DEPARTMENT OF COMPUTER SCIENCE
BROWN UNIVERSITY

What's the big picture?

Visualizing protein networks, canonical signaling pathways and proteomic experimental data together

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CONDUIT

Notes from the Chair: the Latest News from 115 Waterman

Greetings to all CS alums, supporters and friends!

With the fall upon us, the semester is well underway and the CIT is bustling with activity. Exciting events continue to happen in the department and I am thrilled to be able to share the highlights with you.

John "Spike" Hughes and David Laidlaw (Sc.B. '83 and Sc.M. '85) have been promoted to professor, effective July 1. Both Spike and David are internationally respected in their fields and have a strong commitment to teaching and advising. They make substantial contributions to the department and to Brown, as well as the field of computer science as a whole. Congratulations to Spike and David!

We have also hired two new faculty members, Rodrigo Fonseca and Erik Sudderth, who will both start at Brown in the fall of 2009. Rodrigo will join the department after doing postdoctoral work at Yahoo! Research and receiving his Ph.D. from the Computer Science Division of the University of California at Berkeley. His interests lie at the intersection of networking, operating systems and distributed systems. Erik will come to Brown after serving as a postdoctoral scholar at the University of California at Berkeley. He received his Ph.D. from MIT and his interests include statistical machine learning and computer vision.

With the addition of Erik and Rodrigo, the department is expected to reach a record number of 26 tenured and tenure-track faculty on its 30th anniversary next fall. Our two new faculty members will help serve our growing population of graduate and undergraduate students. In recent years, enrollment in our introductory courses has been steadily increasing. The number of students taking CS15 has grown by 50% since 2006. Also, since last year, CS17 is up almost 60% and CS19 is up almost 50%. We are delighted to see so many students taking an interest in our curriculum.

Graduates of the department continue to have excellent job opportunities that are both intellectually stimulating and financially rewarding. I am delighted to see so many alumni around the CIT actively recruiting our students for jobs and internships. The department is grateful to all the companies that have made membership in the Industrial Partners Program a priority. Even in these times of economic uncertainty, our Industrial Partners are growing their businesses and hiring new employees. We are pleased that they are impressed with the caliber of students that the department produces.

As you know, not all of our students go on to work at traditional jobs upon graduation and many start companies of their own. For some great examples, please see the September/October issue of the Brown Alumni Magazine to read stories highlighting two companies —Amie Street and Fluther — founded by Brown CS alums.

In other exciting news, the department has launched a Distinguished Lecture Series on topics of broad interest given by prominent computer scientists from academia and industry. The first two lectures were given by Martin Rinard (Sc.B. '84) of MIT (September 25) and RISD President John Maeda (October 16). Additional speakers over the remainder of the academic year are Michel Goemans of MIT (February 26) and Daphne Koller of Stanford (April 29). Our Distinguished Lecture Series also includes the Eighth Annual Paris C. Kanellakis Memorial Lecture, to be delivered on December 4, 2008 by Anna Karlin of the University of Washington.

Looking ahead, please mark your calendar for the next Computer Science Reunion and Networking Reception to be held on Saturday, May 23, 2009. We encourage all alums, friends and supporters to stop by. As those who attended the previous events can attest, it's certain to be a fantastic time—we hope to see you then!

Finally, please contribute your research and personal stories for inclusion in upcoming issues of the Conduit. Your support of and participation in department activities is always appreciated and we are thankful to have such a passionate and involved community.

Roberto Tamassia
Professor and Chair
Department of Computer Science
Brown University

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What's the big picture?

Visualizing protein networks, canonical signaling pathways and proteomic experimental data together

By **Radu Jianu**, **Kebing Yu**, **Lulu Cao**, **Vinh Nguyen**, **Arthur R. Salomon**, **David H. Laidlaw**

Introduction

The interactions of proteins within a cell determine the cell's response to an external event as signaled by special types of proteins called receptors that are placed on the cellular membrane. A cascade of such protein interactions peculiar to a specific cell, stimulation or cellular outcome is called a signaling pathway (Fig. 1). Understanding these pathways allows researchers to discover efficient drugs that can influence a cell without causing unwanted side-effects.

Recent advances in proteomic experimental techniques now yield vast quantities of experimental data on protein interactions. To use this data efficiently, however, researchers must collate it with existing knowledge. Just as in doing a jigsaw puzzle, it's easier to attach a piece to an already connected part than to start an entirely new region.

For protein interactions, existing knowledge is contained in databases holding tens of thousands of proteins and interactions among them, signaling pathway models and additional proteomic metadata such as sequence, class, etc. The huge data volume makes it impractical if not impossible to think about the data at its original low level. New computational techniques are required that either extract relevant information automatically or let researchers process data faster by looking at condensed visual representations.

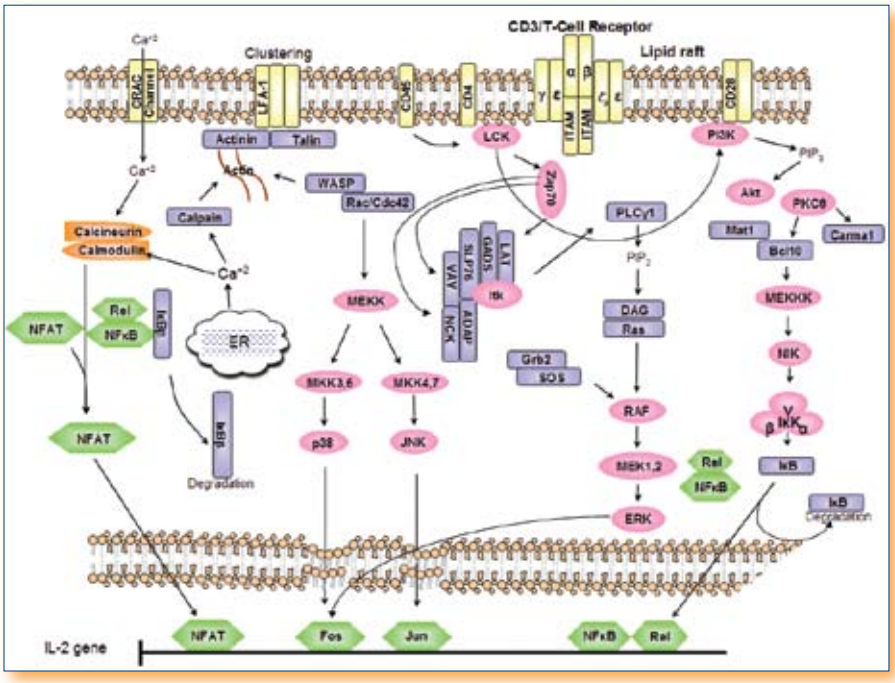


Figure 1: T-cell canonical signaling pathway: proteins relay a signal from the cell membrane (top) to the nucleus (bottom).

When protein-protein interaction databases first emerged a couple of years ago, the limitations of query-based workflows became acutely evident: traversing lists containing thousands of interacting protein pairs was impossibly laborious. This problem triggered the development of several visualization systems that used traditional graph-drawing algorithms to produce node-link diagrams. These systems, however, had a number of flaws from a visualization and analysis standpoint: generic graph-drawing techniques can yield visualizations that are unintuitive to proteomic researchers because they do not incorporate drawing conventions for protein cellular locations and signaling pathways that proteomicists hold dear, and data from large-scale proteomics experiments was not sufficiently integrated into the protein interaction visualizations.

In recent research, the authors introduced novel visual solutions to address some of these issues and evaluated them in work with Brown's Division of Biology and Medicine.

Findings

Following an iterative design process and working with collaborators in Brown's Division of Biology and Medicine, we discovered several visualization paradigms that work well in analyzing protein interaction networks.

Visually combining experimental data and known protein interactions enhances analysis: We found that coupling new experimental data with protein-interaction data extracted from public databases within a unified visual analysis system facilitated a systematic exploration of proteomic data. Although some of the workflows available in our system could be performed previously using various disjointed components, our network visualization and data integration approach can shorten the process from weeks to days; what's more, researchers found that spending less time between ideas let them integrate the ideas more efficiently into a cohesive hypothesis.

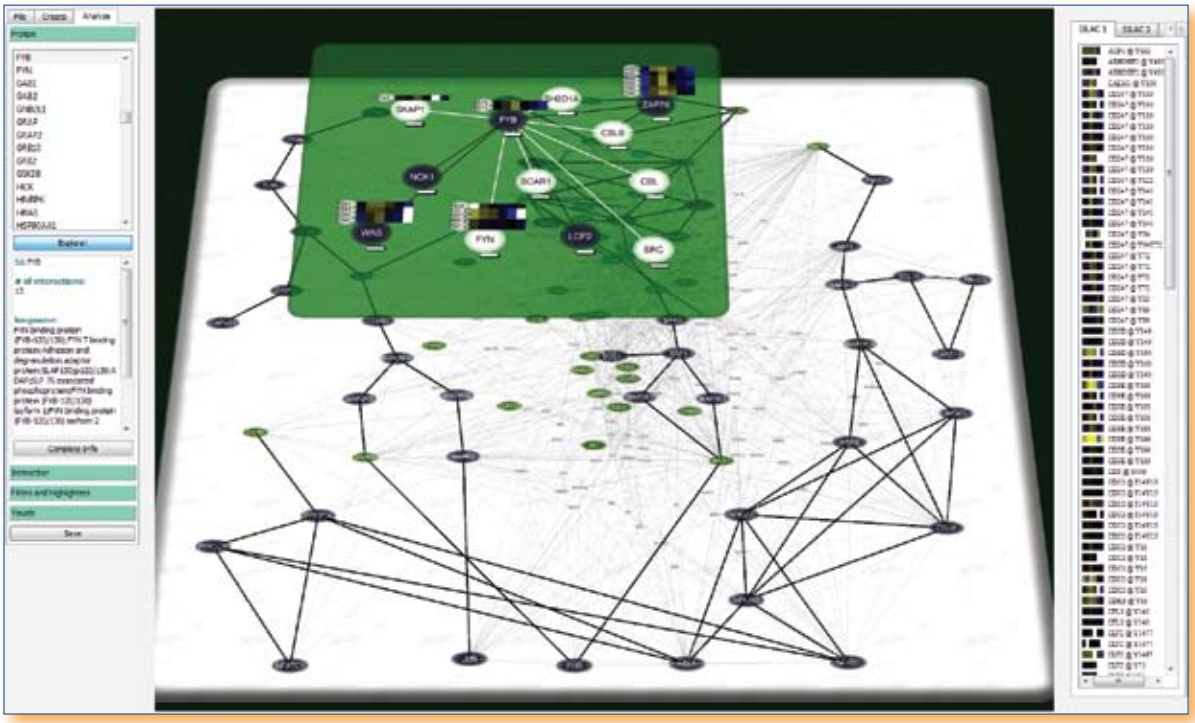
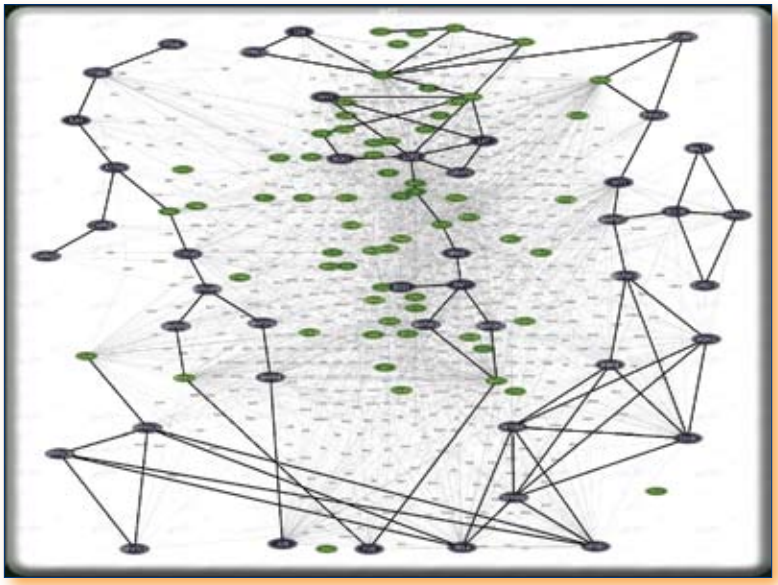


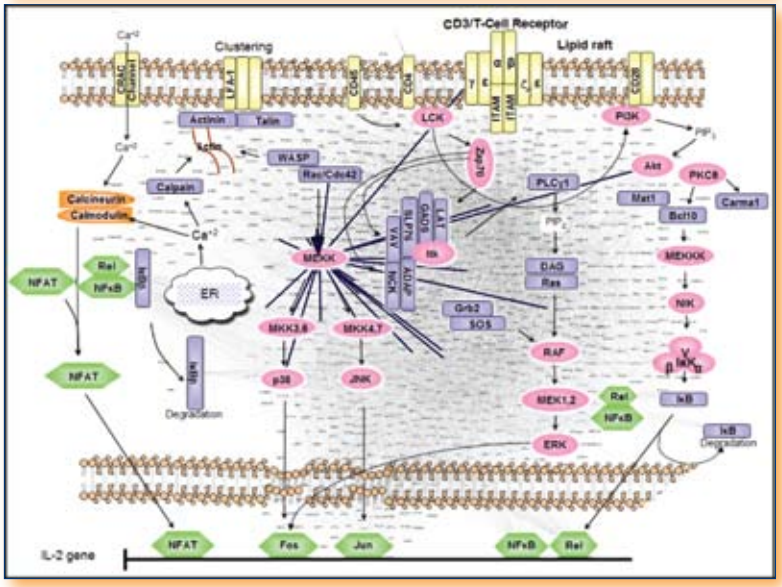
Figure 2: Exploring signaling pathways and protein interaction networks using a focus-context metaphor—one protein and its interactors are shown in detail with the entire network visible. Experimental data from a phosphorylation experiment is displayed on the right.

Our system makes possible the following workflow: users load experimental data into the system, for instance some quantitative proteomic data related to a particular signaling pathway. (We briefly discuss the type of experimental data in the methods section below.) Users then specify the model of the signaling pathway being analyzed, i.e. the known major players in the pathway and the interactions among them. Protein interactions are then extracted from online databases and a network is constructed around the pathway model. Users can now explore the experimental data, known protein interactions and signaling pathway model simultaneously. A local, detail-rich exploration mode is available to enable the user to cope with the clutter inherent in network visualizations (Fig. 2). The ability to understand visually how the experimental data fits into the existing pathway model let our users quickly process their data and derive hypotheses.

Canonical pathway-driven layout is intuitive for proteomic researchers: The intuitive visualization yielded by structuring dynamically extracted protein interactions around a familiar canonical pathway helps proteomic researchers



(a)



(b)

Figure 3:a) T-cell interaction network structured around a user-drawn pathway model; b)T-cell interaction network integrated directly into the canonical pathway image. Notice how the pathway elements are kept in the foreground without being occluded by the dynamically generated network.

orient themselves and learn the interaction network quickly. Learning unfamiliar proteins revealed by experiments is greatly facilitated by placing those proteins within signaling pathway-structured protein interaction networks.

Instead of drawing the network using a traditional graph-drawing technique that displays only the graph topology (i.e., the nodes and edges), we structure the network around a signaling-pathway model provided by the researcher (fig. 3). This pathway-structured method was motivated by negative feedback on a prototype that used a standard force-directed network layout: the positions into which generic network-drawing algorithms place proteins, we learned, are not meaningful from either a biological or a pathway-conventions standpoint. Feedback on this new layout method was positive: the familiar pathway model that seeds the exploration appeals to proteomic researchers, helps orient users and reduces the initial ball-of-strings shock associated with most network visualizations. Moreover, after some preprocessing, users can build the interaction networks directly from pathway images they have been working with, thus turning a static pathway model into a dynamic one.

Global and local exploration modes (multilayer, multiscale views) are helpful: We have found that researchers prefer to explore an interaction network by using a local view of each protein and to look at a single protein and its interactors at a time.

In our system, the network can be explored at two levels simultaneously: at a global level, showing clusters of proteins and other high-level structures, and at a local level, showing only one protein and its neighbors in detail as the researcher jumps from protein to protein in the network. The two types of visualization coexist as two parallel planes, the local one gliding above the global one (Fig. 2). Testing showed that the local plane is the most popular mode of protein-network exploration, even though regular zooming and panning were available. This preference probably arises because in the local view a single protein and its interactors can be analyzed without clutter from other network elements, all interactors are visible at once without panning and the space can be distorted to make room for experimental data glyphs.

Comparative displays of multiple experiments help identify important pathway players: Loading and comparing multiple experimental results, say from cells containing deleted or mutated proteins, helped researchers link cell behavior to experimental results. Researchers also found it helpful to have the experimental data permanently visible to drive the exploration.

For multiple experimental data sets, we display separate tabs for both individual experiments and pairwise comparisons of experiments. This feature can be particularly useful in knockout-type experiments in which a protein is removed from a pathway to analyze the effect of its absence on an experiment rerun. Showing pairwise experiment comparisons makes the differences between a normal and a mutated cell immediately evident. The experimental data panel is always visible on the right side of the screen so that researchers can use it to explore the new quantitative data systematically. Items in the experimental data panel can be used to start the exploration by linking directly to the expanded multiplane representation.

Methods

Displaying experimental data: The experimental data takes the form of lists of protein peptides with associated arrays of numbers. In protein phosphorylation experiments, these numbers can indicate the abundance of a protein across different time steps; in this case, we transform these into colored heatmap representations (Fig. 4) indicating fold change across conditions and display them in several places. For multiple experiments special types of heatmaps are

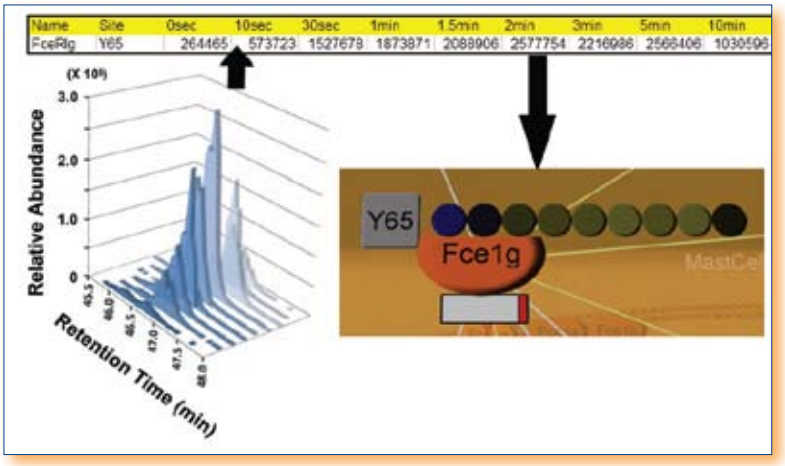


Figure 4: From phosphorylation experiment to visual heatmap-glyph representation.

computed to reflect changes: yellow then indicates a major change between two experiments while black corresponds to no change.

Network generation: We structure protein networks around the canonical signaling pathway model for a cell, a visually pleasing overview model of how the protein interactions in cells are thought to function that is used extensively by proteomic researchers (Fig. 1). A pathway model enters into our system in two ways: by placing and dragging proteins and interactions on an empty drawing canvas or by loading an actual pathway image and preprocessing it to help the system extract the structure. In the second case, the network is integrated directly into the pathway image.

Next, the software constructs a protein-protein interaction network structured on the user-provided pathway skeleton. First, a network is grown using the pathway proteins as seeds. While the canonical pathway proteins have predefined positions, the software must compute where to put the dynamically extracted proteins. These proteins are placed depending on their distance, in terms of number of interactions, from each of the pathway proteins. If protein P interacts with protein A and is three interactions away from protein B, it is placed on the line segment between A and B, closer to A. This methodology yields identical positions for some proteins and a force-directed approach is used to push close or overlapping proteins away from each other.

Augmenting a pathway image with dynamic data: When the signaling pathway is provided as an actual image, special operations create the illusion that the dynamic network and pathway image coexist and interact. A preprocessing step ensures that the positions, sizes and approximate shapes of proteins in the image are known. The sizes are used to push proteins further away from large neighbors to reduce the chances of overlap. The approximate shapes are used to copy corresponding image regions and redraw them on top of the dynamic network so as to keep the pathway structure in the foreground.

Exploration view: Exploration is done in a plane that hovers above the global view and shows in detail only one protein and its interactors. Clicking one of the interactors shifts the center of the view to this selected protein, a change performed through smooth animation to maintain context understanding. Standard zooming and panning with mouse controls are also available but test cases show they are less

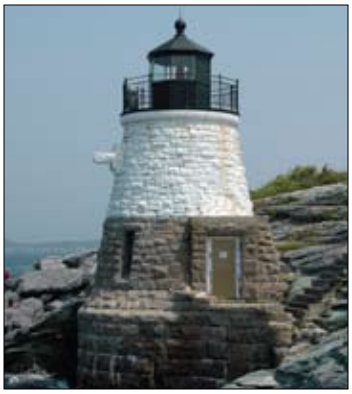
favored by users. Proteins in the exploration plane can be arranged so as to mimic their placement in the global layer while satisfying aesthetic criteria such as minimum interprotein distance or interaction overlap (Fig. 2).

Conclusions

We used several novel visualization methods and paradigms for the analysis and comparison of multiple proteomic data sets in the context of published protein-protein interaction networks and known signaling pathways. In addition, we evaluated the effectiveness of the methods in terms of data insights, hypothesis generation and improvements in analysis time.

This research was facilitated by tight collaboration among researchers from computer science and proteomics that helped us understand the requirements and specifications of proteomic visualizations. The canonical pathway-driven network layout and the experimental data-guided exploration of networks are tangible results of our collaboration. While the establishment of workflows and requirements is generally laborious for both proteomic and computer science researchers, it is highly beneficial for both parties because it identifies where computers can be most helpful. ■

Storytelling About Lighthouses
Criticizing Professor Dijkstra Considered Harmless



By **Sorin Istrail**
Julie Nguyen Brown Professor of Computational and Mathematical Sciences and Professor of Computer Science

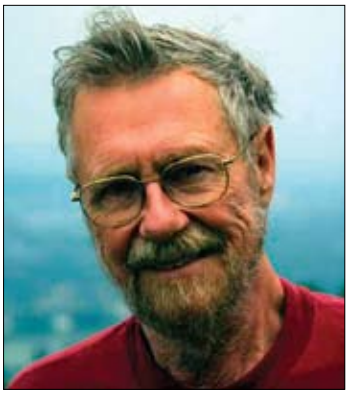
Introduction

I have a growing sense that scientists of the 1940s, around the time of the Manhattan Project, developed a substantive toughness through the process of critical dialogue. They worked in an environment in which not only did they *not* shy away from colleagues' criticism, they sought it out with the expectation that exposing their ideas to the harsh light of criticism would enhance their scientific survival. Such dialogue made the work of science fun.

This article is about criticism, about personal experiences and observations that lead to the obvious conclusion that criticism should be encouraged and that it could and *should* be taught.

In many ways, I envision collegial criticism serving the same function as lighthouses: On one hand, lighthouses signal safe harbor—sail on. On the other, they warn of rough and hazardous shoals—beware and explore other routes. I am drawn to lighthouses as symbols of how scientific truth is won.

"In many ways, I envision collegial criticism serving the same function as lighthouses: On one hand, lighthouses signal safe harbor—sail on. On the other, they warn of rough and hazardous shoals—beware and explore other routes. I am drawn to lighthouses as symbols of how scientific truth is won."



Professor Edsger W. Dijkstra

Such beacons are the motivation for "Storytelling About Lighthouses," a series of articles for *Conduit* about inspiring scientists I've encountered in the random walk of my career. Telling such stories can be difficult, especially if they appear to be self-promoting or of dubious authenticity. Yet stories about these luminaries are priceless—they should be collected and shared, for they inspire long after their first telling. Certainly, one would prefer stories consistent with the following two impressionistic principles: Axiom 0, *Primary source material is prime;* and Axiom 1, taken from the Romanian proverb, *Dupa razboi multi viteji se-arata,* roughly translated as *"After the war, many heroes show up."* I look forward to your feedback and—in the spirit of collegial criticism—intriguing counterarguments, responses to my calls for priceless stories and your solutions to my silly games for consideration in future *Conduit* articles (sorin@cs.brown.edu).

Perhaps it is fitting to begin with "Criticizing Professor Dijkstra Considered Harmless," prompted by this year's 50th anniversary of *Communications of the ACM*, its new leadership and an exciting renaissance in the journal's next half century. In the January 2008 anniversary issue, the publication, in honor of E.W. Dijkstra, reprinted his paper "Go-To Statement Considered Harmful," the most famous letter to the editor ever published in *Communications of the ACM*. "Considered Harmful" became a Dijkstranian hallmark of critical reflection. [1] My article is about an anniversary of my own: Twenty-five years ago, I wrote my first letter to Professor Dijkstra.

Dijkstra the critic

Donald Knuth put it well in 1974: "A revolution is taking place in the way we write programs and teach programming… It is impossible to read the recent [Dijkstra] book, *Structured Programming,* without having it change your life. The reasons for this revolution and its future prospects have been aptly described by E.W. Dijkstra in his 1972 Turing Award Lecture, 'The Humble Programmer.' "[2]

Indeed, Dijkstra was an outspoken and critical visionary. A prolific writer, he authored more than 1,300 papers, many written by hand in his precise and elegant script. They were essays and parables; fairy tales and warnings; comprehensive explanation and pedagogical pretext. Most were about mathematics and computer science; others were trip reports that are more revealing about their author than about the people and places visited. This "Dijkstranian style" of writing flourished on the frontier between technical computing science and the philosophy substantiating its distinguished development.

It was his habit to copy each paper and circulate it to a small group of colleagues who would copy and forward the papers to another limited group of scientists. I have in my basement a box with several hundred papers from the series. [3] I read them with joy and excitement and my love for mathematics and computer science has been influenced in no small measure by his works. (The University of Texas has since digitized the Dijkstra manuscripts, known as EWDs, and makes them available online at http://www.cs.utexas.edu/users/EWD/. I hope the current generation of students and young scientists enjoys reading some of his papers and gets inspired.)

He offered criticism with a combination of dramatics and humor—an approach I liken to Don Quixote tilting at windmills. (Imagine my surprise when I met Dijkstra not far from a lighthouse in Newport and discovered that he resembled Peter O'Toole's Quixote in the movie *Man of La Mancha*.)

Take for example EWD498, "How Do We Tell Truths that Might Hurt?" In it, Dijkstra wrote that "the use of COBOL cripples the mind; its teaching should, therefore, be regarded as a criminal offense" and "it is practically impossible to teach good programming to students that have had prior exposure to BASIC. As potential programmers they are mentally mutilated beyond hope of regeneration." (I am curious whether he commented about C++ or Java. Might you have a story to share about this?) Other titles hint at the passionate arguments of his favorite themes. [4]

Nothing and absolutely no one was safe, not the "real" programmer, the "real" mathematician, the electrical engineer, the industrial manager, the "systems people" nor American computing science. [4] Not even von Neumann or Turing. "The fathers of the field had been pretty confusing: John von Neumann speculated about computers and the human brain in analogies sufficiently wild to be worthy of a medieval thinker and Alan M. Turing thought about criteria to settle the question of whether Machines Can Think, which we now know is about as relevant as the question of whether Submarines Can Swim." [5]

But whether he was lecturing on algorithm design, writing an essay on the need for rigorous mathematical thought or taking programmers to task, elegance and simplicity were Dijkstra's common denominators. His demand for elegance was based on his essential formation as a "pragmatic industrial mathematician." As he wrote in EWD538, *A Collection of Beautiful Proofs,* "we have to fight chaos, and the most effective way of doing that is to prevent its emergence."

One of Dijkstra's core beliefs was in mathematical rigor as the foundation for reliable software design. It was a philosophy he outlined in "Why Correctness Must be a Mathematical Concern," an inspiring keynote address (later published as EWD720) presented at the University de Liege, Belgium, in 1979. It was this presentation—and what he called a "silly game" played by one person with an urn and as many white balls and black balls as needed—that emboldened me to contact him.

(What is a "silly game"? What are the axioms for it? We'll save that discussion for another time.)

The first letter

It was 1983 and I was a junior researcher at the Computing Center of the University of Iasi, Romania, just four years out from my Ph.D. I had read Dijkstra's paper on correctness and after years of dreaming about corresponding with this inspiring and mesmerizing man, I felt I finally had something to say.

In my letter dated January 19, 1983, I solicited his comment and guidance on a technical report I had sent him previously. It contained two programming puzzles: "The Father-in-Law vs. the Pajamas" and "On a Chinese Olympiad Problem." The technical report was inspired by Dijkstra's art of problem solving—his "silly games." I wanted so much to master his style—striving for elegance in defining new puzzles, especially in the mathematical derivation of the algorithms that solved them.

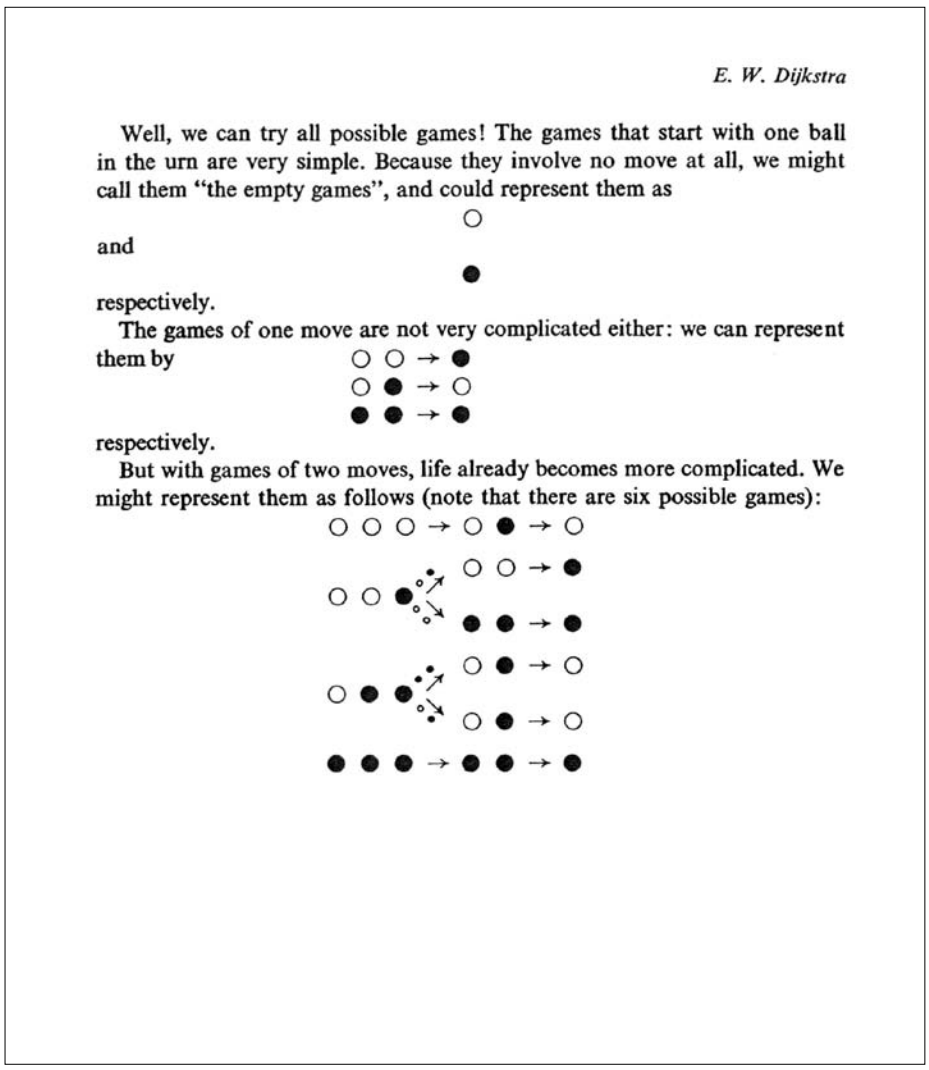
"I would be very much obliged if you could have a look at the problems… and if they deserve such a favor, please give me a reply," I wrote. "My deep hope is that you like these problems, and maybe use them in your celebrated conferences."

But my January 19 letter also included a manuscript I had written titled, "On the Facets of a Jewel." In it, I pointed out a certain mathematical difficulty concerning the game with the urn and balls described in EWD720. "My remarks point to some nice mathematical properties underlying the game and adding to its beauty. Shall I turn it into a publishable form?" I asked.

I never shared the manuscript with anyone, but in discussing my findings with colleagues, I told them I was considering sending the manuscript to Dijkstra.

Some colleagues suggested otherwise. Pointing out "some nice mathematical properties" and actually meaning "I found a certain difficulty with your problem" could be construed by this exceedingly tough perfectionist as a severe critique. I'd be committing professional suicide, they said.

I did not consider my manuscript a critique at all. Instead, I was eager to demonstrate to Dijkstra



E. W. Dijkstra

Well, we can try all possible games! The games that start with one ball in the urn are very simple. Because they involve no move at all, we might call them "the empty games", and could represent them as

○

and

●

respectively.

The games of one move are not very complicated either: we can represent them by

○ ○ → ●
○ ● → ○
● ● → ●

respectively.

But with games of two moves, life already becomes more complicated. We might represent them as follows (note that there are six possible games):

○ ○ ○ → ○ ● → ○
○ ○ ● → ○ ○ → ●
● ● → ●
○ ● ● → ○ ● → ○
● ● → ○
● ● ● → ● ● → ●

Dijkstra's "silly game" of the urn and the balls, above, illustrates his teaching philosophy while offering insight into his patterns of thought.

how to enhance the beauty of his game. I thought he would like it. Rather than being a show of bravery, it was a show of excitement—or perhaps the stubbornness of a young man ignoring senior colleagues' advice. (Not that bravery is unrelated to criticism, but if it was then present in any small measure it was because of his inspiration.)

The "silly game"

Dijkstra's game of the urn and the balls magnificently illustrates his teaching philosophy while offering insight into his patterns of thought.

"You cannot expect me to explain in a few words what mathematics is all about… but I would like to show you one simple argument in order to give you in a nutshell some of the flavors of mathematics," he wrote in EWD720, "Why Correctness Must Be a Mathematical Concern."

"Consider the following silly game to be played by a single person with an urn and as many white balls and black balls as he needs. To begin with, an arbitrary positive number of balls is put into the urn and as long as the urn contains two or more balls, the player repeats the following moves: he shakes the urn and, without looking, he takes two balls from the urn; if those two balls have the same color he throws one black ball into the urn, otherwise he returns one white ball into the urn. Because each move decreases the total number of balls into the urn by 1, the game is guaranteed to terminate after a finite number of moves and it is not difficult to see that the game ends with exactly 1 ball in the urn. The question is: 'What can we say about the color of the final ball when we are given the initial contents of the urn?'"

On the facets of a jewel

The manuscript I sent offered my view that the problem statement was vague and imprecise. It also vindicated, through my mathematics, that the vagueness cannot be removed; a sort of "incompleteness."

The following excerpt from my paper conveys the key to my reasoning:

I have read for the first time your problem with the urn and the balls, in David Gries' monograph. [6] By following his advice, I spent 10 minutes on the problem. But neither did a solution come nor did I really start to solve it. In fact, I spent these 10 minutes trying to convince myself that having started with an initial content of the urn, the color of the final ball would be unique, i.e., it would not depend on the sequence of used rules …. It was clear to me that due to non-determinism, there are many ways to follow, but it was unclear whether all the ways led to Rome!

… What seemed clear was that the question demanded the final color as a function of the initial content only; the sequence of applied rules did not matter. My initial feeling was that the function might be undefined for some values of the arguments…

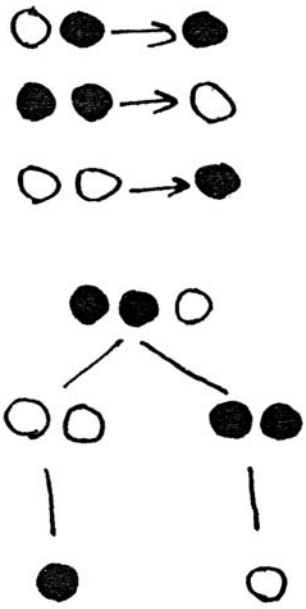
However, the question captured this case too–"what can we say" was: Nothing!

I cried out when I saw the solution: Extraordinary!!![7] I realized that the invariant pointed out by the solution assured the uniqueness of the final color—but somewhat a posteriori. *I felt then that "proving uniqueness" and "solving" were somewhat inseparable: a feeling close enough to the truth!*

Though I saw the solution, I couldn't explain in a transparent way why the color was unique; what was at hand seemed to be only an *a fortiori* proof.

Indeed, here is another game with non-unique final ball:

Rule0: W,B ->B, rule1: B,B->W, rule2:W,W->B for which {B,B,W} –r1->{W,W} –r2->{B} and {B,B,W}-r0->{B,B}-r1->W.



Clearly there must be a property that distinguishes the two games, assuring for the first the "uniqueness" property.

My paper concluded sharply:

"*The question of the problem contains a vague tone which cannot be made more precise. My initial desire of adding the statement '… it is simple to observe that the game has a uniqueness property, so find the* function *the game describes' is not advisable, and this is so because proving uniqueness is a task nearly as difficult as solving the problem. So, vagueness is the best possible form, giving at the same time a certain flavor to the question…*"

Programs and games

Let us think that the black ball is represented by 0 and the white ball by 1. Then the three rules of the game define a binary function from f:{0, 1}➔{0,1}. The function is commutative as indeed we pick the two balls together not in any particular order f(x,y)=f(y,x). With this notation, the move of the game becomes: "take two balls from the urn, {b0, b1} and return in the urn the ball f(b0, b1)." To see how this notation works, suppose that we have an urn with initial content {b0, b1, b2}. If the first pick is {b0, b1} then after the first move the urn has content{b2, f(b0,b1)}. After the second move then the urn will contain the ball f(b2,f(b0,b1)). Thinking this way, if all the plays starting from the initial contents of the urn end up with the same color for the final ball, i.e., is completely predictable, this is equivalent to the fact that all the f-expressions evaluate to the same value. This insight led me to the proof of the following:

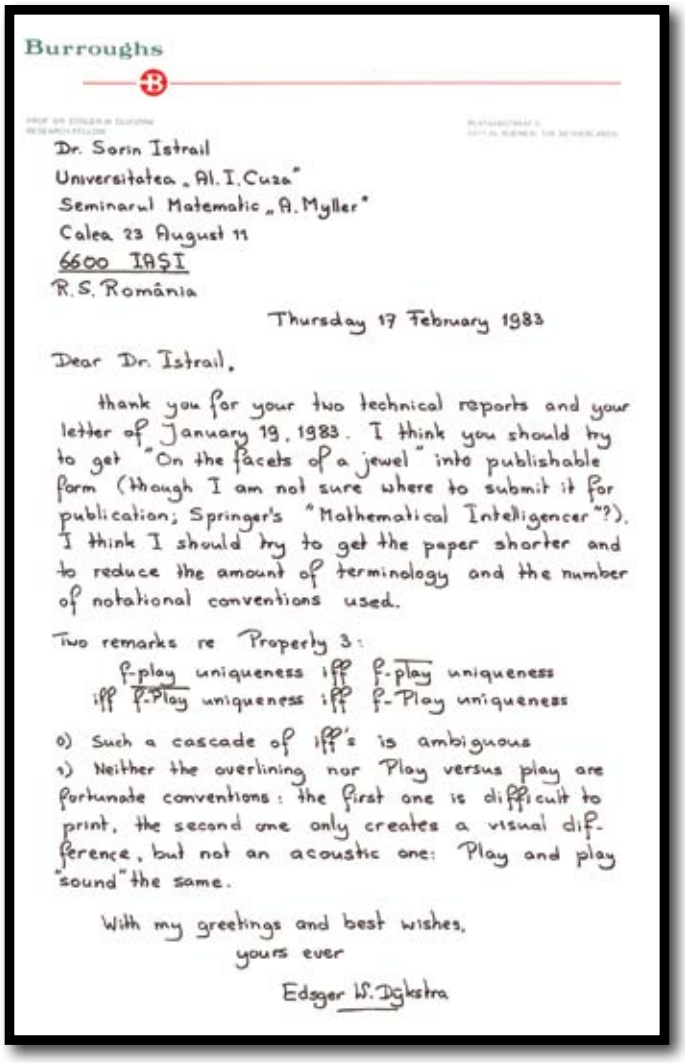
Theorem 0. A Dijkstra f-game with f commutative is completely predictable if and only if the function f is commutative and associative.

To understand the role of commutativity, I considered a new type of game, this time played with balls arranged in a sequence. (The distance between consecutive balls does not matter.) Pick two adjacent balls and return the resulting ball to the middle point of the removed two. This is equivalent to having an f-game that is no longer necessarily commutative. It turns out that we can prove the following:

Theorem 1. A Dijkstra f-game is completely predictable if and only if the function f is associative.

Anyone for a game on a Conway's Monster group Co1 with 4,157,776,806,543,360,000 elements? Any finite group would do. We start by bringing a contestant and do not share with her our secret from Theorem 0. We put in the urn a multi-set of elements of the group and we bet on the "color" of the final element in the urn. We can easily compute it (most of the time) and always win!

I sent my manuscript along with a letter seeking Dijkstra's forgiveness for its "somewhat sentimental" tone, a function of what I said was my "heartfelt desire" to correspond with him. But would that desire backfire as my colleagues suggested?



Burroughs

Dr. Sorin Istrail
Universitatea „Al. I. Cuza"
Seminarul Matematic „A. Myller"
Calea 23 August 11
6600 IAŞI
R.S. România

Thursday 17 February 1983

Dear Dr. Istrail,

thank you for your two technical reports and your letter of January 19, 1983. I think you should try to get "On the facets of a jewel" into publishable form (though I am not sure where to submit it for publication; Springer's "Mathematical Intelligencer"?). I think I should try to get the paper shorter and to reduce the amount of terminology and the number of notational conventions used.

Two remarks re Property 3:

P-play uniqueness iff P-play uniqueness
iff P-Play uniqueness iff P-Play uniqueness

a) Such a cascade of iff's is ambiguous
b) Neither the overlining nor Play versus play are fortunate conventions: the first one is difficult to print, the second one only creates a visual difference, but not an acoustic one: Play and play "sound" the same.

With my greetings and best wishes,
yours ever

Edsger W. Dijkstra

It's just business

My answer arrived from the Netherlands a month later in an envelope bearing Dijkstra's unmistakable handwriting.

Dear Dr. Istrail,

Thank you for your two technical reports and your letter of January 19, 1983. I think you should try to get "On the Facets of a Jewel" into publishable form (though I am not sure where to submit it for publication; Springer's "Mathematical Intelligencer"?) I think I should try to get the paper shorter and to reduce the amount of terminology and the number of notational conventions used."

He offered two excellent comments regarding one of the properties that I had noted and signed the letter, *"With my greetings and best wishes, yours ever, Edsger W. Dijkstra."*

There it was. A simple, elegant and generous response, scientist to scientist. Perhaps in reading the hundreds of EWDs I had discovered a message between the lines that my colleagues—concerned for my professional reputation—had not seen: Criticism is as fundamental to science as asking questions and Dijkstra was unafraid of honest, intellectual exchanges. As Michael Corleone said in *The Godfather*: It's nothing personal; just business.

But did he hold a grudge? We ultimately met face-to-face in Newport, R.I., in 1986. I call the episode "When Professor Dijkstra Slapped Me"—another story for another time.

What are the principles of criticism?

Clearly this is a difficult topic, yet it is important—criticism can and *should* be taught. But how? We should follow Dijkstra's lead and be substantively critical—verbally, by injecting tough questions at a technical talk, and in written analysis. Each has different challenges and inhibitions.

Why be critical at all? Clearly, it is easier to remain noncommittal. Obviously, there is resistance to opening your big mouth and asking a difficult question. You are moving from a state of equilibrium—of somewhat disengaged listening—to a state of non-equilibrium, on alert in dangerous territory. You would be making a statement, a public evaluation, perhaps pompous self-promotion—"Do you know who I am?"—in which your personal scientific weight is not unrelated to the seriousness of the answer from the speaker you critique.

What if this backfired? Are you prepared to clearly restate your point if the exchange becomes heated? Can you summarize eloquently and concisely the deep belief that triggered the comment without diluting the scientific integrity of the dialog?

In the end, substantive criticism says more about the critic than the critiqued. The unwritten rules of giving scientific talks are such that it is okay to ask tough questions; this is part of being alive scientifically. It is a lot of fun and to experience such rare and inspiring exchanges offers important lessons.

As for being on the receiving end of a tough question, how do you react? After all, it is not easy to receive criticism, especially in real time when you must respond coherently, defend your work and present counterarguments. On the plus side, being criticized means that the inquirer is so stimulated by your talk, she willingly leaves her equilibrium state to venture a question in order to learn more about your work.

I was privileged to write papers with Eric Davidson at the California Institute of Technology, Albert Meyer at MIT and Craig Venter at Celera Genomics—famously tough scientists who are legendary in their fields. Criticism offered by Davidson and Venter in the biological sciences bore a pronounced sense of urgency for the speed of discovery. Meyer, in computer science, delivered his criticism with intimidating, mathematically deep power. Venter's dramatic delivery was designed as a "poke in the eye" of deadlocked researchers. In sounding an alarm to leaders of the Human Genome Project about the "genome sequencing crisis," he echoed Dijkstra's

alarm to the computing community about the "software crisis."

Through my years of close collaboration, I learned that their criticism, though passionate, pointed and pronounced, was nothing personal; it's just business. Criticism is essential.

But sometimes being the critic has its price.

In 1994, while working at Sandia National Labs, I had the pleasure of hosting David Botstein of Stanford University (now at Princeton), inventor of the RLFP molecular biology procedure that revolutionized forensic analysis.

Our meeting occurred during the O.J. Simpson trial and Botstein, an outspoken and eloquent critic, had remarked that "biological data has the O.J. Simpson problem: No matter how good the data looks, it is full of errors!" I told Botstein that because of the O.J. Simpson trial, society would have a better understanding of his discovery, which, in my view, would lead him to winning a Nobel Prize. He disagreed. Big awards have components of popularity contests and political games, he said, and being bluntly honest and critical would not always win brownie points. I know that my three distinguished and exceedingly critical collaborators are only too aware of this. But as Cervantes' novel was revolutionary in discussing the distinctions of class and worth, I hope that (as we will see from our criticism equation, "Responsibility" cancels out "Inconvenience") the Nobel Prize and Turing Award committees are hard at work to include my three collaborators and Botstein—lighthouses worthy of highest distinction in their classes.

The axioms

"Chivalry is only a name for that general spirit or state of mind which disposes men to heroic actions and keeps them conversant with all that is beautiful and sublime in the intellectual and moral world."[8]

As knight-errant, Don Quixote tried bravely to force his contemporaries to face a crisis in chivalric code. Similarly, Dijsktra fought forcefully to have the computer programming community face a crisis in software code. Dijkstra's criticism was the analogue of Quixote's lance. Honor was the founding and guiding principle of chivalry and of Don Quixote, leading to battles in honor's name. Likewise, Dijkstra's approach to programming as a high intellectual challenge was the founding and guiding principle of his battles against anti-intellectual solutions to program construction. "Real programmers don't reason about their programs, for reasoning isn't macho. They get their substitute intellectual satisfaction from not quite understanding what they are doing in their daring irresponsibility and from the subsequent excitement of chasing the bugs they should not have introduced in the first place."[9] Don Quixote's belief in enchantment parallels Dijkstra's belief in mathematical beauty and simplicity, always the ultimate goal of reliable software design.

The Association of Computing Machinery's 1972 citation for Dijkstra's Turing Award reads not only like an induction as the Knight of Programming, but also as the Spiritual Leader of the Software Code. "The working vocabulary of programmers everywhere is studded with words originally or forcefully promulgated by E.W. Dijkstra… but his influence on programming is more pervasive than any glossary can possibly indicate. The precious gift that this Turing Award acknowledges is Dijkstra's *style*, his approach to programming as a high, intellectual challenge… and his illuminating perception of problems at the foundations of program design… his memorable indictment of the go-to statement… We have come to value good programs in much the same way as we value good literature. And at the center of this movement, creating and reflecting patterns no less beautiful than useful, stands E.W. Dijkstra." The ACM-EATCS Edsger W. Dijkstra Prize in Distributed Computing recognizes that "no other individual has had a larger influence on research in principles of distributed computing."

His silly games are not just elegant mathematical puzzles. They go to the heart of computer science. They are *simplest but not simpler* about the exceedingly difficult task of writing reliable large programs. They are unique in highlighting subtle points mathematicians often miss. His urn and

balls game is included in programming textbooks [6] as an example of a problem where design and testing would not quite do the job; it is the discovery of program invariants that holds the key.

Dijkstra's mathematical beauty axioms

In these axioms, "mathematics" and "computer science" are referred to especially in the context of "mathematical arguments relevant to automatic computing." And "mathematical beauty" is especially about the elegance of solutions and of proofs.

Axiom 0: Mathematical beauty is more important for computer science than for mathematics

Axiom 1: Proofs are more important than Theorems

Axiom 2: Mathematical beauty could and should be taught

Dijkstra's criticism axioms

How do we teach criticism? Here's one way: The NSF recently funded our proposal, "Sweatbox Q&A Boot Camp at Brown: Asking Tough Scientific Questions." I admiringly borrowed the concept from the Marine Biological Laboratory at Woods Hole, where legend says visiting speakers at its famous embryology course were brought to a warm room for a so-called sweatbox Q&A session.

Eric Davidson, for many years the course's teacher-in-chief, told me the story; our proposal also was inspired by his beacon of critical discourse. At the boot camp, Dijkstra's papers will be a must-read.

In talking about criticism, there are a several impressionistic quantities: authority (a), inconvenience (I), bravery (B), responsibility (R), substance (s) and energy of criticism (C). We have that C is proportional to R and B and that B and R are proportional to a, while R is proportional to I and s, and B is inverse proportional to I. It makes sense to define then $B = \frac{a}{I}$, $R = sIa$, and $C = RB$. It follows that "I" cancels and we get the *criticism equation* $C = sa^2$.

Axiom 0: It's nothing personal; just business [10]

Axiom 1: Principles only mean something if you stick to them when it's inconvenient [11]

Axiom 2: Authority is the speed of criticism

Though I've already stated my view that criticism is essential, I should mention that I also admire luminaries who have the opposite view. In fact, my hero-in-chief, John von Neumann, has put forward what we can call the von Neumann's criticism axiom, formulated by his daughter Marina von Neumann Whitman, who pointed out that he showed an impressive adherence to the old adage: *if you can't say something good about someone, don't say anything at all.*

The last letter

I did not share with Dijkstra, before his untimely death from cancer in 2002, my second set of results concerning the computational complexity of his urn and balls game. I would have enjoyed writing to him again about them. I probably would have written:

Dear Professor Dijkstra,

I have not written to you in a while. In 1983, I did more work on your urn and balls problem from "Why Correctness …" but then lost the manuscript (or so I thought). Earlier this year, I rediscovered it in a box in my basement. I am now finally writing "On the Facets of a Jewel" and intend to submit it, as you advised, to Mathematical Intelligencer.

I am including a second manuscript, "On the Facets of a Jewel II," containing several results on computational complexity that are related to your game and generalizations. It is quite interesting that they recapitulate some of the deepest concepts of computing science, such as Chomsky grammars, graph theory, NP-completeness and the UNSOLVABLE. So much for silly games!

The 2007 Turing Awards for Model Checking, given to Professors Edmund Clarke, E. Allen Emerson and Joseph Sifakis, are a splendid tribute to "Dijkstra's dream"—an era when designing programs and their mathematical proof of correctness go hand in hand. As you wrote in "Why Correctness…," "The most general topic… of the widest significance could be called "the scaling up of mathematics." As far as the traditional mathematician is concerned, "there is a big, big difference: never in his life has [he] encountered such big formulae." The hard-won battles of so many around logic, automata and graph theory led to the discovery of these two beautiful islands of practical tractability: LTL and CTL (You may call it a case of "after-war heroes," but I would like to have seen cited the 1995 paper "Bisimulation Can't Be Traced," which Albert Meyer, then-student Bard Bloom and I published in the Journal of the ACM. *We showed, conceptually, the above "2" by proving the impossiblity of axiomatizing Bisimulation within the axiom systems of linear processes.[12]).*

As Johnny von Neumann pointed out, "The very concept of 'absolute' mathematical rigor is not immutable"(see

[13]). Nor is "program correctness proof," as we can see from the spectacular achievements of model checking, which could aptly be called, using Lewin's quote, "There is Nothing So Practical as a Good Theory" or—even better—"Practical Theory Considered Beautiful."

The breakthroughs we are witnessing in computer science in the 21st century, including those of the Turing awardees and of Dijkstra Prize-winner Maurice Herlihy, my next-door colleague at Brown, are clear indications that the era of scaling up of mathematics has arrived.

To dream the impossible dream
To fight the unbeatable foe
To bear with unbearable sorrow
To run where the brave dare not go

To right the unrightable wrong
To love pure and chaste from afar
To try when your arms are too weary
To reach the unreachable star

This is my quest
To follow that star
No matter how hopeless
No matter how far

To fight for the right
Without question or pause
To be willing to march into Hell
For a heavenly cause

And I know if I'll only be true
To this glorious quest
That my heart will lie peaceful and calm
When I'm laid to my rest

And the world will be better for this
That one man, scorned and covered with scars
Still strove with his last ounce of courage
To reach the unreachable star [14]

Thank you for everything.

Yours ever,
Sorin Istrail

Looking at the three single moves possible, we observe that the last two (○ ● → ○ and ● ● → ●) leave the number of white balls in the urn unchanged, while the first move (○ ○ → ●) reduces the number of white balls in the urn by two. In other words, each move leaves the so-called "parity" of the number of white balls in the urn unchanged: an even number of white balls in the urn remains even, and an odd number of white balls in the urn remains odd. In short: if the initial number of white balls is even, the final ball is black, and if the initial number of white balls is odd, the final ball is white. And that answers the question!

References

[0] I would like to thank Tracie Sweeney, my editor and writing partner, for her wonderful work on this article. I would also like to thank Erin Klopfenstein for her many contributions to this article. Thanks go also to Shriram Krishnamurthi for an insightful discussion about model checking and to Franco Preparata who inspired my search for one of the axioms. Copies of original documents related to this article can be found at http://www.cs.brown.edu/~sorin/dijkstra

[1] http://en.wikipedia.org/wiki/Considered_harmful

[2] E.W.Dijkstra, *"The Humble Programmer"* Communications of the ACM, Vol. 11, No. 3, pp. 147–148, 1968
D.E. Knuth," *Structured Programming* with go to Statements", Computing Surveys, Vol. 6, No.4, pp. 261–301, 1974

[3] *I would receive once a month from Teleprocessing Inc. an envelope with the latest EWD writings—about 10–15 of them.*

[4] EWD340: "The Humble Programmer"; EWD473: "On the Teaching of Programming i.e., on the Teaching of Thinking"; EWD480: "Craftsman or Scientist?"; EWD709: "My Hopes for Computing Science"; EWD898: "The Threats to Computing Science"; EWD920: "Can Computing Science Save the Computer Industry?"; EWD1036: "On the Cruelty of Really Teaching Computing Science"; EWD1095:"Are 'Systems People' Really Necessary?"; EWD 1209: "Why American Computing Science Seems Incurable"; EWD1304: "The End of Computing Science?"

[5] EWD898, "The Threats to Computing Science"

[6] D. Gries, *The Science of Computing,* Springer, 1981

[7] The solution of the silly game is in on one of the pages of this article. However, the reader must discover it.

[8] K. Henry Digby, *The Broad-Stone of Honour*

[9] EWD1012: "Real mathematicians don't prove"

[10] Mario Puzo, *The Godfather,* 1962

[11] A line from the 2000 movie *The Contender*, directed by Rod Lurie, about the strength and triumph of a male Democratic U.S. president who refused to be intimidated in his selection of a powerful woman as vice president.

[12] B.Bloom, S. Istrail, A. Meyer, *Bisimulation Can't Be Traced*, Journal of the ACM, Vol. 42, No. 1, pp. 232–268, 1995.

[13] Sorin Istrail and Tracie Sweeney, "Randomness is Beautiful: In Search of von Neumann," *Conduit* Magazine (Brown University, Computer Science Research and Alumni News Magazine, Spring/Summer 2006, p. 10–15)

[14] "The Impossible Dream" from *Man of La Mancha*, music by Mitch Leigh, lyrics by Joe Darion ■

The Faculty Speak Out

Ugur Cetintemel

Q&A with Ugur Cetintemel

How did you first become interested in computer science?

Through games. Growing up I had a Commodore 64 and spent a lot of time playing games. I probably spent as much time waiting for games to load from the data tape—anywhere from five to twenty minutes—and adjusting the tape head with an electric screwdriver to make them load correctly. The more time I invested, the more I understood and appreciated the technology.

How do you pick your research problems?

The motivation usually comes from an application domain not well supported by current systems software. A project typically starts with a question like, "wouldn't it be cool to have a system that does x?" If we can convince ourselves that the answer is yes, then we roll up our sleeves and try to build a prototype. All sorts of architectural and algorithmic challenges surface along the way. More often than not, there are simply too many challenges to address, so it becomes crucial to also decide what not to do.

"More often than not, there are simply too many challenges to address, so it becomes crucial to also decide what not to do."

What do you consider the most interesting and exciting challenges of your research?

My work is mostly experimental and follows the basic scientific method. We define the problem, hypothesize a solution and experimentally evaluate it. Based on the results, we refine the solution and repeat the process. There is much unpredictability and complexity in all stages of the process—this makes things different and interesting each time we do it.

Do you have a favorite project that you've worked on?

My Ph.D. thesis work is my favorite; it is on maintaining the consistency of replicated data in weakly connected systems. I like it not because it led to the best publications or made the most impact, but because it is the project on which I've had the most sweat equity.

How do you see your field evolving over the course of your career?

The database field has been broadening continuously, but the pace significantly increased in the last five years or so. The field started as a response to transaction processing applications. It then evolved to also address data analytics and warehousing. Recently more and more data-centric application domains have been emerging—web, big science, sensor streams. All these domains can benefit from the core data management principles: top-down design, declarative tasking and data independence. Thus, people have started to develop domain-specific database systems, which look very different than the good old Oracle or DB2.

What's the "next big thing" in databases?

I think there will be a shift of attention from database systems to data management systems. Database systems provide valuable services if you take the time to clean up your data, normalize it and load it in a single system. This is becoming infeasible in many cases—today data is spread across a large number of diverse applications, data repositories and formats. Managing access to the flow of data is accomplished through ad-hoc approaches, leading to performance, correctness and security issues. A data management system that oversees how data is maintained and accessed across disparate sources in a principled fashion would solve a lot of problems.

If you had enough extra time to study one additional area, what would it be?

There are so many interesting things to learn but if I had to pick one I would go with industrial design. Closer to home, it would be computational finance.

Q&A with Ben Raphael

How did you first become interested in computer science?

As a high school student I read many articles about neural networks, which were one of the hot topics in artificial intelligence at that time. I went to college planning to major in computer science, thinking I would program computers to learn like humans. Instead, I ended up studying mathematics and molecular biology (it's a long story). But after graduate work in mathematics, I returned to computer science via computational biology. So my route to a computer science department was fairly circuitous.

What motivated you to focus on your current research?

"Doing research at the interface of two disciplines is not easy but successfully using techniques from computer science to advance biological knowledge is tremendously rewarding."

Ben Raphael

One of my current research interests is examining the genome sequences of cancer cells and developing algorithms to identify and characterize the mutations responsible for "reprogramming" normal cells into cancer cells. This project began several years ago during my postdoc when cancer biologists contacted my advisor about a new approach they had developed for sequencing cancer genomes. We found their data intriguing from a computational perspective and developed some techniques to analyze it. While writing the paper with our results, I thought it would be helpful to learn some cancer biology. So I read a bunch of biology papers and talked with the biologists. I discovered that there are many challenging computational problems in understanding cancer development.

What do you consider the most interesting and exciting challenges of your current research?

Working in an interdisciplinary field like computational biology is challenging because computer science and biology have very different goals and cultures. Biologists aim to answer biological questions. Although they might require new algorithms to analyze their data, they typically do not care how efficient the algorithm is, as long as it works. A computer scientist on the other hand will not be impressed with a brute-force solution and will want to design the most efficient algorithm possible. Ultimately, as computational biologists, we aspire to design computational techniques that allow new biological questions to be asked and answered. Thus we aim to work on problems that are both biologically and computationally interesting. This requires working closely with biologists and bridging the communication barriers between the two fields. Doing research at the interface of two disciplines is not easy but successfully using techniques from computer science to advance biological knowledge is tremendously rewarding.

Do you have a favorite project that you've worked on?

The short answer is that my favorite project is always the one I'm currently working on. Nevertheless, I will always have a fondness for some of the first times that I felt the exhilaration that comes from making a new discovery. One time that comes to mind is during my Ph.D. work. We had developed some theoretical techniques that allowed us to reduce an open conjecture in a branch of mathematics called operator theory into a calculation that could be done on a computer. I implemented our approach, ran it and found a counterexample to the conjecture. Looking at the computer screen at that moment, I knew that I was seeing a mathematical object that no one else had seen before. Having just a few of these "discovery moments" are enough to carry me through the years of hard work that it can take to reach them.

How do you see your field evolving over the course of your career?

Computational biology, and arguably biology in general, are driven by technological development. New technologies for DNA sequencing and gene expression measurement have revolutionized biology in the past decade and increased the demand for computational and statistical methods. In some ways, computer science and statistics provide a bridge between the measurements that are currently feasible and the biological question one wants to answer. As the technologies change, so too do the needs for new algorithms. Someday we might have a miracle machine that measures the quantity and spatial locations of all molecules in a single cell at a fixed time. Analyzing and interpreting the measurements from this machine to reverse-engineer the workings of a cell would be a fascinating problem. I'm not worried that all of the fun problems in computational biology will be solved before my career ends.

What's the "next big thing" in genomics?

DNA sequencing technology is developing very rapidly and becoming orders of magnitude cheaper and faster. There are many researchers pursuing the "$1000 genome," which compares very favorably to the $2-3 billion estimated cost for the original Human Genome Project. Cheap DNA sequencing will transform much of genomics and genetics by making it possible to compare the complete genome sequences of many different species and many individuals within a species.

continued on page 21

Michael Black

Michael Black

In January, Michael assumed the role of director of graduate study, replacing Maurice Herlihy.

Michael's conference travels took him to Alaska to see the glaciers before they melted, Venice to see the city before it sank and Sweden to sweat in the sauna before the whole world became a sauna. He spent a good part of the summer in Stockholm working with colleagues at the Royal Institute of Technology (KTH) and enjoying the long days of the Scandinavian summer.

Michael received a grant for $370,000 from the National Science Foundation to support his group's research on "Human Shape and Pose from Images." He also updated the video and motion capture lab with eight new synchronized high-definition color cameras.

Amy Greenwald

Amy's summer was bookended by conferences; her first without either of her kids (they're growing up!). She spent Memorial Day at Caltech at a mini-conference on Microeconomics Dynamics where she gave an invited talk about an algorithm to compute the stochastically stable distribution of a perturbed Markov matrix. She spent Labor Day in Liverpool at a workshop on Market-Based Control. There, she gave an invited talk about a novel algorithm for ranking individuals in a social network. Both of these invited talks discussed her joint work with John Wicks, Ph.D.

In the middle of the summer, Amy went to Chicago to attend three overlapping conferences: EC, AAAI and Games. This time, her husband Justin flew out with the kids to spend the intervening weekend.

Although Amy did not attend any European conferences this summer, Geoff Gordon presented their work (joint with Casey Marks, Ph.D.) at ICML and Warren Schudy presented their work at COLT.

John "Spike" Hughes

Spike (along with Steve Reiss, Tom Doeppner and Shriram Krishnamurthi) was awarded a National Science Foundation CPATH grant for Applied Computer Science, Social Sciences and Humanities. He was also selected as the new chair of the SIGGRAPH Technical Awards Committee.

Sorin Istrail

Sorin's first postdoctoral fellow at Brown, Fumei Lam, completed her term here and moved on to work at the University of California, Davis. Sorin and his Ph.D. student, Ryan Tarpine, participated in a number of conferences including the 2008 Sea Urchin Meeting in April, at which Ryan gave a talk entitled, "CYRENE: A cis-Browser and cis-Module Lexicon Database for Gene Regulatory Networks." Three of Sorin's undergraduate students graduated in May 2008, one of whom, Lian Garton, received the SC Lamport Award for her outstanding achievements, including an honors thesis. Lian is now working at Amazon. Undergraduates David Moskowitz and Allan Stewart received named UTRA awards; David received the UTRA Program Award and Allan received the George I. Alden Trust UTRA. Six undergraduate students, including one from Carnegie Mellon University, worked in Sorin's lab this past summer. Finally, Sorin's small army of annotators was enriched by the recent hire of eleven more undergraduates (biologists and computer scientists) for the fall and spring semesters to continue work on the Cyrene cis-Lexicon project.

Sorin was invited to give a distinguished lecture at the University of Illinois at Urbana-Champaign. His lecture entitled, "The regulatory genome and the computer," was held on April 28, 2008. He also gave a keynote lecture at the Georgia Institute of Technology in October 2008. Sorin made two visits to Caltech so far this year, one in March and the other in August, to continue the ongoing collaboration he and his lab have with Eric Davidson. In September, Sorin participated in "The Genomics of Common Diseases 2008," a *Nature Genetics* and Wellcome Trust annual meeting. Sorin also went to the National Academy of Sciences conference, "From Science to Industry: Successes and Challenges of the U.S. – Israel Binational Model," on June 17, 2008.

Sorin hosted several visitors in his lab. Visitors included Antonio Piccolboni (Affymetrix), Shibu Yooseph (Venter Institute), Bjarni Halldorsson (deCODE Genetics/Reykjavik University), Jonathan Yewdell (NIH National Institute of Allergy and Infectious Disease), Mitchell Sogin (Marine Biology Laboratory), Jeremy Smith (Oakridge National Laboratory), Christian Masalagiv (Ai.I.Cuza), Simon Kasif (Boston University and Children's Hospital, Boston) and Roded Sharan (Tel-Aviv University). Each visitor gave a lecture as part of the Center for Computational Molecular Biology Seminar Series. Additionally, Sorin hosted a month-long visit in August by Professor Solomon Marcus (see photo below), his former Ph.D. adviser, who gave eight lectures in the Department of Computer Science under the title, "The Loneliness of the Mathemetician." Professor Marcus is a member of the Romanian Academy of Sciences and Emeritus Professor of the University of Bucharest. He is recognized as one of the founding fathers of mathematical linguistics.

Sorin was awarded a National Science Foundation grant for his proposal entitled, "Sweatbox Q&A Boot Camp at Brown University: Asking Tough Questions." The proposal is for student support for the next symposium in the symposium series entitled, "The Genome and the Computational Sciences: The Next Paradigms." Students involved in the workshop will have the unique opportunity not only to attend the distinguished lectures, but also to play a novel role in the Sweatbox Q&A Sessions.

Philip Klein

Philip returns to Brown this fall after being a visiting scientist at MIT while on sabbatical. He is teaching a new course on applications of linear algebra in computer science.

Philip's Ph.D. student, Glencora Borradaile, graduated and is now a postdoctoral fellow at Waterloo.

Shriram Krishnamurthi

Shriram had an extremely productive summer with a new group of students, including several sophomores. His senior Ph.D. student, Jay McCarthy, defended, started on the faculty at BYU and became a father for the first time—congrats, Jay! Shriram spent two weeks in Brazil where he gave a keynote talk at the Brazilian programming languages symposium. In addition to the joy of being back amidst tropical fruit, his personal highlight was attending football games at Maracãn, a stadium. In the spirit of equality he attended games of both the great rivals, Flamengo and Fluminense, accidentally ending up in their cheering sections amidst samba drums and flares.

Anna Lysyanskaya

In May, Anna's first Ph.D. students, Mira Belenkiy and Melissa Chase, received their Ph.D.s and are now at Microsoft: Mira in the Crypto Tools group and Melissa as a postdoctoral fellow at Microsoft Research. Although Anna misses them already, she is going to visit Microsoft in December and Mira and Melissa won't get rid of her any time soon!

continued from page 19

Another exciting development is that Anna wrote an article for the September 2008 issue of the Scientific American magazine. Her task was to explain the state of the art in cryptography for a general audience; that is, an audience that has never heard about the P vs. NP problem and does not have the faintest idea about computational hardness.

So, saying things like "forging a signature is computationally intractable" is not allowed. Luckily, the SciAm has amazing editors and unbelievable illustrators, so the end result is pretty accessible to non-CS people.

A travel highlight for this summer was attending the Summer School on Rational Cryptography, co-organized by Nikos Triandopoulos (Ph.D. '06) in Bertinoro, Italy. This was about the intersection of cryptography and game theory. The format was great—every speaker had a couple of hours, so you could really learn something in-depth and Nikos and company put together a great program (and also gave great talks themselves). Anna's talk was on the Brownie points project—the project where we want to incentivize peer-to-peer systems such as BitTorrent using electronic cash (www.cs.brown.edu/research/brownie).

Claire Mathieu

Claire was the program chair of the 2009 ACM-SIAM Symposium on Discrete Algorithms (SODA). It was a major endeavor! During the summer of 2008, the program committee, scattered over seven different countries (Canada, France, Germany, Israel, the Netherlands, the U.K. and the U.S.) read 459 submitted papers and had an electronic meeting to select the best 135.

Claire also did a short Tour de France, giving talks at Sophia-Antipolis (INRIA), University of Bordeaux and Ecole Polytechnique. Finally, Claire spent a few days vacationing on the beach of Houlgate, Normandy.

Barbara Meier

Animation is alive and well in computer science after budget woes last spring threatened its future. Many thanks to all former students and alumni who wrote letters that helped convince the University to continue their support of our computer animation courses. The overwhelming response was a surprise and personally very heartwarming. It was also great to learn that about a quarter of students who took my animation courses at Brown have worked in production related jobs or are studying animation in graduate school. Once bitten, always smitten!

The animation courses continue to evolve. While the underpinnings of great animation—story and visuals—remain the same, the ways of creating animation change significantly every year with advances in hardware and software. At the same time, resources for learning—books, DVDs and online tutorials—have proliferated. As we revamp our introductory course this year, we will be asking students to learn more of the basics outside class and have more discussions and labs during class where we can guide the application of the basic knowledge. We hope the new format will pay off in even better films than previous years for our end-of-semester show.

Ben Raphael

Evan Raphael

Ben had a great time teaching his first undergraduate class at Brown, CS22, in the spring semester. He found that the buzz about the pleasures of teaching Brown undergrads and working with the UTAs was true. Hopefully the students shared similar feelings. This year he will teach a new undergraduate class in computational biology in the spring and a graduate seminar in the fall. Ben's research group continues to expand and now includes two Ph.D. students and one master's student. He is very proud that Anna Ritz, one of his Ph.D. students, received an NSF Graduate Fellowship this spring. Ben received a grant from the Susan G. Komen Breast Cancer Foundation with Susan Gerbi and Alex Brodsky in the MCB Department. Ben and his wife Pat's ambitious plans for exotic summer travel were curtailed by the birth of their son Evan in early August. But earlier in the year, Ben gave invited talks at UCLA, the University of Connecticut, the SIAM Meeting on Discrete Mathematics and the Bertinoro Systems Biology Meeting. He also travelled to Vancouver for a review panel, a trip that was much too short to sample many of the excellent restaurants there.

John Savage

This fall John is on sabbatical leave, which has provided a natural breaking point in his service on three committees, namely, the Faculty Committee on the Campaign (chair), the Nominations Committee and the Computer Science Curriculum Committee (chair). He has published three papers with Eric Rachlin. The first, "Analysis of a Mask-Based Decoder," appeared in *IEEE Transactions on Computers* in February. The second, "A Framework for Coded Computation," appeared in the proceedings of the IEEE International Symposium on Information Theory. The third, "Nanowire Addressing with Randomized-Contact Decoders," appeared in the special issue of *Theoretical Computer Science* and honors John's colleague, Franco Preparata. John also presented a poster with Jennifer Long at NSTI-Nanotech 2008 entitled, "Modeling and Analysis of a Membrane-Based Randomized-Contact Decoder." John gave invited lectures at the University of Texas, Austin in Feb-

One area attracting attention is "personal genomics," which includes the identification of all of the genetic differences in an individual's DNA sequence and the correlation of these variants with traits such as disease risk or drug sensitivity. There are already a few consumer personal genomics companies that offer such services, although the information they provide is fairly limited.

A related area is "personal oncogenomics," which is the measurement of the mutations in an individual tumor and the use of this information to guide treatment decisions. There are now several such personalized treatments in use and more in development. For my research, I am very excited about using these new DNA sequencing technologies to examine how mutations differ between cancer patients, differ between cells within one tumor and change over time or in response to drug treatment. We have already developed some algorithms for this type of data but there will inevitably be new computational challenges. Ultimately, we may have enough information to model cancer development as an evolutionary process in a population of cells.

Q: If you had enough extra time to study one additional area, what would it be?

Music. Someday I hope to have the time to master a musical instrument. Maybe I will learn with my kids… after tenure, of course. ■

Meinolf Sellmann in Chicago

ruary and the University of Connecticut in March. He also gave an invited lecture at the IEEE International Symposium on Defect and Fault Tolerance in VLSI Systems in October.

Meinolf Sellmann

Meinolf's spring semester was mostly filled with research related activities. He served as PC member for CPAIOR, ECAI and AAAI, for which he also put the workshop program together, fulfilling his role as workshop chair in collaboration with Simon Parsons (Brooklyn College).

At CPAIOR in Paris, Meinolf presented two papers, one of which investigated the accuracy of search heuristics (joint work with Brown alum Daniel Heller, see Conduit Spring '08). At AAAI in Chicago, Meinolf presented the results of his work with Brown graduate student Serdar Kadioglu on efficient grammar constraints (see photo above).

Other travel took Meinolf to Pittsburgh, where he gave two invited presentations at Carnegie Mellon University, the Max Planck Institute for Informatics in Saarbruecken (Germany), where he presented his Cornflower project, and Montreal (Canada), where he worked with his colleagues from the University of Montreal. In collaboration with Gilles Pesant and Bernard Gendron (both University of Montreal), Meinolf served as editor for a special issue of Computers and Operations Research. He also hosted his friend Carlos Ansotegui from the University of Lleida (Spain) as part of Carlos' sabbatical in July. Finally, Meinolf continues to serve as president of the Constraint Programming Society in North America and is happy that the society's constitution has been ratified by its members in June.

Don Stanford

In addition to his teaching duties in CS and the PRIME program in Engineering, Don has recently been asked by his former company, GTECH, to return for a period of time to lead the technology organization. Now he is spending a good deal of time there as the interim CTO and Technology Fellow working on several initiatives that are critically important to the Company. His retirement is on hold for the time being. Thankfully Don's arrangement with GTECH still enables him to continue as an adjunct at Brown!

Roberto Tamassia

Roberto received a new grant from the National Science Foundation for a project entitled, "Algorithms for Graphs on Surfaces," which he is doing in collaboration with David Eppstein and Mike Goodrich of UC Irvine. This is the fourth active NSF award for which Roberto currently serves as an investigator.

Roberto's travels last summer included a visit to Yahoo! Research in Silicon Valley where he gave a talk entitled, "Efficient Authentication of Outsourced Data" and participation in the CRA Conference at Snowbird, UT, a biannual meeting for chairs of Ph.D.-granting CS and CE departments and leaders from the computing industry and government agencies. Additional excitement came from surviving a tornado in Chicago and an earthquake in California.

In September, Roberto delivered an invited lecture entitled, "Graph Drawing for Security Visualization" at the Symposium on Graph Drawing, which was held in Heraklion, Greece. The lecture included a demonstration given by Ph.D. student Charalampos (Babis) Papamanthou of a system for visualizing file permissions, a project also done in collaboration with undergraduate student Alexander Heitzmann and visiting Ph.D. student Bernardo Palazzi. On their way back to the U.S., Babis and Roberto visited General and Mrs. Kanellakis in Athens (see page 33).

As Roberto was starting his second year as department chair, he was amused by the following note in an email from an alum and decided it appropriate to share here: "I see that you are now the chairman of the department. Congratulations! (I'm assuming this was a choice you made, not punishment for some sin)."

Eli Upfal

Eli is back from a year long sabbatical at the University of Padova, Italy. The University of Padova is one of the world's oldest universities (Galileo taught there during the 16th century) and is still one of Europe's leading universities. The university and the historic town of Padova are full of art and cultural treasures (and excellent restaurants), which made the stay there particularly enjoyable. While in Europe, Eli visited and gave talks at the University of Paris, Warwick University (UK), Chalmers University (Sweden), La Sapienza University (Rome) and he also taught a week-long crash course on probability and computing at the prestigious Scuola Normale di Pisa. Of all the papers Eli published during his sabbatical year, he is particularly happy with the title, "The Hiring Problem and Lake Wobegon Strategies," which evaluates hiring selection strategies that promised a work force "where all employees are above average."

Pascal Van Hentenryck

In May, Pascal gave invited talks at the SIAM Optimization meeting in Boston and at CP-AI-OR'08 in Paris. Together with Gregoire Dooms, Luc Mercier and Laurent Michel, he also had four papers at CP'AI'OR. In July, Pascal travelled to Patras in Greece to deliver another invited talk at ECAI'08, the European Conference on Artificial Intelligence. Patras is the hometown of Yannis Vergados, a former Ph.D. student at Brown, so Pascal had the chance to enjoy Greek hospitality at its best. Greece has changed in the last ten years but it still retains its charm and the countryside remains as beautiful as ever. Justin Yip, Pascal's Sc.M. student, went to AAAI'08 in Chicago to present his paper on constraint programming over sets, while Manuel Cebrian, who was a postdoctoral student in the department, presented their joint work with Peter Clote and Ivan Dotu on structure prediction for proteins. This summer, Pascal spent a week in Normandy with his family and their cousins—his son being passionate about US and world history. It is a unique experience that even recent movies cannot really capture. Finally, this fall, CS031 (aka CS-0310, since the Banner software at Brown loves leading and tailing zeros) has its largest enrollment in six years (an increase of about 20%), which is reassuring for computer science and the US economy. ■

Department Awards and Honors

John Hughes

David Laidlaw

Amy Greenwald

Hughes and Laidlaw Promoted to Professor; Greenwald and Lysyanskaya Promoted to Associate Professor

The department is excited to announce the promotions of John "Spike" Hughes and David Laidlaw to professor and Amy Greenwald and Anna Lysyanskaya to associate professor with tenure, effective July 1, 2008. "These faculty members are highly visible, internationally respected in their fields and have a strong commitment to teaching and advising. They contribute in important ways to the department and Brown University, as well as the field of computer science as a whole," said Department Chair Roberto Tamassia. "We are thrilled that the Corporation of Brown University has recognized the outstanding work of Amy, Anna, David and Spike by promoting them to a higher academic rank."

John "Spike" Hughes

Spike joined our department after being on the math faculty at Brown for several years. His research is in computer graphics, focusing on problems that involve substantial mathematics. In particular, he has worked on geometric modeling, user interfaces for modeling and non-photorealistic rendering. Spike is among the handful of authors worldwide who have 20+ papers published in SIGGRAPH, the premier publication venue for the field of computer graphics. He has served as an associate editor for ACM Transaction on Graphics and the Journal of Graphics Tools and has been on the SIGGRAPH program committee multiple times. Spike has just been appointed chair of the SIGGRAPH Technical Awards Committee. He is co-author of "Computer Graphics: Principles and Practice," a standard textbook and reference work and is currently developing a major rewrite of the book.

Spike's recent projects include a gesture-based interface to creating 3D models, methods for the representation and sketching of free-form shapes and a multi-focus, single-view-axis camera for automated matte-extraction for video. Together with three other CS faculty, he was recently awarded a large grant from the NSF to develop an integrated and rigorous set of courses for teaching computer science to students in the humanities and social sciences. The project aims to fill an educational void by providing the appropriate computer science skills to these students and stressing web-based gathering and dissemination of information.

David Laidlaw

A Brown CS alum (Sc.B. '83 and Sc. M. '85), David returned to our department as a member of the faculty after completing his Ph.D. and postdoctoral research at Caltech. His current research interests revolve around visualization and modeling applications of computer graphics and computer science to other scientific disciplines. David has been PI or co-PI for multiple projects sponsored by NIH, NSF and private foundations with overall funding exceeding $10M. He has served as associate editor of IEEE Transactions on Visualization and Computer Graphics and has received several awards from IEEE, ACM and NSF for his work on visualization. He is the recipient of an NSF CAREER award and a Henry Merritt Wriston Teaching Fellowship from Brown.

Several compelling applications give a real-world direction to David's computational research. He is working with researchers in developmental neurobiology, evolutionary biology, medical imaging, neuropathology, orthopedics, art, cognitive science, remote sensing and fluid mechanics to develop new computational applications and to understand their strengths and weaknesses. David is currently focusing on the visualization of multi-valued multidimensional imaging data, comparisons of virtual and non-virtual environments for scientific tasks and applications of art, perception and cognition to visualization.

Amy Greenwald

Amy joined our department after completing her Ph.D. at NYU and postdoctoral research at the IBM T.J. Watson Research Center. Her honors include an Alfred P. Sloan Research Fellowship, a Presidential Early Career Award for Scientists and Engineers (PECASE) and an NSF CAREER award. Amy's current research has twin goals: to design and implement AI agents that interact effectively in complex environments and to understand, explain and accurately predict the dynamics of such interactions.

Humans make hundreds of routine decisions. In our increasingly networked world, fewer and fewer of these decisions can be made in isolation. Someday soon, our interactive decision-making will be carried out by AI agents—artificially intelligent, programmed decision-makers—that "understand" our individual preferences and

Anna Lysanskaya

negotiate with one another accordingly. These AI agents will learn to both cooperate and compete with other agents, both human and artificial. Proxy bidders in online auctions are early evidence of this coming generation of AI agents. Amy's research is helping to lay the foundation for a future where AI agents figure prominently in our daily lives. She has recently co-authored a book on autonomous bidding agents that provides the first integrated treatment of methods in the emerging field of trading agent research.

Anna Lysyanskaya

Anna came to our department after completing her Ph.D. at MIT. She was awarded an Alfred P. Sloan Research Fellowship and an NSF CAREER award and was included in the 2007 Technology Review TR35, an honor given each year to 35 innovators in science and technology under the age of 35 whose inventions and research the magazine finds most exciting.

Balance between privacy and accountability is a central theme of Anna's research. When accessing an online service provider, a user must present evidence that she is authorized to do so. For example, she may be authorized to participate in an online game once a day if she has a license to play. On the other hand, if users are required to disclose their identities and show their credentials in the clear, their privacy is jeopardized. Anna has found that the two requirements—the service provider's need to verify that the user is authorized and the user's need to protect her privacy—do not contradict each other. What is needed is an "anonymous credential" system that would allow a user to prove that she is authorized without revealing her identity and further, to obtain additional credentials without revealing additional information. Anna's research in this area has attracted industry attention: for example, it has been incorporated into the Trusted Computing Group's industry standard and it has been implemented by IBM.

Rodrigo Fonseca

Rodrigo Fonseca and Erik Sudderth to Join the Department as Assistant Professors

The department has hired two new faculty members, Rodrigo Fonseca and Erik Sudderth, who will both start at Brown in the fall of 2009. Rodrigo will join the department after doing postdoctoral work at Yahoo! Research and receiving his Ph.D. from the Computer Science Division of the University of California at Berkeley. His interests lie at the intersection of networking, operating systems and distributed systems. Erik will come to Brown after serving as a postdoctoral scholar at the University of California at Berkeley. He received his Ph.D. from MIT and his interests include statistical machine learning and computer vision.

With the addition of Erik and Rodrigo, the department is expected to reach a record number of 26 tenured and tenure-track faculty on its 30th anniversary next fall. Our two new faculty members will help serve our growing population of graduate and undergraduate students. "Both Rodrigo and Erik are exceptionally bright, talented young scholars and we are thrilled to have them join our department," said Chair Roberto Tamassia. "We are all looking forward to welcoming them to Brown next fall."

Rodrigo Fonseca

Rodrigo received his M.S. and B.S. in computer science from the Universidade Federal de Minas Gerais in Brazil and expects to complete his Ph.D. in 2008 from the Computer Science Division of the University of California at Berkeley. In 2004, he was the recipient of a UC Berkeley/United Nations Industrial Development Organization Fellowship and in that year he also served as a research intern at Hewlett-Packard Labs in Palo Alto, working on wide-area internet latency and bandwidth measurement. He has been invited to give a number of talks including, "4-Bit Link Estimation" at Stanford University and "X-Trace: A Pervasive Network Tracing Framework" at Cisco, Google and Nortel. Rodrigo's current research deals with providing visibility into the execution of widely distributed applications with heterogeneous components with the purpose of improving performance and troubleshooting. He is also working on projects related to wireless sensor networks and information forensics.

Broadly, Rodrigo is interested in understanding the behavior of systems with many components for enabling new functionality and making sure they work as they should. He is also interested in the impact that telecommunications and computing may have on development.

"I am very excited to be joining the CS Department at Brown," Rodrigo said. "The University

has the right combination of a friendly, productive environment and excellent faculty and students.
I am eager to contribute to teaching and research and to foster productive collaborations."


Erik Sudderth

Erik Sudderth

Erik received his B.S. from the University of California, San Diego and his Sc.M. and Ph.D. from MIT and comes to Brown after serving as a postdoctoral scholar at the University of California at Berkeley. In 2004–2005, he was the recipient of an Intel Foundation Doctoral Fellowship. He served as a research intern at Mitsubishi Electric Research Laboratories, using graphical models to design and analyze error correcting code. Erik has been invited to give a number of talks including, "Learning Object Appearance Models via Transformed Dirichlet Processes" at Stanford University and at Google and "Visual Tracking using Nonparametric Belief Propagation" at the Institut National de Recherche en Informatique et en Automatique in Rennes, France as well as at MIT and Intel Research. His research explores computer vision systems that detect, recognize and track objects in complex natural scenes.

Erik's current focus deals with developing and applying statistical tools including: probabilistic graphical models, nonparametric Bayesian statistical methods, object recognition and scene understanding and image processing.


Maurice Herlihy

According to Erik, "The Brown CS Department has a tradition of interdisciplinary research, which I find very appealing. My own work in statistical machine learning and computer vision has interesting connections to ongoing research in the departments of cognitive and linguistic science, neuroscience, engineering and applied mathematics. Moreover, the CS Department's small size and friendly atmosphere create great opportunities for internal collaboration. I look forward to exploring exciting new application domains for statistical methods."

Doeppner, Hughes, Krishnamurthi and Reiss Awarded $540,000 from the NSF

The National Science Foundation has recently awarded Professors Tom Doeppner, Spike Hughes, Shriram Krishnamurthi and Steven Reiss a grant in the expected amount of $540,000 to develop an integrated and rigorous set of courses for teaching students in the humanities and social sciences concepts from computer science. The project entitled, "Applied Computer Science for the Humanities and Social Sciences," aims to fill an educational void by providing the appropriate computer science skills to these students and stressing web-based gathering and dissemination of information. It will give students in the humanities and social sciences the appropriate background to apply computational resources and techniques to their chosen fields of study and their eventual careers.

A key premise of the project is that students in the humanities and social sciences will be better motivated to get the computing and mathematics background they need if they can see its immediate applicability to their personal areas of study. This program is designed as an adjunct to a student's normal concentration. It provides application-tailored knowledge and tools without the depth and breadth of a complete computer science degree. The program is aimed at applying computer science rather than mastering computer science and at motivating the necessary mathematical material through a goal-directed approach where topics are introduced when they serve to let students cross a hurdle.

The Brown community is enormously supportive of this work. Colleagues in the archeology, classics, economics, german studies, music, political science and sociology departments and the University's Scholarly Technology Group have expressed an interest in participating. "This project demonstrates Brown's collaborative environment at its best and the department is grateful to Tom, Spike, Shriram and Steven for spearheading such an important experiment," stated Roberto Tamassia, chair of the Department of Computer Science.

Maurice Herlihy Honored with ISCA Influential Paper Award

Along with coauthor J. Eliot B. Moss, Maurice Herlihy was given an award for the most influential paper by the Association for Computing Machinery Special Interest Group—Computer Architecture (ACM SIGARCH) and the Institute

of Electrical and Electronics Engineers—Computer Society Technical Community on Computer Architecture (IEEE-CS TCCA) for his 1993 paper, Transactional Memory: Architectural Support for Lock-Free Data Structures. The presentation took place at the 35th International Symposium on Computer Architecture (ISCA), held in Beijing, China on June 24, 2008.

This award recognizes his paper from the International Symposium on Computer Architecture Proceedings 15 years earlier that has had the most impact on the field in terms of research, development, products or ideas during the intervening years and includes an honorarium of $1,000 for the authors and a certificate.

This paper introduced "Transactional Memory," an approach to programming multiprocessor systems that avoids many of the hazards and pitfalls of conventional lock-based approaches. According to the award-winning paper, "Transactional memory allows programmers to define customized read-modify-write operations that apply to multiple, independently chosen words of memory. It is implemented by straightforward extensions to any multiprocessor cache-coherence protocol. Simulation results show that transactional memory matches or outperforms the best known locking techniques for simple benchmarks, even in the absence of priority inversion, convoying and deadlock."

"Transactional memory is a large, lively area today, but this paper went mostly uncited for a decade until technological changes caught up," commented Maurice. "Therefore, I'm especially thrilled to receive the distinction of most influential paper fifteen years later."

Another one of Maurice's papers that was presented in 1993 at the 25th Annual ACM Symposium on Theory of Computing, "The asynchronous computability theorem for t-resilient tasks," led to his 2004 Göedel prize in theoretical computing.

Sorin Istrail to Establish John von Neumann Distinguished Lecture Series

Sorin, along with Leon Cooper, Thomas G. Watson Senior Professor of Science and Director for the Institute for Brain and Neural Systems, Stuart Geman, James Manning Professor of Applied Mathematics and Roberto Serrano, Harrison S. Kravis University Professor of Economics have received funding from the university to establish a John von Neumann Distinguished Lecture Series. This series will provide an opportunity to bring speakers of highest distinction that work on "von Neumann themes" to campus that will further build research bridges between the four departments represented by the organizers.

Planning for the first event, a symposium entitled, "The Genome and the Computational Sciences: The Next Paradigms—When John von Neumann Met Francis Crick," is underway and will involve a number of distinguished speakers. This symposium will take place in spring 2009.

Chad Jenkins Awarded $1 Million from the Office of Naval Research

The Office of Naval Research has recently awarded funding in the expected amount of $1 million to Chad for his research project on the development of physics-based methods for human tracking from video.

As a recipient of the PECASE award, Chad was eligible to apply for this substantial funding.

This research pursues physically plausible methods for human motion tracking from video using algorithms for Newtonian physical simulation and models human neurobiomechanics. This work is expected to enable more accurate human tracking robust to physical interactions, such as foot contacts with various ground surfaces and disturbances (inter-person collisions), as well as provide precise estimations of additional loads carried by humans observed in video, like the weight of a briefcase, and actions performed on these objects. Previous approaches to tracking that have concentrated on efficient inference algorithms, typically with strong motion constraints, will be enhanced through explicitly accounting for the physical plausibility of recovered motion. To this end, this research will extend methods for probabilistic human tracking to account for the dynamics of feedback control by developing and incorporating models of physical simulation.

Cooper, Galor, Kimia and Taubin Receive Joint NSF Grant to Promote Paradigm Shifts in Archeology through Computer Vision, Computer Graphics and Visualization

The National Science Foundation has awarded Brown a $2,638,964 grant to perform research in computer vision and visualization to "Promote Paradigm Shifts in Archaeology". This is a multi-disciplinary digital archaeology project within the NSF Information Integration and Informatics Program lead by Katharina Galor (judaic studies), Benjamin Kimia, David B. Cooper (engineering) and Gabriel Taubin (engineering & computer science).

This project builds on a longer-term intellectual program originally funded in 1998 under two previous NSF ITR grants, which have proven to be innovative in multiple ways. The proposed work is an artful interdisciplinary blend of computer vision, physics, mathematics, algorithm development, efficient computation, graphics and visualization in a rapidly emerging area that might best be termed computational archeology, although the methods are generalized to other domains. The project involves an interdisciplinary team of archeologists and computer vision/graphics/visualization researchers developing methods and software for capturing and analyzing archeological data. In this project, the Brown University engineering/computer science team will collaborate with the Brown University Joukowsky Institute for Archaeology and the Ancient World, the nonprofit educational outreach Institute for the Visualization of History, Williamstown, MA, archaeologists at Tel Aviv University, Israel and several computer vision experts from European institutions. The primary test-bed project will be a crusader castle in Israel. There are four sub-projects proposed: a collection system and database for video and 3D data captured on-site during excavation, three-dimensional reconstruction of both small artifacts and architectural sites, assembly of pottery and glass fragments and visualization of sites and artifacts. The project builds on and extends earlier work that focused on the Petra archaeological site and assembly of artifact fragments. The advances in computing technologies over the past five years in processing power and storage capacity, combined with decreases in cost, allow the researchers to expand their ambitions and develop more powerful tools and analytic techniques.

In addition to the Brown members of the team, the project also includes external collaborators and consultants: Dr. Donald Sanders, a prominent archaeologist in the field of digital archaeology and preservation of national heritage, president of VIZIN (The Institute for the Visualization of History, Inc.), an interactive computer graphics and educational outreach organization in Williamstown, Massachusetts; Engineering Professor Andrew Willis at the University of North Carolina, Charlotte; Archaeology Professors Oren Tal and Israel Roll from the Institute of Archaeology at Tel Aviv University, Israel; Mathematics Professor P. Giblin, from the Mathematics Department at Leeds University; and Dr. J.P. Tarel, a researcher at LCPC (Department of Roads and Bridges), Paris, France.

This team is a sizeable group of international and inter-disciplinary individuals who have demonstrated their ability to successfully work together. NSF and the evaluation panel from the computer and information sciences community is enthusiastically supporting this project and have confidence that this team will achieve something that is highly unusual, exciting and will have far-reaching effects.

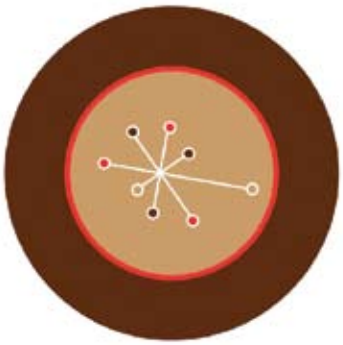
Ph.D. Student Anna Ritz Receives NSF Graduate Fellowship

Anna Ritz, computer science Ph.D. student, recently received a fellowship from the National Science Foundation's Graduate Research Fellowship Program, a prestigious and highly competitive fellowship program.

Anna's proposed plan of research is to design new algorithms to analyze high-throughput, temporal measurements of cellular signaling networks. She hopes her computational tools will be useful to biologists studying how cells transmit information and respond to external stimuli. Anna's recent work, "Quantitative Time-Resolved Phosphoproteomic Analysis of Mast Cell Signaling," was published in the November 2007 issue of The Journal of Immunology.

The NSF Graduate Research Fellowships provide three years of support leading to research-based master's or doctoral degrees and are intended for individuals in the early stages of their graduate study in the fields of science, technology, engineering and mathematics. Awards are granted based on previous research experience, the proposed plan of research and the student's ability to make a "broader impact" in their program of study in terms of educational, industrial and societal relevance. ■

Report on the 40th IPP Symposium: Web Programming Technologies



By Associate Professor
Shiram Krishnamurthi

Jacob Baskin and Shriram Krishnamurthi

Shriram, Jacob, Mark Miller, Erik Meijer, Luke Ma, David Ellis and Arjun Guha

The contemporary web has irrevocably changed our expectations of software platforms. In particular, it has enabled data-sharing and distributed decision-making on a global scale. With these benefits come obstacles and perils that force us to (re-)consider basic notions of identity, security and programming. What new programming challenges do we face? If we can share data freely, how do we circumscribe that sharing? What forms of security threats arise and how can we combat them?

To this end, on May 8, 2008, I hosted an IPP Symposium on the topic of Web Programming Technologies. In response to feedback from industrial partners, we changed the format somewhat—instead of having only guest speakers, we also highlighted some of the work currently happening at Brown. The resulting schedule still featured a diverse group of companies, interleaved with Brown speakers.

We split the symposium between two foci: broadly, how to enable good things and how to prevent bad things. Enabling "good things" was a focus on new technologies that simplify the development effort and yield tools for new functionality; preventing "bad things" was, of course, about the different forms of security necessary on the web.

Erik Meijer (Microsoft) began by telling us about Volta. Volta is a toolkit for building web applications by exploiting the integration of languages in .NET. It is also a secret weapon for popularizing several ideas from research into daily practice; the most notable example of this may be LINQ, which has its origins deep within monadic functional programming, but which programmers simply see as a better way to integrate databases in their programming language instead of having to painfully construct queries using strings. Per Erik's manner, the talk was part description, part rant and part philosophy.

Luke Ma (Cisco), a Brown alum ('03), told us about an extremely productive web development framework they've assembled at Cisco. Luke's point was that because there is already so much useful code on the web, it's better to spend time integrating it intelligently than recreating the wheel—and that's just what his team has done. Specifically, he told us about three frameworks: Hibernate, Spring and Wicket and their interactions. By combining these, a large portion of the content of traditional web applications—persistence, data access and Ajax—are generated using a combination of code-generation and reflection techniques, while exporting abstractions robust enough for developers to build atop. Luke's talk felt a bit like attending a code inspection at the highest level, absolutely heady.

Jacob Baskin (Google), also a recent Brown alum ('08), presented his senior honors thesis work. Distributed decision-making is now a standard metaphor on the web, but the processes—and therefore the decisions—remain weak. On a site like Amazon where most people review only a small portion of resources, how do we arrive at consensus? A process like averaging scores is meaningless. You might argue that it's unimportant to determine the "best book" on Amazon (and I agree), but there are other venues where sparse reviews must converge, such as when choosing which papers to discuss for acceptance to a conference. Jacob's talk was on optimization techniques for supporting such decision-making. It was a lovely presentation and I can say this freely because, much as I wish I could take some credit for it, Jacob devised it all of his own accord.

Mark Miller (Google) talked about the problems of application security from first principles. He pointed out that traditional access-control list mechanisms misplace trust and applications freely abuse this. Instead, Mark is an advocate of object-based capability systems, integrated into modern programming languages. He presented the many problems that these address and in particular the better abstractions they enable. Mark is the architect of the e programming language, and now of Caja, a capability-enriched subset of JavaScript that is in development and use at Google. Listening to him, and I have many times, is a wonderful experience: one leaves the talk feeling like a true believer in object capabilities (the feeling sometimes passes, however).

Arjun Guha (Brown), a Ph.D. student, presented his work on intrusion detection. When a web application sends JavaScript to a client, it has no guarantee about what actually executes in the browser (and what other code may be injected by attacks). But by using program analysis, we

Erik Meijer, Arjun Guha and Greg Cooper

can generate a profile of what the program is expected to do and accordingly, create a monitor that ensures the client's compliance with this expectation. Arjun presented his static analysis work that does this, showing that it generates non-trivial monitors that protect against vulnerabilities in real applications. This is a tremendous feat, given the complexities posed by real-world JavaScript code.

David Ellis (Facebook), yet another Brown alum ('07.5), spoke about another central protection concern. Facebook is not just a site; it's a platform upon which people build non-trivial applications. Ellis asked the question, 'How should we give these application authors a sufficiently powerful language while preventing them or their applications from vulnerability?' Facebook's answer, Facebook Markup Language, shares many qualities with the capability work Mark presented earlier in the day, leading to a rousing discussion.

We had two additional talks in which I presented some of the other work my students and I are doing. I spoke about Flapjax, a new programming language we've been developing at Brown; at some point I'll write about Flapjax in Conduit, so I'll spare you the duplication here. I also described our work on analyzing access-control policies, a preliminary version of which I wrote about in the Spring 2005 Conduit.

As an aside, getting a speaker from one of these companies (to remain nameless) was a bit of a challenge: none of the people they approached was free on the day we had chosen. It was time to pull out the heavy artillery: namely, our alums. Within 24 hours, the Brown CS alumni network had kicked into gear, churned its machinery and generated a speaker. Thank you all. We feel the love. ■

Industrial Partners Program

The primary goals of the Industrial Partners Program (IPP) are to exceed the expectations of our partner companies in terms of recruiting and outreach; to allow our faculty to engage in meaningful research collaborations and to provide resources and employment opportunities to our students.

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

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To learn more about the IPP visit:
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Commencement

Reunion











The Artemis Project

The Artemis Project, a department-run community outreach program, celebrated its thirteenth year of introducing young women to computer science this summer. Advised by Meinolf Sellmann, undergraduate coordinators Jihan Chao '10, Megan Hugdahl '11, Emily Mellor '10 and Ashley Tuccero '11, led eighteen rising ninth-grade students through five weeks of Photoshop, HTML, CSS, programming and robotics. Additionally, the girls attended talks given by a host of Brown's finest faculty members and graduate students, each of whom generously took the time to present a topic in his or her area of research. Topics included graphics, security, artificial intelligence and computational biology.

"The mission of Artemis is simple: to provide girls entering high school with the chance to learn about computer science, completely free of charge, in an environment where females interested in technology are not an anomaly, but the norm."

Outside the classroom, students were encouraged to explore their science-related interests with field trips to destinations including the Boston Museum of Science and the MIT Museum. They were also fascinated by visits from two of the program's corporate sponsors, Google and Goldman Sachs. Each company sent a group of female professionals for a day of presentations, team projects and learning about the careers of women in technology. Between lectures, field trips and corporate visits, the girls were encouraged to bond over popsicles and games.

The mission of Artemis is simple: to provide girls entering high school with the chance to learn about computer science, completely free of charge, in an environment where females interested in technology are not an anomaly, but the norm. We are very grateful to everyone who made it possible to reach this goal. While we optimistically plan for 2009, more funding is needed before we can commit to running Artemis again. If you would like to become a sponsor of Artemis 2009, please contact: Amy Greenwald–amy@cs.brown.edu or 401-863-7678 or Anna Lysyanskaya–anna@cs.brown.edu or 401-863-7605. ■

A Visit with General and Mrs. Kanellakis

Roberto dedicates his talk at the Symposium on Graph Drawing to the memory of Paris Kanellakis.

General and Mrs. Kanellakis along with Roberto on the walk back.

General and Mrs. Kanellakis welcomed Babis (above) and Roberto into their home. Here they are shown viewing an archive of documents about Paris's professional life.

On September 25, 2008, Department Chair Roberto Tamassia and Ph.D. student Charalampos (Babis) Papamanthou traveled to Athens, Greece, to visit General and Mrs. Eleftherios Kanellakis, the parents of our former distinguished colleague Paris Kanellakis, who died with his family in an airplane crash in December, 1995. Thanks to a generous gift from General and Mrs. Kanellakis, Brown has established a graduate fellowship that has supported several Greek Ph.D. students in the department over more than a decade. Babis and Aggeliki Tsoli are the current recipients of this fellowship.

In the preceding days, Babis and Roberto had attended the Symposium on Graph Drawing, held in Crete, Greece, where Roberto gave an invited talk dedicated to the memory of Paris. The talk included a system demonstration given by Babis of a tool for visualizing file permissions (joint work also with undergraduate Alexander Heitzmann and visiting Ph.D. student Bernardo Palazzi).

General and Mrs. Kanellakis warmly welcomed Babis and Roberto to their home, which is filled with memories of their son and lies in a quiet and pleasant neighborhood in the outskirts of Athens. Babis and Roberto gave them a book about the Brown campus and a booklet prepared especially for them, which includes photos of people and places in the department so that they can keep up-to-date with recent developments. Babis and Roberto were very appreciative to receive their gifts, including a carefully crafted archive of documents about Paris's professional life—prepared by the General himself—and a book about the Parthenon.

The ensuing lively conversation focused on memories of Paris, recent accomplishments of Paris's colleagues and students and the latest news on the Kanellakis fellows. It also touched on the state of the European and US economies and the presidential elections in the US. General and Mrs. Kanellakis took Babis and Roberto out for lunch at a great local restaurant in the middle of a park. At the end of the visit, General and Mrs. Kanellakis expressed their appreciation of Roberto's initiative to visit them and of the fact that Paris's legacy is very much alive in the department.

Babis said "I was overwhelmed with warm feelings after visiting the Kanellakis family. General and Mrs. Kanellakis are doing great and really appreciated our visit. I could see that they were so touched to have people from Brown in their home, since it brings back memories of their son's lifetime accomplishments and recognition. I cordially thanked them for the Kanellakis fellowship I have been receiving for the last year and promised to visit them again, since I realized how important this is both for them and for me." ■

NEMS Comes to Brown

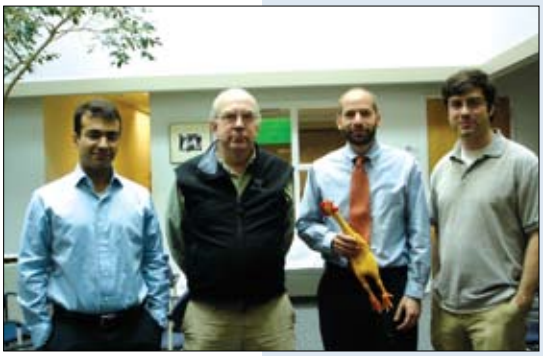
On Friday, May 30, Chad Jenkins and the Brown Robotics Group hosted the Fourth Annual New England Manipulation Symposium (NEMS). Researchers from Clark University, the University of Connecticut, Dartmouth, ENERGID, Harvard, MIT, Olin College, Roger Williams University, Rensselaer Polytechnic Institute, University of Massachusetts at Amherst, Union College, Worcester Polytechnic Institute and Yale attended the one-day symposium to explore common research interests, to establish and strengthen collaborations and to give students the opportunity to network and present their work.

Fourteen presentations were given during the symposium including, "Sparse Incremental Learning for Interactive Robot Control Policy Estimation," by Brown Ph.D. student Dan Grollman. According to Chad Jenkins, "The event was a great opportunity to exchange ideas with our peer institutions in the substantial New England robotics community and to promote greater regional collaboration on this increasingly important topic for society. We also appreciated the opportunity to host our colleagues and showcase robotics research efforts at Brown." ■

Dan Grollman gives a demo during a break at NEMS.

New Ph.D.s

Recent Ph.D. Thesis Defenses included Guy Eddon, Jeong-Hyon Hwang, Casey Marks, Jay McCarthy, Luc Mercier, Dana Tenneson and John Wicks



Guy Eddon

Jeong-Hyon Hwang

Casey Marks

Jay McCarthy

Luc Mercier

Dana Tenneson

John Wicks

Parenthetically Speaking

"Parenthetically Speaking" is a feature column by Associate Professor **Shriram Krishnamurthi**.

Shriram with Dewey

For some years now, I've wanted to increase the emphasis on testing in programming classes. I won't go into detail here on why I think testing is important; I might if I get enough flames from readers.

In this article I'd like to lay out an idea I've been experimenting within my courses. We call it a TestFest (though some alums may recognize it by the name War Grading; we're trying to tone down the name). Credits are at the end.

What Students Turn In

Students submit programs and test suites. They can submit each independently, early and often. A test suite is a collection of discrete tests. It's critical—both from the perspective of our technique and philosophically—for tests to specify not only inputs but also outputs (a common student error is to omit the latter even in situations when the output can be checked easily).

What We Create

There are many variants of TestFests. In one variant, we write three things: a very good test suite, a reference implementation of the solution (which we'll call the Gold Implementation) and a buggy implementation of the solution. These are added to the mix of what the students contribute.

The Central Idea

Run every program against every test.

The Process

When a student submits a program, it is immediately run against all the other tests in the system. We have tests in the mix to prevent collusion between students (whereby they all turn in no tests), though one hopes the competitive student (yes, dear reader, we think this species exists even at Brown!) will prevent this from happening.

When students submit tests, these are first run against our Gold Implementation. If a test fails, we assume the test is to blame and notify the student. If the test passes, we sequester it for eyeball treatment from a TA. Tests that pass this visual inspection now enter the pool of all tests.

Scoring

There are many ways to score and even more ways to weight scores, all depending on the objectives of the instructor. Essentially, students get points for programming and points for testing. In one version of a TestFest, the total score is the sum of these two.

Programming

Students start with some predefined number of points.

They cannot score any higher through programming alone.

But they can lose points for every test their program fails, no matter who wrote the test.

Testing

They start with zero points.

They get points for every time one of their tests exposes a bug in some program.

They lose points when their test fails against the Gold Implementation.

The Twist

I don't want to just encourage testing. I want to have students write tests before they write programs. How do I encourage that?

Easy: it's all in the incentive structure. If your test finds an error in someone else's program, you don't just get points—you get points *proportional to the time elapsed between when you submitted your test and when the program ran afoul of it.* This encourages writing the most fiendish tests as early as possible.

Indeed, we saw this happen on some of our assignments where some teams spent the first day of a two-week assignment constructing wicked tests and the rest of the time not only writing better programs (for having thought of these cases), but also racking up the points.

Some Consequences, Design Considerations and Solutions

If the same test is in every test suite and your program fails it, you lose points each time. Isn't this unfair? To the contrary, it means that it's a really common test (it showed up in numerous independent test suites!) and you should especially get the common case right, so you deserve to lose a lot of points.

If you create a really obscure test that every program fails, you get points for each program's failure. Isn't this unfair? To the contrary, you're

clearly a very smart tester—you can think out the intended system behavior in greater detail than anyone else. You deserve to be given credit for that.

If you write a mediocre program you'll lose lots of points; if you write a weak test suite, you will not recapture enough of those points. Thus, if your programming is going poorly, you have an incentive to concentrate on testing. This is a good principle: it's better to prevent errors than introduce them and if you're having trouble writing a program, you should find a different way to be productive. Unlike most homeworks, this assignment structure gives you a way.

In the limiting case, if you turn in a blank program, you're going to get a very, very negative score. Your best bet for recovering from this is to write an excellent test suite. If you prove to be a superlative tester, you could recover much of what you lost. This is as it should be: software companies need both great programmers and great testers and you may just have found your calling.

You seem to get no reward for writing tests that don't expose errors, even though these tests matter. Your reward is in fact for your own program: those tests have helped make your program better.

If everyone writes a perfect program then it appears to not matter how much testing you do; you can never get any credit. This is not true. This is where our buggy program comes in; you will always get some credit for finding the bugs in it. This is incentive for you to provide a non-empty test suite.

If you make a mistake, perhaps someone else will make the same mistake. If you wrote a regression test to make sure you didn't repeat the error and someone else fell afoul of it, you will earn credit for finding that bug in their program. Therefore, this rewards regression testing (it would really infuriate them if they knew about the bug, fixed it, reintroduced it and failed to make a regression test out of it…so much the better).

There is the small danger that, if you provide redundant tests that do catch an error, each redundant test will score. This means there is incentive to pad a test suite with redundant tests (in the worst case, blindly making numerous copies of each test). This is why we eyeball the tests (also, because each of these tests is costing some other developer, we are sure to hear about it from your victim).

If a test does not expose an error, then redundant tests will not either. This therefore discourages redundant testing. To improve your score, you will do better to move on. This therefore forces you to think hard about coverage.

Because catching bugs is more valuable than writing buggy programs, testing earns more than programming.

An Observation

When we deployed this system in CS173 last year, we got the predictable response; skepticism combined with a willingness to try out a novelty, followed by a flood of useful feedback (Itay Neeman particularly disliked it and we learned a great deal from his complaints). What was amusing, however, was the depth of dislike for *losing points* for errors in their programs; students simply did not like this idea. Because this is Brown, not the real world, we went along with their wishes. I will probably be less malleable in the future.

Credits

Thanks to Guillaume Marceau, with whom this idea was developed. Matthias Felleisen, Robby Findler and Kathi Fisler have tried versions of this in their courses. My TAs last year (Daniel Winograd-Cort, Sean Smith and Arjun Guha) prototyped it at Brown; the CS173 students suffered with great cheer through the various details we hadn't considered. Special thanks to Arjun for the very slick interface he's constructed for it—in Flapjax (and Haskell and Scheme), natch. ■

An Interview with Top Young Innovator Meredith Ringel Morris '01

By **Amy Tarbox**

Meredith Ringel Morris '01 was recently named a Top Young Innovator by Technology Review. This honor is given each year to 35 innovators in science and technology under the age of 35 whose inventions and research the magazine finds most exciting. Merrie's extraordinary work in developing a tool to enable joint searching of websites led to her inclusion in this elite group of accomplished young innovators. After receiving her Ph.D. from Stanford, Merrie became a computer scientist in the Adaptive Systems and Interaction Group at Microsoft Research. Her tool, SearchTogether, is a plug-in for Internet Explorer that makes it easy for groups to share the work of searching without duplicating each other's labor. Merrie was kind enough to take time out of her busy schedule to be interviewed by *Conduit*.

Dan and Merrie Morris on vacation in Sydney, Australia.

Can you tell us more about the SearchTogether tool?

SearchTogether is a tool for helping groups of people work together on web searches. Before designing the system, I conducted a survey to learn more about what kinds of tasks people wanted to be able to collaborate on. Some of the most common tasks involved students or colleagues working on group projects, friends or family members planning vacations together, families researching a medical condition that affects a loved one or spouses shopping online together for expensive items, such as cars or electronics.

"Search tools like SearchTogether can simplify the task of planning a family vacation."

SearchTogether is meant for situations where everyone has their own computer, but group members don't necessarily need to be online at the same time since all of the data in a SearchTogether session is persistently stored. SearchTogether's collaboration features include group query histories, split searching, page-level rating and commenting, automatically generated shard summaries, peek-and-follow browsing and integrated chat.

SearchTogether is a fantastic plug-in. What challenges did you and your team overcome to bring it to fruition?

One big challenge for all collaborative technologies is achieving critical mass. Like any collaborative tool, SearchTogether is most useful if your friends, family and colleagues also have it.

Can you tell us about your next project/tool?

I've been working on several other methods of enhancing the collaborative search experience. For example, my intern Saleema Amershi (University of Washington) and I created a system called CoSearch that enables groups of people to use their mobile phones together with a shared display. Group members can do things like text search terms from their phones to the display or download search results from the shared display to preview on their phones. I've also been working with Jaime Teevan (Microsoft Research) on algorithms for re-ordering search result lists to be customized to the shared interests of a group of people searching together.

What inspired your current focus on collaborative search?

When my husband (Dan Morris, Brown '00) and I moved to the Seattle area in 2006, we were doing lots of web searching, trying to find information about houses, neighborhoods, etc. We were both interested in learning about those topics together and in making joint decisions about things like where to live or what new parts of the city to explore, but we were each conducting separate searches and then discovering that we had done a lot of redundant work finding the exact same things as the other person. So, once we finally moved and I started my new job at Microsoft Research, I decided that the first thing I would work on would be thinking about better ways for groups of people to search the web together.

What courses did you take at Brown that had the most impact on your research?

I took two independent study courses in computer science, for which I worked with Professors Steve Reiss and David Laidlaw on developing visualizations of software performance. Working on those independent study projects made me excited about applying to graduate school and

Alumni Update

pursuing computer science research as a career. I also took a lot of psychology courses that helped prepare me to do HCI (human-computer interaction) research, which draws on skills from both computer science and the social sciences.

Was there a specific professor or class that had a profound effect on you?

My high school didn't offer computer science classes but on the tour I took of Brown as a pre-frosh I heard that the character in *Toy Story* was named after CS professor Andy van Dam, so I decided to take Andy's CS15 course my freshman year, just to see what he was like! I hadn't planned on concentrating in computer science but I liked CS15 so much that I kept taking more classes. Later on, Andy helped convince me that I should take extra CS classes in order to earn the Sc.B. degree and that I should apply to Ph.D. programs, so he was definitely a big influence.

What do you know now that would have been beneficial to know as an undergraduate?

When I was an undergrad, I didn't appreciate how unusual it was that Brown offered undergraduates the opportunity to become involved in the CS department as teaching and research assistants. I realize now that the types of experiences I was able to enjoy as an undergrad at Brown are often reserved for graduate students at other universities. ■

Brown CS alums gathered at the wedding of Harry Li (Sc.B. '02)

(l to r) Shriram Krishnamurthi, Jon Warman, Susannah Raub, Harry Li, George Cabrera III, Rebecca Sun, Emily Eng and Pete Demoureille

Jay McCarthy (Ph.D. 2008)

Jay and Libby McCarthy became parents on September 8th. In addition to the baby's arrival, it has been quite a year for Jay as he finished up his Ph.D. and became an assistant professor at Brigham Young University. Congratulations Jay and Libby!

David Salesin '83 Creates Foldit

In the effort to mine the mysteries of unfolded proteins, David Salesin '83, now a professor of computer science and engineering at the University of Washington, and David Baker, a professor of chemistry at UW and a Howard Hughes Medical Institute investigator, turned to the unlikely realm of online gaming. Zoran Popovic, an associate professor of computer science and engineering; Seth Cooper, a doctoral student in computer science and engineering; and Adrien Treuille, a post-doc in computer science and engineering, all at UW, helped to design and develop the game.

The online game, called Foldit, aims to determine the structure of unfolded proteins, launching the field of protein analysis into the video game arena. According to Salesin, the game resembles a 3D version of the game Tetris. "It's all about fitting geometry together," he said. By clicking and dragging different protein parts on a computer screen, players determine the shape of protein structures. The game is available online at http://fold.it/portal/adobe_main.

Scott Raposa '94

In September, Scott released an album in collaboration with New York Times best-selling authors Esther and Jerry Hicks. The work titled "Law of Attraction Directly From Source," weaves Raposa's upbeat electronic music with the inspirational voice of Esther Hicks. Previously, he released Stillness of Mind, an electronically produced ambient meditation CD, which many call their favorite in the genre. Scott's album is available in bookstores around the world and at Amazon.com. ■

Comments?

Send your views to: Conduit, Department of Computer Science, Brown University, Box 1910, Providence, RI 02912
or e-mail conduit@cs.brown.edu

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