CIMS Celebrating 75 Years
The Courant Institute of Mathematical Sciences at New York University

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The ultimate goal should be "a strong and many-sided institution… which carries on research and educational work, not only in the pure and abstract mathematics, but also emphasizes the connection between mathematics and other fields [such] as physics, engineering, possibly biology and economics."

— Richard Courant, 1936

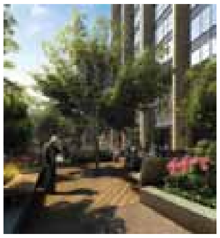
Inevitably, much has changed over the past 75 years, most notably the advent of computers, which are now central to much of our activities. Nonetheless, viewed broadly, this statement continues to characterize our research mission, as illustrated by the research profiles in each issue of the newsletter.

75th Anniversary Courant Lectures

Photo: Mathieu Asselin

Leslie Greengard and Persi Diaconis

As a part of the Courant Institute's 75th Anniversary celebrations, over 250 Courant Institute faculty, students, alumni and friends gathered at Warren Weaver Hall for the Courant Lectures on April 7th. The talk was given by Persi Diaconis, Mary V. Sunseri Professor of Statistics and Mathematics and Stanford University. In the talk, "The Search for Randomness," Prof. Diaconis gave "a careful look at some of our most primitive images of random phenomena: tossing a coin, rolling a roulette ball, and shuffling cards." As stated by Prof. Diaconis, "Experiments and theory show that, while these *can* produce random outcomes, usually we are lazy and things are far off. Connections to the use (and misuse) of statistical models and the need for randomness in scientific computing emerge." The lecture was followed by a more technical lecture on April 8th, "Mathematical Analysis of 'Hit and Run' Algorithms." ■



This past Fall the construction on Warren Weaver Hall's Mercer-side entrance was completed. Atop the new "green" Co-generation power plant and at Warren Weaver Hall's front entrance is a new open space garden. As stated in NYU Today, "conceived as a green urban plaza beneath the canopy of a park, three garden-size "rooms" with wood decks and 190 linear feet of benches have been carved out of the planting beds to provide space for sitting and relaxing."

(Left) Rendering of the Mercer Street Garden.

In this Issue:

Assaf Naor: Quantitative geometry, the power of algorithms, and their limitations

by M.L. Ball

A Courant Institute faculty member for four and a half years, Mathematics Professor Assaf Naor was born in Israel, earning his BS, MS, and a Ph.D. in mathematics from Hebrew University in Jerusalem. Professor Joram Lindenstrauss was his advisor, whom Prof. Naor warmly described as "a senior excellent mathematician."

After spending three years in Rochester, NY as a child, Prof. Naor returned to the United States in 2002, working in the Theory Group at Microsoft Research. "It's a research institution very similar to a university—research faculty and seminars, conferences, and pure research," he explained. "There are no students but there are interns and students who come from other universities. It was a lot of fun."

Working also on computer science, Prof. Naor is mainly a pure mathematician, an analyst and a geometer. "The Courant Institute, in my opinion, is the best place in the world for this," he said. "It has a great geometry group, and amazing analysts and probabilists. The kind of math being done here is exactly what I like. Also, in the computer science department there are people whom I talk with a lot and collaborate with. The specific interests of the faculty here are perfect for me. And New York is an absolutely wonderful city."

> "I realized that math problems I had been working on can be reinterpreted as problems in computer science" — Assaf Naor

Math problems reinterpreted as computer science ones

"As a graduate student, I realized that math problems I had been working on can be reinterpreted as problems in computer science," Prof. Naor said. "I was giving a talk on something I had proven and there was a computer scientist in the audience who said, 'You know this means you actually solved something in computer science.' I was really surprised by this—I had no idea."

For Prof. Naor, it's a good sign of the importance of problems when they get rediscovered. "For fifteen years now, people have been realizing that all kinds of problems that are coming up naturally in computer science are just restatements of problems that analysts and geometers like me have been thinking about for many decades. Sometimes the reinterpretation isn't obvious but once you actually think about it, you realize this is something you would have worked on anyway," he said. "This is what I love, all these connections. It's the beginning of something huge."

He continued, "To explain what theoretical computer science is, consider the following example: an applied computer scientist trying to use current hardware technology to build something might say, 'We don't have the technology to do what I'm trying to do.' Then a theoretical computer scientist might prove a theorem saying, 'Even in idealized computers, independent of whatever technology will ever be invented in the future, this problem cannot be solved.' So we have to argue not about what current technology is, but that certain tasks cannot be done because of the nature of what it means to compute. This is very theoretical *and* very mathematical."

This proving of limitations and possibilities in the abstract—what would the best hypothetical computer be able to do—is what Prof. Naor does. "My results are related to finding new algorithms but also to proving that all kinds of things are impossible and that certain algorithms must fail," he said. "I like what it means to prove that something is impossible. This requires thought, it involves coming up with new ideas and proving the limitations of things. Many of my positive results came from me trying to prove that you can't do it and then failing, which means that I figured out how to do it."

The Center for Computational Intractability

Prof. Naor is involved in many projects, among the most significant being the Center for Computational Intractability project, funded by a $10 million 'Expeditions in Computing' grant from the National Science Foundation. Part of a team working on the *Expedition to Understand, Cope with, and Benefit From Intractability*, Prof. Naor and the other Principal Investigators are charged with attacking some of the deepest and hardest problems in computer science and trying to bridge fundamental gaps in our understanding about the power and limits of efficient algorithms, which will lead to a better understanding of the boundary between the tractable and the intractable.

"This is a very exciting project which is also a big success," Naor said. "'Expeditions in Computing' is attempting to focus a major effort on a problem which is an 'expedition' in the sense that we want to try our hand at doing something very difficult but very important. Subhash Khot in Courant's computer science department, who comes from complexity theory and uses a lot of geometry, and myself from the math department, made the proposal, along with people from Rutgers University, the Institute of Advanced Study, and Princeton University, where the Center is located. We have monthly meetings and many conferences and lots of postdocs and visitors coming in—there's a lot of activity. And we've solved problems, which has happened much faster than would have happened without 'Expeditions in Computing.'"

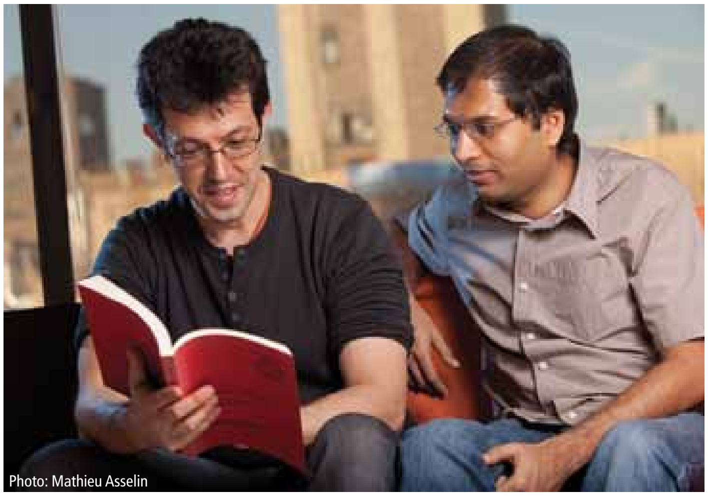


Photo: Mathieu Asselin

Assaf Naor and Subhash Khot

Further explaining the *Expedition to Understand, Cope with, and Benefit From Intractability*, Prof. Naor said, "Assume that you have some algorithmic task and you found the boundary beyond which finding a good solution of it is intractable. Beyond this boundary it is impossible to do this on a computer, but up to this boundary you *can* do it. The definition of finding the frontier between tractable and intractable means that you did both: you proved that something is impossible but also proved that something *is* possible because this is the frontier. This side of the line versus that side of the line. At the Center for Computational Intractability, we're interested in finding the line."

Quantitative Geometry

Another project currently occupying much of Prof. Naor's time is a very large program he is organizing called Quantitative Geometry, which will take place at the Mathematical Sciences Research Institute in the fall of 2011. "This is related to my main interest, quantitative geometry, which is understanding the structure of geometric objects in a quantitative way," he said. "There is a whole field of geometry which involves problems which are inherently quantitative, such as allowing for errors and then measuring the size of the errors and asking questions about which errors are allowed."

Incessantly working

Describing his work patterns, Prof. Naor said with a laugh, "I work all the time. But that is true for all mathematicians. Nobody makes it to Courant without being an idealist. You're doing what you love, that when you fall asleep at night you dream about. Even when I'm on vacation I can't stop my brain so all of a sudden I see a geometric shape that reminds me of something. I'm not doing it for my salary—I'm doing it because this is something that I think is truly important and it's just part of me."

He continued, "There is so much to do and so many problems to understand, and I don't have enough time to do them all. Then when you discover something, you realize that you should now investigate in another direction that you didn't know before. So there's always more to do."

Limitless future

"I truly think that these quantitative geometric or analytic questions, whether they are applied to computer science or internal studies within mathematics, are genuinely interesting. They are important with an absolutely huge future. It's a very active field—there are lots of young people getting involved and exciting results coming in all the time."

Fortunately, Prof. Naor has the energy and the passion to take on this new frontier, and we eagerly await the results. ■

The "Tiger Partition" as a method to obtain the first improved estimate on the "Grothendieck constant" since 1977. This result has been very recently obtained by Assaf Naor and his collaborators Mark Braverman, Konstantin Makarychev and Yury Makarychev. Numerical computations suggest the following classification procedure for high dimensional vectors obtained as maximizers of a certain quadratic energy that arises as a continuous relaxation of a key discrete optimization problem: partition the Euclidean plane into orange and black points as depicted at left, then project points in a high dimensional space onto a random plane and classify them according to the color of their shadow (i.e., orange or black). It turns out that such nonstandard rounding procedures can improve the best-known bounds in a variety of mathematical and algorithmic problems. While the success of the partitioning method based on the Tiger Partition is currently not proven rigorously, numerical computations indicate that the planar partition depicted at left might be the best way to partition the plane for these purposes. The new improved bound in the work of Braverman-Makarychev-Makarychev-Naor is proved rigorously using a (suboptimal) partition of the plane arising from the graph of a certain carefully chosen polynomial. This new type of partitioning method disproves a widely accepted belief on the best possible classification scheme for high dimensional vectors and highlights the possibility of new higher dimensional rounding methods for combinatorial optimization problems.

Marsha Berger: Innovative Real-World Problem Solver

by M.L. Ball


Photo: Mathieu Asselin

Arriving at the Courant Institute as a postdoc in 1982, Computer Science Professor Marsha Berger has spent her entire professional career here, and in the almost 30 years since, has developed codes that have solved problems for such national entities as NASA and the U.S. Air Force. "Courant is, and always has been, at the forefront of applied mathematics," Prof. Berger recalled. "And all these years later this is still a great place to be."

Collaborating with NASA Ames

Prof. Berger has participated in numerous collaborative projects. Now she is working with her long-time colleague at NASA Ames, aerodynamicist Mike Aftosmis. The two are developing software that computes fluid flow in complex engineering applications. "If you're designing a new spacecraft or an airplane," Prof. Berger explained, "you want to try out many designs before you lock onto one and fine-tune it. When we started, a simulation that would take only a few hours to run might take days or weeks to set up. It took years of research to find computational methods that don't need case-by-case customization. By now, software based on our research is used throughout NASA and has also been commercialized."

Mesh refinement and the GeoClaw code

Another of Prof. Berger's projects that has been used to solve real-world problems is mesh refinement. "My thesis was on mesh refinement and I have been developing aspects of it off and on since then," she said. "I'm currently working with another long-time collaborator, Randy LeVeque at the University of Washington, and one of his former students who now works at the U.S. Geological Survey."

The project is tsunami modeling using a code called GeoClaw, a derivative of the Clawpack software to solve conservation laws that is specialized for geophysical flows. The code uses adaptive mesh refinement to track a tsunami as it moves across the ocean and then adds additional levels of resolution to see what happens when it hits land. According to Prof. Berger, "Tsunamis are relatively long waves that travel hundreds or thousands of kilometers in the open ocean, but they get shorter and taller in shallow water near land. They are refracted in complicated ways by bathymetry (underwater topography) of the ocean bottom near land."

Prof. Berger explained that there is no way to know before the simulation where the important wave structures will be. Adaptive methods allow the computational algorithm to change with the simulation results to achieve the necessary resolution only where and when it is absolutely necessary. This makes it possible to do much more interesting simulations with the same amount of computer power.

Mesh generation

In earlier research, Prof. Berger worked on mesh generation, a method for choosing the set of points used to compute a fluid flow around complicated geometries. "For example, in an airplane air flow simulation," she described, "if you want to compute the flow in the little gap between the flap and the body, a lot of grid points are required. Otherwise the mesh won't even 'see' the gap, much less accurately simulate that part of the flow. You have to generate a mesh that reflects both the flow and the geometry appropriately."

When the U.S. Air Force had an urgent problem, it was the mesh generation code developed by Prof. Berger and Mike Aftosmosis that helped solve it when other codes could not. "The problem involved the C-17, an Air Force transport plane developed in the 1990s," Prof. Berger said. "The requirements were that the plane would fly over the drop zone for four minutes, in which time 400 men had to jump out of the doors and the payload had to go out the back. When two marines jumped out simultaneously from a door on each side of the plane, they were being entrained into the air flow and were colliding in the back of the plane. This was called a 'parachute entanglement problem.'"

It was too late to re-machine the doors to change their positions; an aerodynamic response was the only option. Since the C-17 is a very heavy plane, the flaps go all the way to the body, which meant that the air was being deflected right in front of the door, catching the parachutists. "Once my NASA collaborators were able to simulate the problem using our code, the aerodynamicists then recommended that the plane fly decked, putting the flaps at a slightly different angle to deflect the air flow away from the door to the plane," Prof. Berger said. "So our research actually had impact in a timeframe that is not typical for mathematics research and our code, Cart3D, currently has many Air Force users."

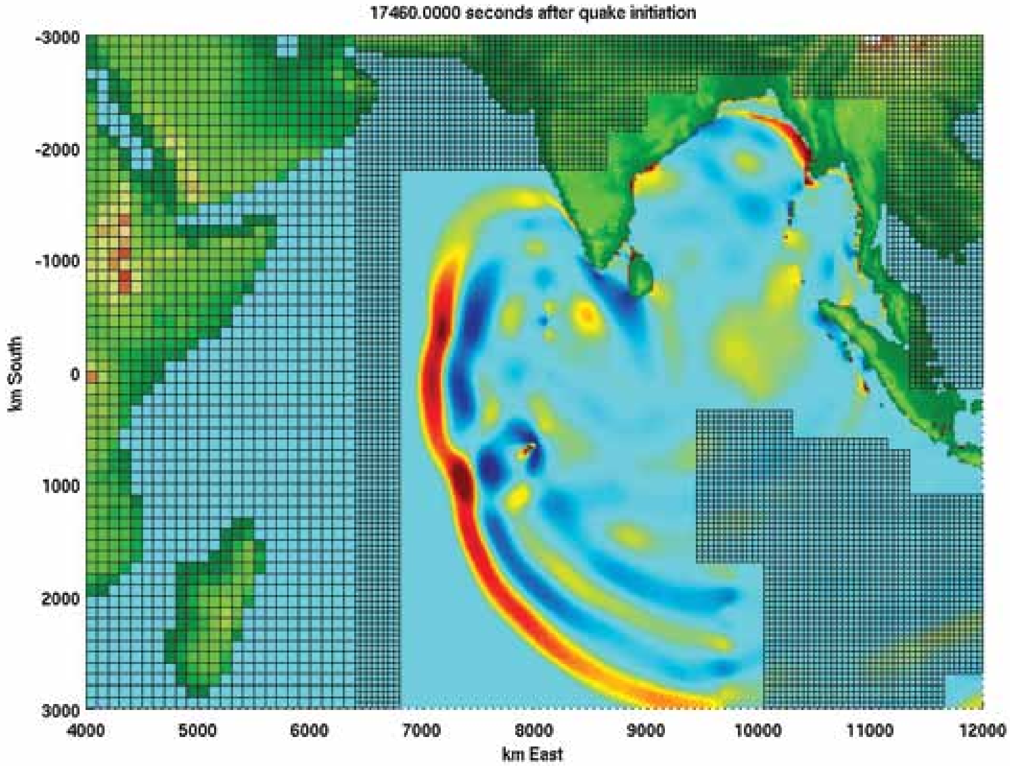
This same Cart3D code contributed to NASA's investigation of what led to the Space Shuttle *Columbia*'s explosion upon re-entry into the Earth's atmosphere in 2003. "NASA thought the problem was due to a piece of foam that came off during liftoff and hit the wing, making a small hole that during re-entry allowed hot gases to enter and destroy the shuttle," Prof. Berger explained. "Cart3D was used to do hundreds of simulations of the foam breaking off and flying through the air around the shuttle. We were able to find a reasonable set of parameters – such as size of foam and its initial direction and velocity – that showed that foam was a feasible hypothesis. This is now part of the record in the Columbia Accident Investigation Board's report."

Courant Mathematics and Computing Laboratory (CMCL)

Along with Professor Leslie Greengard, Prof. Berger is the co-Principal Investigator of the Courant Mathematics and Computing Laboratory, a large effort funded by the U.S. Department of Energy. "The DOE supports much of the numerical development and high-performance computing development in this country," Prof. Berger said. "It has funded and operates the most powerful supercomputers in the U.S. The faculty in the CMCL are applied mathematicians and analysts working on developing new algorithms and analyzing problems of interest to the DOE."

In 1965, Peter Lax, then Director of what was to become the CMCL, was instrumental in bringing the first supercomputer installed at a university – a CDC 6600 – to the Courant Institute. That was funded by the AEC (Atomic Energy Commission), the precursor of the DOE. "It was a really big deal," Prof. Berger said, "and Peter was very much involved in it. He believed strongly, and his work convinced lots of others, that mathematicians had much to contribute to what is now called scientific supercomputing. He started a long tradition of this kind of mathematics applied to computing here at Courant."

Prof. Berger pointed out that the Courant Institute has a 50 year relationship with the DOE, and used to be regarded as one of its laboratories, much in the same way as Brookhaven or Idaho National Laboratory. "Richard Courant, the founder of the Courant Institute, had the vision that pure and applied mathematics could work together and re-enforce each other. Peter Lax saw computing as a central part of applied mathematics. That atmosphere first attracted me here and continues to make the Institute a great place to do my kind of computational work," Prof. Berger said.



Simulation of 2004 tsunami using GeoClaw and adaptive mesh refinement.

The infinite appeal of computer science

When asked why computer science continues to hold her interest, Prof. Berger emphatically replied, "Because there's always more to learn, new ways to look at things." ■

2011 Courant Institute Student Prizes

Bella Manel Prize
Piriyadharshini Devendran

Henning Biermann Award
Vasilis Gkatzelis

Sandra Bleistein Prize
Adriana Lopez-Alt

Hollis Cooley Prize
Nathaniel Weinman

Janet Fabri Prize
Piotr Mirowski and
Ameet Talwalkar

Kurt O. Friedrichs Prize
Ivan Corwin and
William Perkins

Max Goldstein Award
Felipe Cole

Harold Grad Memorial Prize
Peter Bella and
Aditya Dhananjay

Moses A. Greenfield Research Award
Adam Stinchcombe and
Qi Zhang

Wilhelm Magnus Memorial Prize
Antonio Auffinger and
Enkeleida Lushi

Masters Student Thesis Prize
Isaac Wagner

Matthew Smosna Prize
Uma Balasubramanian and
Brendan Linn

Alex Barnett: Courant Instructor and Applied Math Convert

by M.L. Ball


Photo: Cheryl Sylivant

Visiting Members

As is widely appreciated, the Visiting Members Program constitutes a vital part of the life and activities of the Courant Institute. Each year, the Institute serves as a temporary home for more than 125 visitors at different stages of their careers who stay for several weeks to several years. One of the core components of the Visiting Members Program is the Courant Instructorship, a highly competitive postdoctoral appointment for recent Ph.D.s in mathematics or an affiliated field. These appointments last up to three years and carry a teaching load of one course per semester. The Program currently has approximately fifteen Courant Instructors in residence during any given year.

Alex Barnett: from Cambridge to Cambridge to Courant

One Courant Instructor who has enjoyed a non-traditional yet successful career path as a result of his Instructorship is Alex Barnett. Originally from England, he was awarded a BA (First class) in Theoretical Physics from Cambridge University, UK, then earned his Ph.D. in Physics from Harvard University, Cambridge, MA, advised by Professor Eric J. Heller.

After receiving his doctoral degree, Alex then spent seven months at Massachusetts General Hospital in Boston working on brain imaging. "What was valuable for me about imaging the brain is that it opened up other interesting problems outside the field of physics, ones that involve numerical computing," Alex explained. "I realized that's what I really like—inventing computer algorithms to solve real-world problems."

While at Mass. General, Alex was also applying for postdoc positions. "It was kind of a long shot because I didn't have a math background—my Ph.D. was in physics," he said. "But then the Courant Institute called and offered me the Instructorship. That was very exciting because this is a top place. But I was still very surprised to get the offer. I think they were thinking broadly, which is a very good thing, and it changed my life."

Dramatic transition from physics to math

A Courant Instructor from 2002-2005, Alex Barnett is now an Assistant Professor of Mathematics at Dartmouth College. Having returned to the Courant Institute this winter for the month of February to continue a collaboration on wave scattering with Professor Leslie Greengard, he warmly described his three years here in Warren Weaver Hall.

"Being offered the Courant Instructorship was a huge transition for me. I was really thrown into the deep end," Alex recalled with a laugh. "I don't know if they were aware that a physicist doesn't necessarily know that much mathematics! We solve equations and we know how to solve a lot of integrals. We know about functions, but we don't know about proving things. It's a totally different tradition. So it was a huge learning experience. I tried to read books on functional analysis because that's what everyone's using all around you, and you need those tools to prove things," he said.

According to Barnett, "Physicists don't prove things, but they do derive beautiful formulae and equations, and loosely speaking, if everyone agrees the equation's correct, and it agrees with the experiment, then it's correct. And if your computer produces data that agrees with it too, then it's all good. But you never take the step of writing down precise conditions and a theorem, something that holds whenever those conditions hold, and then proving it. That's mathematics," he said.

"However," he explained further, "within applied math, one doesn't always have to prove theorems. There are some applied mathematicians who never prove any theorems, and I started out in that style. Now I've proven a few theorems, so it's become one part of my language," he said. "I learned that here at Courant, partially by sitting down and talking to people like Jonathan Goodman and Percy Deift and Bob Kohn. I would go to them and say, 'I'm stuck on this,' and they would suggest all sorts of techniques."

Professor Percy Deift, in particular, took an interest in Alex and exposed him to important fundamentals of analysis. "What made it so special was that, later, I realized that well-known senior figures usually provide the problems and then get others interested in what they want to solve," Alex said. "In my case, I wasn't very strategic or maybe a little stubborn, in that I came here with my own problems coming out of physics research. These were fast numerical methods for eigenvalues that are relatively obscure, and I was asking, 'Can we prove things about them? Can we turn them into reliable numerical tools that the engineering and applied math communities can use?'"

Maybe because the problem involved spectral theory, Prof. Deift found it interesting. Alex remembered, "I said to him, 'Here are the equations for this method and now I want to prove something about it but I'm stuck.' So, he and Jonathan Goodman guided me and said, 'Throw all that away. You shouldn't be using infinite series, you should be using operators.' So I decided to learn about operators. Percy basically gave me some of the key ideas that went into my paper on this. We spent hours talking together, which was amazing, because sometimes top people don't want to know about a problem that a young reseacher brings to the table," he said.

Another mathematician who encouraged Alex was Professor Peter Sarnak. "He's at Princeton but was visiting Courant for a year," Alex said. "We got to know each other because we co-taught an undergrad course for honor students the first semester I was here, which was essentially me learning from him and his postdoc Steven J. Miller (now at Williams College), and then guiding the student projects."

At the time, Alex was interested in an area of physics called quantum chaos. "Peter said to me, 'You should keep working on this quantum chaos stuff because there are some interesting conjectures that pure mathematicians care about,'" Alex said. "And he asked me to do some numerical calculations that addressed those things. That's not a direction where applied math people usually go, but it worked out well because I'm still doing some work in that area. We organized a conference on it last July at Dartmouth and Sarnak and a lot of other well-known people came."

Invaluable connections made at Courant

Barnett states unequivocally that the connections he made during his Courant Instructorship and has maintained throughout the six years since then have been invaluable to him. "The people I met at Courant have been really important for my career, and I've always come back to them. Courant faculty are interested in guiding people," he said.

> "I don't know if they were aware that a physicist doesn't necessarily know that much mathematics! Being offered the Courant Instructorship was a huge transition for me."
> — Alex Barnett

One such faculty member was Professor Mike Shelley, who was sort of a mentor to Alex, even though Courant Instructors are not directly advised by anyone. "He asked if I wanted to work on how fish swim and if I wanted to get into fluid mechanics," Alex said, "so I went to all the seminars in that area—the Applied Math Lab seminar. Later I co-organized the seminar with Professor Jun Zhang, which was a very good experience. When you're a grad student, you have no idea how much work it is to put together a seminar series, or how much you learn about what everyone is doing. You decide whom to invite, you look after them while they're here, and you hook them up with local people—people whom they'll find interesting or who will find *them* interesting," he said.

"That's really the professional network-building that happens here at Courant," Alex stated. "You learn who does what, what areas are exciting or interesting to you, and what areas connect to other areas. That's the invaluable stuff that helps you with your career and what it means to be a mathematician. It's not just the scribbling or the mathematical thought, it's the understanding of the professional landscape."

Courant Instructorship: opportunities and freedom

In describing the Courant Instructorship program, Alex was overflowing with praise. "I love teaching, which the Instructorship gave me the opportunity to do. I'd never been responsible for a full class before, which is always a daunting experience: covering the material, deciding grades, overseeing several Teaching Assistants. That was very good for me to learn those skills. I also learned how to write a grant here, which has proven to be very helpful," he said.

"Another way in which the Instructorship really helped me professionally was when it came time to apply for jobs," Alex said. "I hadn't published as many papers as some other postdocs. However, the letters from Courant faculty must have been good, for which I'm very grateful. For instance, Peter Sarnak, a pure mathematician, wrote a letter for me, a numerical applied person, which is slightly unusual," he added.

Alex characterized the Courant Instructorship as a doubled-edged sword, in the sense that Courant Instructors have complete research freedom but it's essentially up to them to figure out how to make best use of the amazing opportunity. "You're given a light teaching load, one course per semester, and you're free to do your research. But it's up to you to self-motivate and steer the ship; you don't have an advisor breathing down your neck," he said.

Courant Institute experience opened doors to a new career

Although his original field was physics, Alex described himself now as much more of an applied mathematician. "That's directly due to my three years spent here at Courant; otherwise I would've gone on the job market in physics," he said. "Once I saw the range of problems and approaches people have, I said, 'Applied math is a great way to go.' Unlike physics, you can work in many different areas and still be taken seriously, which I love."

Another wonderful aspect of the Courant Institute, Alex added, is that it's like a permanent conference. "You come back here and immediately bump into people you know," he said. "You hang out in the 13th floor lounge—a lot of important interaction and discussion happens in the lounge—and you start discussing math problems with people, like at a conference. I don't know any place quite like that. People's doors are open here; it's nice and friendly. Courant is a really great place for setting you up with future connections throughout the entire math community."

Best of luck at Dartmouth, Professor Barnett, but fortunately for us, you shall always stay firmly connected to the Courant Institute. ■

Faculy Honors

Shravan Veerapaneni

Denis Zorin

Robert Fergus

Jinyang Li

Richard Cole

Chuck Newman

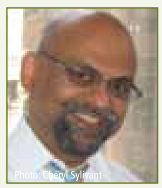
Olof Widlund

The 2010 ACM Gordon Bell Prize for outstanding achievement in high-performance computing has been awarded to a team from Georgia Tech, NYU and Oak Ridge National Laboratory. The NYU members of the team are **Denis Zorin** and Postdoc **Shravan Veerapaneni**. The team was led by **George Biros** who was a Postdoc at NYU in 2000-2003 and is now on the faculty at Georgia Tech.

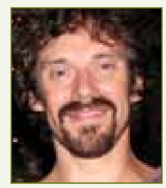
Robert Fergus and **Jinyang Li** have been awarded fellowships from the Alfred P. Sloan Foundation. Sloan Foundation Fellowships are given to early-career scientists and scholars in recognition of achievement and the potential to contribute substantially to their fields.

Richard Cole, **Chuck Newman**, and **Olof Widlund** have been named Silver Professors. Funded by an endowment to the University from alumnus Julius Silver, Silver Chairs are awarded in recognition of outstanding scholarly contributions. The three Courant Institute faculty members will be awarded the distinction at a special ceremony in the Fall.

Assaf Naor



Bud Mishra



Eric Vanden-Eijnden

Assaf Naor has received the 2011 Bôcher Memorial Prize "for introducing new invariants of metric spaces and for applying his new understanding of the distortion between various metric structures to theoretical computer science." The Bôcher Prize, awarded by the American Mathematical Society, recognizes "the most notable paper in analysis published during the preceding six years."

Bud Mishra has been elected a Fellow of the American Association for the Advancement of Science. The AAAS selected Mishra for his "distinguished contributions to the field of computational and systems approaches to the fields of robotics, hardware verification, and computational biology."

Eric Vanden-Eijnden won the 2011 SIAM J.D. Crawford Prize for his "transformative work in stochastic dynamical systems, [which] stimulat[es] new ideas in applied and computational mathematics while also impacting applications." The Crawford Prize is awarded every two years for "recent outstanding work on a topic in nonlinear science."

The Bi-Annual 24-Hour Hackathon

Hack NY held its third bi-annual 24-hour Hackathon this April 9-10 in Warren Weaver Hall. Organized by Evan Korth of NYU and Chris Wiggins of Columbia, the event attracted nearly 300 students. As stated by Rob Spectre in Business Insider, "a full military company of twentysomethings had surrendered the first nice weekend we've gotten in forever to stare at a computer screen for 20 hours straight, load up on caffeine and voluntarily march through a marathon of coding and creating." Sixteen Startup companies presented at the event—including Etsy, FourSquare, Tumblr, 10gen, and Aviary—which received a slew of media coverage, from the Wall Street Journal to popular technology blogs. Evan Korth, Faculty Liaison for Technology Entrepreneurship and Clinical Associate Professor at Courant said, "Hackathons expose students to the power of collaborative development and allow them to exchange their knowledge with their peers. hackNY hopes to foster a network of young makers to mentor and guide one another well beyond their time in college." ■

The Bermuda Yacht Race

by **Dennis E. Shasha** and **Richard Cole**

Jupiter Propp, the fictitious composite yachtsman, uses eddies and the gulf stream to great advantage when racing from Newport to Bermuda. To show his technique he proposes a simple game that can be played by remote controlled cars and a ground level rotating disk.

Please look at Figure 1. The goal is to go, as quickly as possible, from the northern horizontal bar to the southern one — to be precise from the point where the northern horizontal bar meets the dotted line segment (analogous to "Connecticut") to the point where the southern horizontal bar meets the dotted line segment (analogous to "Bermuda"). The disk in between spins clockwise, so trying to follow the dotted line directly is a losing proposition. (As my non-fictitious climbing friend Kentucky Pete puts it, "the shortest path between two points is a straight line, but the easiest path wanders.")

In fact, it may be good to start off going slightly towards the southeast, then navigate somehow across the spinning disk, slightly east of the dotted line, and then go southwest toward the finish as shown in Figure 1.

The problem description uses the following parameters, and, for concreteness, the current values are shown in parentheses.

- b = car speed in meters per minute (100 meters per minute).
- d = distance from the start point to the northern-most edge of the disk (25 meters).
- e = distance from southern end of the disk to the end point (25 meters).
- r = radius of the disk (25 meters).
- s = spin speed of disk in degrees per minute (90 degrees per minute).

Given these parameters and their values, your job is to determine the values for the following two angles yielding the shortest journey time.

- A = angle away from straight line through center of disk leaving Connecticut.
- B = angle away from straight line through center of the disk approaching Bermuda.

Notice that if the disk didn't rotate at all then A and B should be 0. Just take the straight path indicated by the dotted line.

Warm-up 1: If the disk rotates superfast (say 10,000 revolutions per minute), then what values should A and B take?

Solution to Warm-Up 1: Again A and B should be 0 or close to 0. The car could arrive where the dotted line meets the top of the disk and then ride the disk around to the point where the dotted line meets the disk on the bottom.
End of Warm-up 1.

Remarkably, for intermediate values of the disk rotation speed, we want A and B to be positive. But now the question is: how should the car travel across the disk to go from the point where the northern segment arrives at the disk to the point where the southern segment leaves the disk?

Warm-up 2: What do you think?

Solution to Warm-up 2: In the frame of reference of the disk, the shortest distances are straight lines. That is, the shortest path from one point on a circle to another is a straight line segment. In general, the car will therefore traverse a chord through the disk such that the end of the chord is precisely the point where the car wants to exit given the disk's rotation. See Figure 2.

For example, if the car needs to go 130 degrees around the disk in the non-rotational frame, then it might be possible for the car to traverse a chord that subtends say 80 degrees at the same time the disk rotates 50 degrees.

That is, the fastest way to get from one point to the other is to aim the chord at a closer point and let the disk simultaneously swing the car around to the proper point. See Figure 3.
End of Warm-up 2

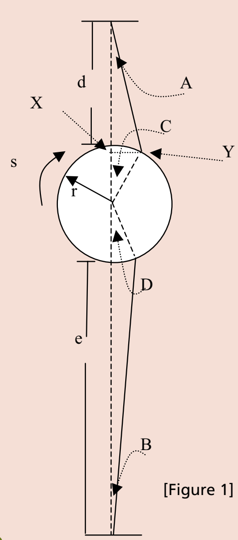
Unusually for this column, I would now like to invite you to calculate. I myself used some trigonometry and a computer language.

1. Give a formula or a procedure to find the best angles A and B, given b, d, e, r, and s as above (and obtain the values of A and B for the values of the other parameters given above in parentheses).

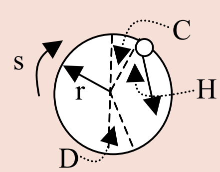
Hint: The main challenge is to set it up as if A and B were known (the H angle from Figure 3 can be derived). Then you can use a computer to test different A and B values. If you have an elegant closed form solution, I'm very interested. Also, you might use some simplifying approximation since the rotation speed is relatively small.

2. Now for an advanced problem: with b, d, e, and r taking on the values specified in parentheses, for which rotational speeds of the disk will A (and B) take on their maximum value? What is that maximum?

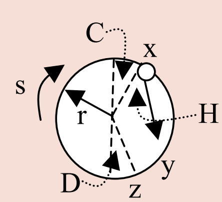
For the solution, email: courant.alumni@nyu.edu



[Figure 1]



[Figure 2] Car represented by oval takes a setting described by a chord that does not aim at its final destination. The spin of the disk will carry the car to that destination.



[Figure 3] If there were no rotation, the car would end up at y. Point y however rotates to z while the car travels the chord from x to y at angle H in the frame of the disk.

Edward A. Belbruno, Ph.D. in Mathematics '80

"Twilight", oil, 24x24 inches, 2011

Edward Belbruno is both a mathematician and an artist. He received his PhD from the Courant Institute in 1980, specializing in celestial mechanics. His advisor was Jürgen Moser. "It was a privilege and inspiration to study under Jürgen Moser," says Belbruno, "one of the leading mathematicians of the 20th century, well known for the Kolmogorov-Arnold-Moser theorem." Belbruno's first job was an assistant professor of mathematics at Boston University in 1980. He went to NASA's Jet Propulsion Laboratory in 1986 where he designed routes to the planets for robotic spacecraft, including the *Galileo* to Jupiter and *Cassini* to Saturn. While there, Belbruno laid the foundations for the first application of chaos theory to space travel, called weak stability boundary theory, by finding new low fuel routes to the Moon and beyond. His work was dramatically demonstrated in 1991 in the rescue of the Japanese spacecraft *Hiten*, which had almost no fuel, by successfully bringing it to the Moon on a new route. NASA's upcoming *GRAIL* mission will be using a similar route. Belbruno has recently applied his work to a wide variety of problems including the origin of the Moon and black hole dynamics.

He has been a regular consultant with NASA and is president of his own research company, Innovative Orbital Design, Inc., appearing twice on NBC's *Today Show*. He has a number of patents on routes in space and has recently published two mathematics books with Princeton University Press – *Capture Dynamics and Chaotic Motions in Celestial Mechanics,* and *Fly Me to the Moon*. He has also been affiliated with Princeton University.

Belbruno is an acclaimed painter, who has had many international exhibitions including Paris, Rome, Los Angeles, Washington, D.C., New York, Minneapolis. One of his paintings is part of NASA's executive collection in Washington, D.C. and he has several in Princeton University's permanent collection. He recently held an exhibition at Lincoln Center sponsored by the Metropolitan Opera House Guild. His most recent exhibition opened at the Gallery 61 in New York City on March 31, 2011. ■

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