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CIMS Newsletter

The Courant Institute of Mathematical Sciences at New York University

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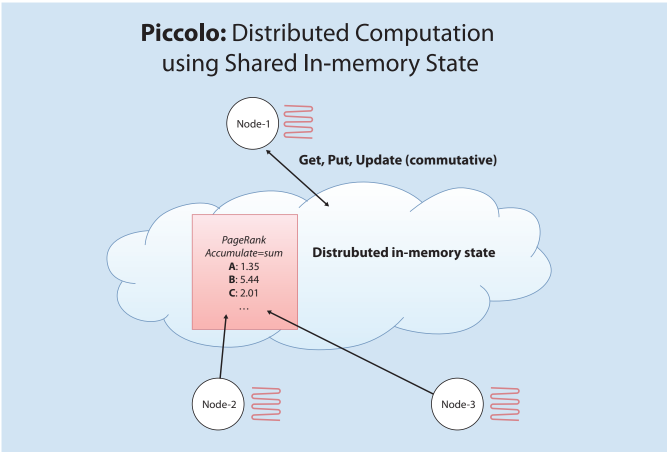
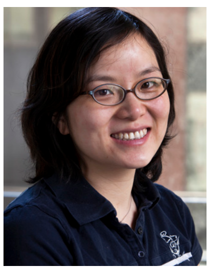
In this Issue:

Jinyang Li: Building Distributed Systems That Bridge Applications and Hardware

by M.L. Ball





A native of China, Jinyang Li received her B.S. in Computer Science (First Class Honors) from the National University of Singapore, and her master's and Ph.D. from MIT, also in Computer Science. After completing a postdoc at UC Berkeley, Jinyang joined the faculty of the Courant Institute in 2006 as Assistant Professor of Computer Science. She is the recipient of an NSF CAREER Award (2007) and a Sloan Research Fellowship (2011).

Networking and Wide-Area Systems Group

Jinyang Li leads the Networking and Wide-Area Systems Group (NeWS), along with Lakshmi Subramanian, a fellow Courant Institute Computer Science Department faculty member. The pair started the group from scratch and now have nine Ph.D. students working with them.

"Lakshmi and I collaborate on many projects and each of us also has separate research interests. My current projects focus on cloud computing, data-centric computing and large scale distributed systems," Jinyang stated. "The people in this group are very diverse, working on various aspects of systems ranging from data-centric infrastructure to data mining to wireless projects."

Systems research: Finding the balance between usability and high performance

Jinyang's passion for her chosen field – distributed systems – is clearly evident in the animated, energetic way she describes her work. "For computer systems research: you can view it as existing between hardware and applications," she explained. "We build systems software that exists at a lower layer than application software, such as machine learning and machine vision software. The systems software interacts with the hardware and makes the programming task of application programmers much simpler. In my specific area, from the programmer's viewpoint, the layer of software that I'm building is going to hide the complexity of directly dealing with hundreds or thousands of machines in a data center," she explained.

According to Jinyang, the reason systems programming is so challenging is because very often there is no clear specification for the systems to be built. "The goal is to provide a simple view of the underlying hardware, the abstraction, so that the programmers can be more effective and productive when designing and writing their programs. Yet at the same time you must not oversimplify – the programmers still need to take advantage of the main features of the hardware. When new hardware is built, without good systems software it's very clumsy to use and won't reach the majority of application programmers. It's a careful balance between making your system very usable and maintaining extremely high performance," said Jinyang.

Jinyang's Project Piccolo: Faster, more robust, and getting lots of notice

When approaching a new project, Jinyang prefers a bottom-up approach. "I like to take a very concrete piece of application that I really care about – like machine learning or processing a lot of text – and then look at the existing hardware and say, 'We have lots of machines and they're connected by a fast network and each of them has a lot of memory and a lot of disks,'" she said. "'How can I enable that application to utilize this array of hardware? What is the glue, what is the infrastructure that's needed? To make the challenges concrete, let me start by building this infrastructure that specifically can process a large amount of text really quickly. And then let's try to generalize this for other problems.'"

Jinyang's Project Piccolo (joint work with her student Russell Power) exemplifies this research style. She described Piccolo as a programming framework for writing large-scale distributed in-memory computation, such as graph algorithms and machine learning.

"In the beginning of this project, we were specifically investigating how to compute the PageRank algorithm quickly using many machines," Jinyang said. "We came up with a design that stored intermediate PageRank values in the aggregate memory of many nodes and relied on the commutativity of updates to merge writes from different nodes efficiently. We were then able to generalize this approach to other types of computation and developed the Piccolo distributed programming framework."

Jinyang stated that compared to the state-of-the-art distributed programming tool Hadoop, Piccolo is 5-11 times faster and supports more types of applications. "Piccolo has generated lots of interest, both within the research community and among industry programmers," she added. "My student, Russell Power, was awarded the prestigious Microsoft Research Ph.D. Fellowship for his work on Piccolo. We got lots of publicity after the project was featured by the prominent technology blog HighScalability.com."

Wireless networking projects

Recently, Jinyang completed several projects which necessitated building a multi-hop mesh network. "The way to provide Wi-Fi connectivity today is to deploy many wireless access points and connect them by way of a wired backend," she said. "You connect by a one-hop wirelessly to the access point, and the access point then shoots the packet over the wire to some Internet gateway node."

The problem, Jinyang said, is wiring all the access points. "Sometimes it's very inconvenient to do that," she explained. "An example would be a community deployment, such as an apartment building, where you don't have the existing wired infrastructure but you want to deploy all these wireless nodes. Can all the access points communicate with themselves wirelessly? The answer is yes! If you only connect one of them to the wired Internet, then all of them essentially get Internet connection by forwarding their packets over multiple wireless hops to that gateway node. I have done a couple of projects like this – we've even deployed 25 nodes on this floor." (The 7th Floor of 715 Broadway.)

Continued on next page

Jinyang added emphatically, “I have wonderful graduate students who are instrumental to the success of all these projects. The ones doing wireless projects are part of the new NYU Wireless Center, founded by Professor Ted Rappaport. And I am starting to collaborate with another NYU-Poly colleague in the center.”

Through teaching, excites others about computer science

Teaching is one of Jinyang’s favorite parts of her job. Whereas her research focuses in depth on particular topics, teaching lets her “take a step back, take a broader view and communicate the excitement of the field to people who are not in it,” she said. “And attract students to do systems.” She teaches once a semester, either distributed systems, networking or beginner systems programming.

The Courant Institute: a very collaborative environment

When describing the atmosphere of the Courant Institute, Jinyang stated, “There’s a lot of collaboration among faculty in the Computer Science Department. One of my new projects involves joint work with the machine learning group to parallelize neural network training across machines.”

Jinyang added that the most meaningful aspect for her is that faculty members, especially younger professors, are given the freedom to build their own groups. “There’s not a push from the department saying you have to achieve this and that by certain deadlines,” she said. “Also, even as an untenured professor in my first five and a half years here, I was consulted on a wide range of important decisions, such as faculty hiring, which is very nice.” ■

New Faculty

Tim Austin

Tim Austin, joined Courant as an Assistant Professor of Mathematics. He received a B.A. from the University of Cambridge (2005) and a Ph.D in Mathematics from the University of California, Los Angeles (2010). He was awarded a Clay Research Fellowship in 2010, and has since spent two years at Brown University.

Antoine Cerfon

Antoine Cerfon, Assistant Professor of Mathematics, obtained his Ph.D. from MIT in 2010, and spent two more years at MIT as a post-doctoral associate at the Plasma Science and Fusion Center. His main research interests are in the development of new models and numerical methods for the study of laboratory plasmas, with a primary focus on magnetically confined fusion plasmas as well nonneutral plasmas in particle accelerators.

Dimitris Giannakis

Dimitris Giannakis, Assistant Professor of Mathematics, received his Ph.D. from the University of Chicago in 2009, followed by a postdoc at Courant. His research interests are in applied mathematics for climate atmosphere ocean science. He is currently working on methods combining spectral graph theory and singular spectrum analysis for spatiotemporal decomposition of high-dimensional data.

Chris Jankowski

Christopher Jankowski, Clinical Assistant Professor of Mathematics, received his Ph.D. from the University of Pennsylvania in 2009 and spent two years as a postdoctoral fellow at Ben Gurion University in Israel. His research focuses on operator algebras, with a particular interest in the theory of E-semigroups.

Trushant Majmudar

Trushant Majmudar, Clinical Assistant Professor of Mathematics, obtained his Ph.D. in Physics from Duke University in 2006, followed by a postdoc at MIT in Mechanical Engineering, and at the Courant Institute, in the Applied Math Lab. He has a deep interest in teaching Mathematics and Physics. His research interests include physics of granular matter and bio-fluid dynamics.

Ted Rappaport

Theodore (Ted) S. Rappaport is the David Lee/Ernst Weber Professor of Electrical and Computer Engineering at NYU-Poly, professor of computer science at Courant, and professor of radiology at the NYU School of Medicine. Rappaport is founding director of NYU WIRELESS, a new kind of academic research center that combines wireless communications engineering and computer science with the practice of medicine and health care.

Oded Regev

Oded Regev joined Courant as a Professor of Computer Science. Regev’s research is in mathematical aspects of theoretical computer science. He is particularly interested in advancing the area of lattice-based cryptography using concepts from quantum computation, analysis, and number theory. Previously he held faculty positions at Tel Aviv University and at the École Normale Supérieure in Paris. He received the ERC Starting Grant in 2008.

Drew Youngren

Drew Youngren, Clinical Assistant Professor of Mathematics, received his Ph.D. from Northwestern University in 2006. He recently completed a fellowship with Math for America while working for Bard College and the NYC Department of Education. His research interests include microlocal analysis and mathematics education.

Mohamed Zahran

Mohamed Zahran joined Courant as a Clinical Associate Professor of Computer Science. Zahran’s field of expertise is in hardware/software interaction. He is also interested in brain-inspired machines. Zahran has a Ph.D. in computer architecture from the University of Maryland at College Park. Previously, he was a faculty member at the City University of New York.

In the accounting software field, **Anne-Claire McAllister's** Courant degree has made all the difference by M.L. Ball

A Non-Traditional Courant Graduate

In 1992, after receiving her Master of Science degree in Computer Science from the Courant Institute, Anne-Claire McAllister did not follow the typical path of a CIMS graduate. She did not go into teaching or R&D. Nor did she return to her pre-Courant job in the systems area of JP Morgan. Instead, she started selling Microsoft Dynamics, accounting software for businesses. In the process, she gained valuable experience training people how to use the software, making sales presentations and developing customized screens and reports. All this came to fruition in 1996 when Anne-Claire founded her own accounting software reseller company, Accountnet, Inc.

Describing her early involvement with Microsoft Dynamics, Anne-Claire said, "I like programming, computer science and technology. When Microsoft Dynamics went to Windows – around the same time I was graduating from Courant – it became a lot more customizable for business practices."

Anne-Claire markets Microsoft Dynamics, a business accounting application

According to Anne-Claire, Microsoft Dynamics was developed years ago by Great Plains Software. "Microsoft bought that company and re-named the application Microsoft Dynamics, which runs on a Microsoft SQL Server database," she said.

A mid-market business accounting software, Microsoft Dynamics provides a company with a basic accounting system but with the added ability to customize the software for that business's specific needs. "This is unique for Microsoft," Anne-Claire explained. "It's not a tool. It's a product that needs to get installed and people need to get trained on it. It's more of a true business application, with more flexibility and customization ability than QuickBooks or NetSuite."

Accountnet, her Microsoft Dynamics reseller firm, has become a national leader

A Microsoft Gold Certified Partner specializing in Microsoft Dynamics, Accountnet markets ERP (enterprise resource planning) software, primarily in the Tri-State New York City area. Selling two of Microsoft's four accounting product lines – Dynamics SL (formerly Solomon Software) and Dynamics GP – Accountnet focuses on five specific vertical industries: financial services, non-profits, project-centric companies (such as government contractors), healthcare and business services.

In Accountnet's early days, Anne-Claire was doing all the software installation, training and customization herself. "Now we have ten people; some are in sales, and others are accounting software implementers and programmers," she said. "I'm on the technical side. I first evaluate people's business needs and then determine whether we can configure the software so that it works for their particular needs or whether we need to customize it."

Accountnet's success is evident: In 2011, it was chosen as a Top Technology Pacesetter for a fifth consecutive year by *Accounting Today*, an online business news magazine. That same year, it was also included in the top 100 VAR in the U.S. in *Accounting Technology* magazine.

What she learned at the Courant Institute has given her a distinct advantage

"My degree from Courant has helped differentiate me from others in the industry, which has been a huge advantage," said Anne-Claire. "We don't just sell the software – we also customize it for people's different business processes. This is where my programming background, augmented by my time at Courant, comes into play."

Anne-Claire explained that most people who do what she does have an accounting background and lack the programming and technical background that she has. "Accountants might be able to code but there are a lot of ways to optimally code," she said. "Having my Courant degree has allowed me to better customize the software so I can more thoroughly solve people's business problems."

In addition, an advantage to having 25 years (and counting) in the accounting software industry is that, along the way, Anne-Claire has learned a lot about accounting. "Coupled with my programming and coding background, that's very unique. With my strong computer science background, and having gone through Courant's master's program, I really understand how to put together a development project. This has helped me differentiate myself within peer organizations that sell Microsoft Dynamics," she said.

This dual knowledge base has also enabled Anne-Claire and her business partner, John Peace, to offer proprietary solutions which they've developed over time. "We know how to set up software that's specific to these industries," she explained. "The master's degree helped me learn technical concepts but then be able to relate those concepts to people who aren't technical. We have to do that a lot with this accounting software – we have to explain why our solution is better than somebody else's."

She added, "In a very real sense, I bridge the gap between the technical people and the accounting people: Why they should buy our software and why they should set it up in a certain way once they get it."

One Courant course has stayed with her throughout her career

While pursuing her masters at Courant, Anne-Claire took a TCP/IP class, "Networking Design," in the spring of 1991. "That class got down to the lowest level of communications, the foundations," she said. "It has permeated my whole career. It taught me how the internet started, its history. What I learned way back then still bubbles up."

The Courant Institute: Invaluable preparation for real life

Receiving her masters from Courant not only readied Anne-Claire for the business world, it prepared her for the actual environment she would encounter there.

"Being at Courant was a great experience because it was very challenging for me," she recalled. "There were a lot of brilliant people there. People worked in groups; they were very collaborative. Three or four of us would work on projects together, which really teaches you how to work with people – very important. Together we'd work out which approach to take to solve the problem we had, and then people would do different pieces. And that's real life."

She continued, "In real life, you're not programming by yourself. You're in teams and you need to know how to work well within a team. Courant was definitely a collaborative environment, and you learn so much more that way. You learn how different people approach problems and you need all those points of view to solve the problem. And the teachers were very approachable. It was, for me, a very positive experience." ■

How can the mysterious connection between nature and mathematics be explained? It can't, says **Henry McKean** by M.L. Ball

Born in Wenham, MA, Henry P. McKean received his B.A. in mathematics from Dartmouth College in 1952, followed by his Ph.D., also in mathematics, from Princeton University in 1955. He then taught at Princeton, Kyoto University, MIT, Rockefeller University and Balliol College at Oxford University. Prof. McKean is a member of both the American Academy of Arts and Sciences and the National Academy of Sciences, and served as Director of the Courant Institute from 1988-1992. In 2007, he was awarded the Leroy P. Steele Prize for his life's work. ("I was pretty pleased to get that one. That was nice. A surprise," McKean commented.)

Henry P. McKean has spent his professional career studying the "peculiar business of mathematics," as he puts it. Yet after nearly 60 years in the field, he is (by his own admission) still stumped by the seemingly coincidental connections between natural laws and mathematics.

McKean cited Eugene Wigner, recipient of the Nobel Prize in Physics in 1963. In an article titled *The Unreasonable Effectiveness of Mathematics in the Natural Sciences*, Wigner discusses, in McKean's words, "this strange business of an unexpected piece of mathematics having to do with some physical thing for no obvious reason. Everybody who works in pure mathematics and applications comes to that idea. Why does it work? That has interested me continually."

In an excerpt from his 2003 paper, *Some Mathematical Coincidences*, McKean examines this relationship:

Most mathematical questions suggested by Nature are genuinely non-linear, meaning very roughly that the result is not proportional to the cause, but varies with it as the square or the cube, or in some more complicated way. The study of such questions is still, after a couple of hundred years, in its infancy. Only a few of the simplest examples are understood in any really satisfactory way.

Mathematics is a language, providing a mode of very precise, compactly-expressed, rapid thought. That is a commonplace. What is less generally known is that it also permits you to recognize unexpected real connections and/or mere parallels between different aspects of the natural world which, from a so-to-say philosophical point of view, have *nothing to do with each other*.

A mysterious relationship no one can really explain

By way of illustration, McKean said, "The simplest example is electrostatics and gravity. The mathematics is exactly the same except that masses attract and like charges repel. Just a little change. How come? It's very odd."

He then went on to say, "There's a wonderful line by Richard Feynman, maybe the best physicist we produced. He worked in quantum mechanics, which is very strange stuff. His line is, 'Don't keep coming to me and complaining: How can it be like that? Nobody knows how it can be like that but it is like that, and you'd better get used to it.'"

Newton, a great singularity in the field

Every field has its singularities – those who have thought far beyond the reach of the rest of us. In mathematics, one such singularity is Isaac Newton. "One of Newton's greatest achievements," McKean said, "is based on Kepler's three laws of planetary motion. Newton understood that you could deduce all that stuff of Kepler's from f = ma with a little calculus. That was an astounding discovery." He added, "Newton did marvelous things, absolutely marvelous."

When asked if he himself has been able to solve problems that have puzzled his peers, McKean answered, "No, but I worked for years on an equation called Korteweg-de Vries (KdV) which has to do with waves in shallow water. That's physics, with a very nice little nonlinear partial differential equation describing such waves. I had also worked on a beautiful piece of 19th century geometry that leads to the solution of the KdV in a particular case. There is <u>no</u> philosophical reason why it should be so, kind of like gravity electrostatics, but much more complicated." He also said, "This is not entirely mine. It was noticed by S.P. Novikov at the same time."

A mathematician by accident

For McKean, becoming engaged in mathematics was accidental. "When I was in high school," he related, "I had to learn trigonometry, which was exceedingly boring. The same triangle day after day after day. Nothing changed about it. Besides, there was algebra and I never quite understood what x was. But then we had a very good teacher. I started to learn calculus and began to understand that you could do something with it. I liked that very much. And I was quicker at it than the other kids and I liked that best of all. When I went to college, I thought maybe I'd like to do something else, but felt it would be fun to learn some more mathematics. I wasn't bent on a scientific career; all I wanted to do at that stage was anything I could do well. I didn't much care what it was."

Dabbling in oceanography but eventually choosing mathematics

While a teenager, McKean accompanied two oceanographic expeditions. One was out of Woods Hole Oceanographic Institution, traveling to Bermuda and then across the Atlantic. The purpose of the voyage was to study the Gulf Stream, the Mid-Atlantic Ridge, and the distribution of oxygen and salinity at various depths. Another was up to the Labrador all summer, "not nearly as serious but we had a marvelous time," he recalled. Originally thinking he might pursue oceanography, he eventually became more interested in mathematics.

The difference between mathematicians and physicists

In distinguishing physicists from mathematicians, McKean emphasized that the two are very different. "I wouldn't consider myself a physicist but I appreciate the way they think. It's very different from mathematical thought. The mathematician's point of view is that everything should be <u>explained</u> from first principles. They want to know <u>logically</u> how it all works. The physicist's point of view is that if it hangs together and agrees more or less with the experiment, then it's a success."

He continued, "My good friend and teacher, Mark Kac, said what physicists do is a demonstration and what mathematicians do is a proof. Kac liked to say, 'A demonstration is to convince a reasonable man; a proof is to convince an unreasonable man.'"

In spite of McKean's admiration for physicists, just a short time in his presence reveals where his true passion lies. "With mathematics," he said, "you have some interesting problem and you look at the simplest variant of it and see if you can do that, and work your way up. One very interesting part of mathematics is this KdV, which is part of Hamiltonian mechanics. Hamiltonian mechanics is really just a good way of writing what Newton was doing. In Hamiltonian mechanics there are completely integrable systems, which means

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How can the mysterious connection between nature and mathematics be explained? It can't, says **Henry McKean** by M.L. Ball

Continued from page 5

that if you're clever about your coordinates, you can actually integrate the equations explicitly. But nobody tells you how to do that. Besides the KdV equation, there are maybe a dozen similar examples that you can work out completely and they have resemblances to one another but nobody knows any sort of a grand scheme. What I mean to say is that real mathematics is not a logical, deductive enterprise, from the top down. Quite the opposite, in fact."

Long in coming, his most recent book is almost complete

Currently, McKean is in the process of finishing a book on probability, information and coding, and statistical mechanics—"that's the way you deduce how matter behaves, knowing how the molecules interact," he explained. "I'm almost done with it – something I've been working at, off and on, for ten years. I scribbled the whole thing out and left it for two to three years. Then I found it was a complete mess so I wrote it again. Now I've written it a third time. I hope to finish by Christmas."

Courant Institute: "The nicest place I've ever worked"

When asked his thoughts on the Courant Institute, McKean enthusiastically replied, "We've got some really good young people, so I'm happy with that side of things. (And happy to be off the hook of being director.) For the rest, I have to say that CIMS is the nicest place I've ever worked. People are so cooperative. When I was Director, I had to call on people and ask, 'Can you do this, can you do that?' Sometimes they weren't particularly pleasant things to do, but I never got a no in four years except on two occasions. The usual response was, 'Oh sure.'"

The fun of mathematics

With a career full of achievement as testament to his intellect and problem-solving acumen, one might think Henry McKean would be all work, work, work. Refreshingly, no.

Summing up his approach to the "peculiar business of mathematics" at the Courant Institute, he said, "We work hard here but we have fun. We come to work and get all the uninteresting things off the desk, and then we play. That may sound silly, but it's true." ■

Puzzle | WINTER 2013

How Fair is a Fair Coin?

by Dennis E. Shasha, Professor of Computer Science

Bob has a fair coin. He suggests the following game to Alice. He will flip the coin three times: Bob wins if HHT (heads, heads, tails) comes up and Alice wins if HTT comes up.

Warm-Up: What is the likelihood that Alice will win? What is the likelihood neither will win the game?

Solution to Warm-Up: Alice will win 1 in 8 times, because there are 8 possible outcomes of a coin flipped three times. She wins in just one of those. Bob will also win 1 in 8 times. Therefore neither will win 6 out of 8 times. That is, neither will win 3/4 of the time. However, they have the same chance to win.

Now Bob suggests that he will keep flipping until one of them wins. Winning for Bob means that HHT comes up before HTT. Winning for Alice means that HTT comes up before HHT.

1. What is the likelihood that Bob wins? Hint: You might take a coin and see before you answer.

   Alice looks at her losses after 20 minutes of play and says: "Ok, now how about if you choose HHH?"

2. If Bob were to choose HHH, which triplet could Alice choose to beat him 7 out of 8 times in the continuous flip setting?

   Unfortunately, Bob refuses and wants to stick with HHT. Does Alice have an alternative?

3. In the continuous flip setting, what should Alice choose as her triplet for her to beat Bob's triplet of HHT?

For the solution, email: courant.alumni@nyu.edu

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Your donations to the Courant Annual Fund are more important than ever. This unrestricted income supports students and their conference travel, enhances the activities of our student clubs, and helps fund the cSplash and WinC outreach programs. The Annual Fund provides matching funds to secure grants from other sources, enables the Institute to invite distinguished speakers for both technical and public lectures, and assists in creating improved public spaces in both Warren Weaver Hall and the Broadway building.

Please join the Courant Director's Circle with a donation of $1,000 and above. This entitles you to join special events at the Institute, including a Circle only event in the fall, and the exclusive Director's Toast before the holiday party. Your donation will help support a truly extraordinary range of scientific and educational initiatives. ■

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