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Math Scientists Worldwide Embrace MPE2013 Vision

By now, most mathematicians are aware of Mathematics of Planet Earth 2013, the year-long program created to encourage research on a range of topics related to Planet Earth. The distinctive logo has been featured at many conferences, workshops, and lectures. The program, initiated by major mathematics research institutes in North America, has grown to an international year involving more than 140 partners—including professional societies (SIAM, among many others), academic institutions, research institutes, scientific publications, and teacher organizations.

By the end of the year, MPE2013 will have sponsored more than 15 long-term programs at institutes all over the world, 60 workshops, dozens of special sessions at society meetings, two big public lecture series, summer and winter schools for graduate students, research experiences for undergraduates, and an international competition for museum-quality exhibits on MPE themes. In addition, MPE2013 is supporting the development of high-quality curriculum materials for all ages and grades. All these materials, including the winning designs of the competition, are available free of charge on the web.

Encouraging Research

Many of the activities sponsored by MPE2013 are directed to the mathematical sciences community, whose members are encouraged to identify fundamental research questions about Planet Earth. The program provides evidence that many issues related to weather, climate, sustainability, public health, natural hazards, and financial and social systems lead to very interesting mathematical problems.

Planet Earth is a dynamical system, with all the characteristics of a stochastic complex system, where mathematical models and data come together and interact in novel ways. Computer models and observation systems provide vast amounts of data, which lead to feedback and refinements of the mathematical models. Importantly, this process has also opened the door to new mathematical ideas that can enhance the modeling process. For example, ideas from algebraic topology have led to clustering algorithms for the analysis of large data sets; the abstract theory of percolation is used to characterize sea ice; bifurcation theory provides a natural framework for the study of phase transitions and tipping points. Data assimilation, which has been applied very successfully to improve weather forecasting, is finding its way into studies of current as well as past climates. Uncertainty quantification is another field that can give new information about the likelihood of "what-if" scenarios. Statistics of extreme events can play a critical role in the debate on climate change. It is increasingly clear that as mathematicians we have an opportunity to apply our know-how in ingenious ways and, ultimately, to weigh in on some of the big problems we face.

Reaching Out

In addition to highlighting research opportunities for mathematical scientists, MPE2013 sponsors an extensive program of outreach activities. Fifty-nine public lectures have been given since the inception of the MPE2013 public lecture series (in June 2012); the program includes the MPE Simons Public Lectures, which are supported financially by the Simons Foundation. MPE2013 lectures have been presented to audiences on all five continents, by internationally known speakers from mathematics as well as several application sciences. Upcoming public lecturers are Martin Nowak (at the University of Minnesota, October 8), Walter Craig (in New Brunswick, October 10), Emily Carter (at UCLA, November 4), and Christiane Rousseau (in Québec, November 7). The program maintains a speakers bureau, supports the development of curriculum mate-

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SIAM ♥ Students

What would SIAM be without students? SIAM president Irene Fonseca and the SIAM Board of Trustees made their answer clear this summer with a generous boost (matching one of equal value the previous year) for the Student Travel Fund. See page 5.
As illustrated in the photos and articles on pages 4 and 5, students play an increasingly vital role in SIAM activities. Enthusiastic participants in special sessions at the Annual Meeting, they also organize and take part in innovative chapter activities and submit papers to SIAM's undergraduate research journal.
Pictured above is a particularly engaging session at the SIAM Annual Meeting in San Diego: In the time of a minisymposium, students were free to ask participating invited speakers (almost all signed on) questions about research directions, careers, internships, job search . . . .

Super-resolution and Compressed Sensing

By Carlos Fernandez-Granda

It has long been known that a lens, however perfect, has limited resolving power.

As Lord Rayleigh pointed out in his seminal 1891 paper "On Pin-hole Photography," diffraction imposes an inflexible limit on the resolution of any optical system. As a result, in such fields as microscopy, astronomy, and medical imaging, it is often challenging to discern cellular structures, faraway galaxies, or incipient tumours from the available data. Super-resolution aims to meet precisely that challenge—to uncover fine-scale structure from coarse-scale measurements. This problem also arises in electronic imaging, where photon shot noise constrains the minimum possible pixel size, and in many other applications, including signal processing, spectroscopy, radar, and seismology.

In its most general formulation, the problem of super-resolution is ill posed. This becomes apparent in the frequency domain. Low-resolution measurements essentially erase the high end of the spectrum; consequently, we cannot hope to retrieve the missing fine-scale information without prior knowledge of our object of interest. Under one popular assumption, we can model the signal as a superposition of point sources or spikes, which might represent celestial bodies in astronomy, molecules in fluorescence microscopy, or line spectra in signal processing. Figure 1 illustrates the resulting inverse problem: The aim is to estimate the train of spikes at the upper left from the blurry measurements at the upper right or, equivalently, to extrapolate the high frequencies at the lower left from the truncated spectrum at the lower right. Under what conditions can we hope to achieve this? The answer must surely involve exploiting the sparsity of the signal, which suggests connections with compressed sensing.

In a nutshell, compressed sensing allows the recovery of a low-dimensional structure embedded in a high-dimensional space. Surprisingly, this is achieved by taking non-adaptive randomized measurements

See **Super-resolution** on page 8

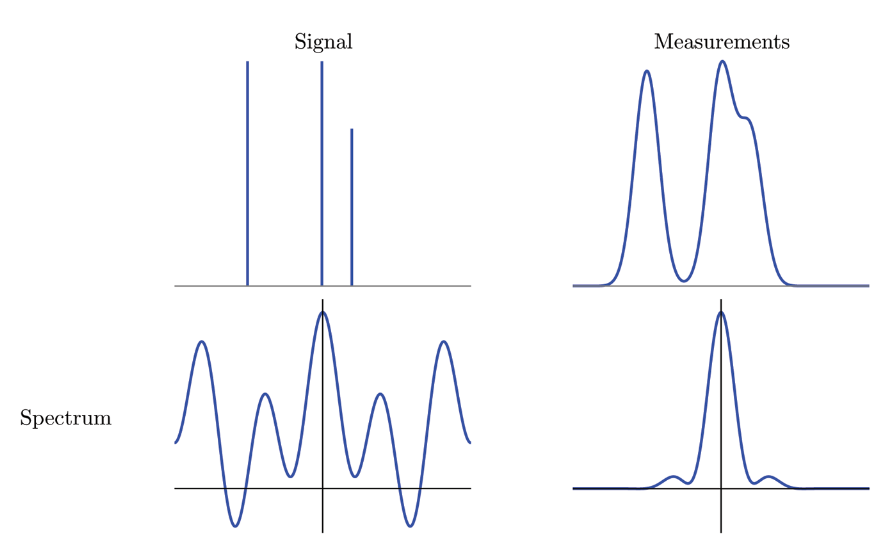

Figure 1. *Schematic illustration of the super-resolution problem. Left, a highly resolved signal and its spectrum. Right, low-pass measurements of the signal and the corresponding truncated spectrum.*

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A New Model of Iterated Prisoner's Dilemma

By James Case

For Freeman Dyson, a lifelong interest in Darwinian evolution has led to "a new career as a self-proclaimed expert in the theory of games" [2]. William Press, a computer scientist and computational biologist at the University of Texas, Austin, set the story in motion with an e-mail message to Dyson. Having identified a previously unnoticed class of strategies for playing the game of iterated prisoner's dilemma, Press was surprised to see his simulations crash when pitting one such strategy against another. Could Dyson explain why this was happening?

Press is an experimentalist concerned mainly with computer programs. Dyson, a theoretician more comfortable with equations, soon identified a determinant that, when equal to zero, permits the singular behavior Press had observed. Their joint paper on the subject [3] has caused a stir in the world of theoretical biology.

Prisoner's dilemma is a deceptively simple, symmetric non-zero-sum binary decision game. In the iconic version, two thieves are apprehended in the vicinity of a crime scene, in possession of stolen goods. They will be interrogated separately by police. Should neither confess, both will be found guilty of some minor offense. If either rats on the other, however, the silent party will receive a harsh sentence while the betrayer walks free. Finally, if each rats on the other, both will serve intermediate sentences, longer than if both had remained silent but substantially shorter than the one that would be imposed on a silent victim of betrayal. The numerical payoff scheme for players ME and THEE is shown in the following matrix, where $S < P < R < T$.

$$
\begin{array}{ll|cc}
 & & \multicolumn{2}{c}{\text{THEE}} \\
 & & \text{Stonewall} & \text{Confess} \\
\text{ME} & \text{Stonewall} & P & T \\
 & \text{Confess} & S & R
\end{array}
$$

Many authors use $(S, P, R, T) = (0,1,3,5)$ for illustrative purposes, and assume that $2R > S + T$ for technical reasons. It is sometimes useful to identify the foregoing "payoff matrix" and its transpose with the 4-vectors $\boldsymbol{\Pi} = (P,T,S,R)$ and $\boldsymbol{\Pi}' = (P,S,T,R)$.

Iterated prisoner's dilemma, in which the same two players play many rounds of PD (enabling each to predicate his own decisions on the other's past behavior), has become an important model in biology, primatology, and various social sciences for situations in which each of two players must decide repeatedly whether to cooperate in the upcoming round of play. In the generalized version of IPD, "stonewall" exemplifies "cooperation" (c); "confess" represents the binary alternative (d), "don't cooperate." A glance at the reward matrix reveals that c is the riskier—but potentially more rewarding—of the two choices. The fact that no two entries in the reward matrix are identical means that ME can tell after each round of PD exactly what THEE did and (if desired) maintain a complete record of both players' decision histories. Perhaps the most surprising fact to emerge from Dyson's analysis—presented in Appendix A of [3]—is that there is *no certain advantage* in so doing. Neither party has anything to gain by possessing a longer memory than the other!

For this and other reasons, it makes sense to focus initially on the version of IPD in which neither player cares to remember anything more of the past than the outcome of the latest round. Because the possible rewards $\{S,P,R,T\}$ in PD correspond to the ME\THEE decision pairs {d\c, c\c, d\d, c\d} = {1,2,3,4}, a stationary mixed strategy for ME consists of a 4-vector $\boldsymbol{p} = (p_1,p_2,p_3,p_4)$ in which p_i represents the probability that ME elects to cooperate (c) in the next round given that $i \in \{1,2,3,4\}$ was the pair most recently chosen. Similarly, a stationary mixed strategy for THEE consists of a 4-vector $\boldsymbol{q} = (q_1,q_2,q_3,q_4)$ in which q_i represents the probability with which THEE elects to cooperate (c) in the coming round when acting on the same information.

For a pair $(\boldsymbol{p},\boldsymbol{q})$ of stationary mixed strategies, one can form the 4×4 Markov matrix $\boldsymbol{M}(\boldsymbol{p},\boldsymbol{q})$ governing round-to-round transitions among elements of {1,2,3,4}. If $\boldsymbol{M}' = \boldsymbol{M} - \boldsymbol{I}$, the stationary vector $\boldsymbol{v}$ of the Markov process then satisfies both $\boldsymbol{v}^T\boldsymbol{M} = \boldsymbol{v}^T$ and $\boldsymbol{v}^T\boldsymbol{M}' = \boldsymbol{0}$. From these Dyson concludes that the dot product $\boldsymbol{v}\cdot\boldsymbol{f}$ of the stationary vector $\boldsymbol{v}$ with an arbitrary 4-vector $\boldsymbol{f}$ can be expressed as a 4×4 determinant $\boldsymbol{v}\cdot\boldsymbol{f} = D(\boldsymbol{p},\boldsymbol{q},\boldsymbol{f})$ in which the second and third columns are the respective transposes of $\tilde{\boldsymbol{p}} = (-1 + p_1,-1 + p_2,p_3,p_4)$ and $\tilde{\boldsymbol{q}} = (-1 + q_1,-1 + q_2,q_3,q_4)$, and the fourth column is $\boldsymbol{f}$ itself. Clearly, $\tilde{\boldsymbol{p}}$ is not influenced by THEE, and $\tilde{\boldsymbol{q}}$ is not influenced by ME. The steady-state payoffs to ME and THEE are $\pi_{\mathrm{ME}} = \boldsymbol{v}\cdot\boldsymbol{\Pi}/\boldsymbol{v}\cdot\boldsymbol{1} = D(\boldsymbol{p},\boldsymbol{q},\boldsymbol{\Pi})/D(\boldsymbol{p},\boldsymbol{q},\boldsymbol{1})$ and $\pi_{\mathrm{THEE}} = \boldsymbol{v}\cdot\boldsymbol{\Pi}/\boldsymbol{v}\cdot\boldsymbol{1} = D(\boldsymbol{p},\boldsymbol{q},\boldsymbol{\Pi}')/D(\boldsymbol{p},\boldsymbol{q},\boldsymbol{1})$, where $\boldsymbol{1}$ denotes a vector of ones. Thus, for any real constants α,β,γ,

$$
\alpha\pi_{\mathrm{ME}} + \beta\pi_{\mathrm{THEE}} + \gamma = \frac{D\left(\boldsymbol{p},\boldsymbol{q},\alpha\boldsymbol{\Pi} + \beta\boldsymbol{\Pi}' + \gamma\boldsymbol{1}\right)}{D\left(\boldsymbol{p},\boldsymbol{q},\boldsymbol{1}\right)}.
$$

This is Dyson's key equation. Plainly, it affords ME (resp. THEE) the unilateral power to choose—simply by requiring that $\tilde{\boldsymbol{p}}$ (resp. $\tilde{\boldsymbol{q}}$) be a scalar multiple of the fourth column $\boldsymbol{f} = \alpha\boldsymbol{\Pi} + \beta\boldsymbol{\Pi}' + \gamma\boldsymbol{1}$ of the determinant in the numerator—a strategy $\boldsymbol{p}$ (resp. $\boldsymbol{q}$) that causes $D(\cdot,\cdot,\cdot)$ to vanish, along with the linear combination $\alpha\pi_{\mathrm{ME}} + \beta\pi_{\mathrm{THEE}} + \gamma$. Dyson and Press call such strategies "zero-determinant" strategies, and report that although they exist for all iterated non-zero-sum binary decision games, the existing literature appears to make no mention of them.

It turns out that, although ME (resp. THEE) can choose a ZD strategy $\boldsymbol{p}$ (resp. $\boldsymbol{q}$) that causes π_{THEE} (resp. π_{ME}) to assume any desired value in the interval $[P,R]$, he is unable to exert similar control over his own steady-state reward π_{ME} (resp. π_{THEE}). Perhaps more interestingly, for any $\chi > 1$, ME can choose $\boldsymbol{p}$ to guarantee that $\pi_{\mathrm{ME}} = \chi \cdot \pi_{\mathrm{THEE}}$. Press calls such $\boldsymbol{p}$ "extortion strategies," and Dyson finds them to exist for both players and for any value of the "extortion factor" χ. Difficulties naturally arise when both players attempt to claim a lion's share of the available rewards.

In an evolutionary setting, attempts at extortion could result in the stronger of two competing species driving, or attempting to drive, the weaker from a previously shared environment. In an economic milieu, it could correspond to a "price war" in which each of two competing firms sets out to drive the other from a market they alone serve. In practice, such campaigns rarely last long, terminating when it becomes obvious to both parties that the price of victory is sure to exceed its possible worth. Thereafter, the situation typically reverts to something resembling the status quo ante. On the rare occasions when price aggression does succeed, it tends to be because the victor began with a larger "war chest" than the vanquished.

The Press–Dyson results contradict recent thinking about IPD, much of which emerged from two round-robin computer tournaments organized [1] by Robert Axelrod in the late 1970s. In both, the most successful strategies were those seeking to establish cooperation rather than dominance. As a result, most game theorists concluded that dominance is rarely more than an unrealizable pipedream.

Press and Dyson strengthen their argument for the efficacy of extortion strategies by demonstrating—in Appendix B of [3]—that they perform as advertised against non-stationary as well as stationary opposing strategies. This leads them to the decidedly implausible conclusion that, unless able to read an opponent's mind, players of IPD can do no better than accept whatever minuscule reward is offered by the executor of an extortion strategy. Price wars, into which both parties enter on the theory that "THEE is less well equipped to prevail than ME," would seem to offer a counterexample. In most such contests, both theories are quickly disproven, and both combatants emerge gratified that they refused the pittance initially offered them. One wonders what feature of the Press–Dyson model enables extortion strategies to perform so well.

Press and Dyson express greater interest in Darwinian evolution than in extended economic competition, despite abstract results concerning IPD that seem equally relevant to both. Dyson, in particular, seems anxious [2] to challenge the currently "fashionable dogma" that *individual selection* is the driving force behind evolution. *Group selection*, in which groups either enforce or fail to enforce rules requiring within-group cooperation, is in his view at least as important. Dyson writes that he does not "take the Prisoner's Dilemma seriously as a model of the evolution of cooperation," because he suspects that groups unable to enforce cooperation lose "the battle for survival collectively, rather than individually." Human beings have evolved a limited ability to cooperate by learning to punish non-cooperators. In Dyson's opinion, "The Prisoner's Dilemma didn't have much to do with it."

References

[1] R. Axelrod, *The Evolution of Cooperation*, Basic Books, New York, 1984.

[2] F.J. Dyson, *The prisoner's dilemma*, IAS Inst. Lett., Fall 2012.

[3] W.H. Press and F.J. Dyson, *Iterated prisoner's dilemma contains strategies that dominate any evolutionary opponent*, Proc. Natl. Acad. Sci. USA, 109:26 (2012), 10409–10413.

James Case writes from Baltimore, Maryland.

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Mathematics and Institutional Change

Honored by the American Educational Research Association with its 2013 Distinguished Public Service Award, Freeman Hrabowski took the opportunity to reflect on his education and career. He accepted Sue Minkoff's invitation to contribute to the SIAM News *Careers Column with the following excerpts from remarks he made in accepting the award.*

Careers in the Math Sciences

By Freeman A. Hrabowski, III

It has been 50 years since I participated in the Children's March in my hometown of Birmingham, Alabama, including spending five frightening days in jail. I was 12 years old in May 1963, and despite my parents' concern for my safety—and my own fears—I was determined to take part in the protest. A few nights earlier, sitting in the back of my church doing my math homework, I had heard the visiting clergyman say that a march by children—unprecedented in the Civil Rights Movement—could lead to better schools for Birmingham's Negro children. Already a math nerd who loved school and learning, I knew instantly—on hearing Dr. King's remark—that I had to participate.

My life's work can be divided into two 25-year periods spanning the years from 1963 to 2013. At the end of the first 25-year period, I had completed a bachelor's degree in mathematics from Hampton Institute and graduate degrees in math and educational statistics from the University of Illinois at Urbana–Champaign; I had also served for 10 years as an academic administrator (dean and academic vice president) and professor of mathematics and statistics at two historically black colleges. I have spent the second 25-year period at UMBC (the University of Maryland, Baltimore County), including 21 years as president. Interestingly, UMBC was established the year I went to jail, 1963, and was the first campus in Maryland founded to serve students of all races. (Today, we are a research university with students from 150 countries.) During this past quarter-century, I have focused my research and publications on STEM education, with special emphasis on minority participation and performance.

I began formulating research questions on this topic as a graduate student. The questions—and my passion for pursuing them—are rooted in my love of mathematics and my academic and personal experiences as an undergraduate and graduate student. I entered Hampton at the age of 15 as an enthusiastic math major. My undergraduate experience there shaped my philosophy of education. My Hampton professors taught me the importance of putting students first, of expecting the most of them, of giving them the support they need to succeed, and of emphasizing leadership and service to others. That philosophy largely governs my approach today as a university president.

My graduate experiences in the early 1970s—not only my coursework and research, but also living with and tutoring undergraduates as a residence hall director, and later directing the Upward Bound program for high school students—also have proven quite useful to me throughout

my career. As I worked with high school students and college freshmen, I saw an important connection between reading well and being able to solve word problems. When I started graduate school, I found that while I was prepared for the academic work in math, I was not prepared to feel so isolated in my classes, usually as the only African American student. While I continued to enjoy math throughout the master's program, my sense of isolation made it difficult to imagine spending another four or five years in the doctoral program. I had become fascinated by the work of the Educational Testing Service, because I wanted to learn much more about why black children were not performing well on standardized tests. My early thinking on this issue was influenced by my sense of the reason I had always done well on these tests: I had grown up in a house with books, and my mother was an English teacher.

I left the math program after completing my master's degree simply because I had no one with whom to talk. My math background proved quite helpful in my doctoral program in higher education, however, as I focused on educational psychology, with emphasis on statistics and on minority student performance in math, science, and engineering. For the past 40 years, I have spent much of my professional career addressing that issue.

For the first decade after graduate school, I worked at two HBCUs with students who had academic deficiencies in math and reading. In 1987, I moved to UMBC, where, in the first year, my research questions, coupled with the poor performance of black students, led to the creation of the Meyerhoff Scholars Program. (In fact, I could not find one predominantly white university that was producing even a handful of black graduates who would go on to get STEM doctorates.) We launched the program with a major gift from Robert Meyerhoff, a Baltimore philanthropist with an interest in African American males, drawing from best practices I observed as an undergraduate and that mathematics professor Uri Treisman identified at the University of California at Berkeley in his work with minority students in mathematics. These practices include setting high expectations, building community among students, emphasizing the importance of faculty involving students in research, and providing financial assistance, strong advising, and mentoring. Today, the program is a national model for preparing students of color and others for STEM research careers. (See sidebar for details.)

Since its inception, the program's approach and results have been the focus of continuous, rigorous, and regularly published process and outcome evaluation studies—combining qualitative and quantitative assessment. Our research team's efforts have led to two books and numerous book chapters, journal articles, and national awards. The program's success is borne out by a decade of NSF data (2002–2011) identifying the top-producing baccalaureate-origin institutions of African American doctoral recipients in the natural sciences and engineering. UMBC was the nation's highest producing predominantly white institution during this period.

Today, 50 years after the Children's March in Birmingham, the nation looks so different to me. The challenge for those of us who have benefited from high-quality educations is to provide that opportunity to the millions of children for whom such an education is currently out of reach. It is imperative that they develop strong verbal and math skills, and that they acquire the values of hard work and discipline. Whether for helping students become educated, in general, or producing scientists and engineers, the nation needs STEM faculty and researchers focused on these issues—now more than ever.

Freeman A. Hrabowski, president of the University of Maryland, Baltimore County, since 1992, is a consultant on science and math education to national agencies, universities, and school systems. Named one of the 100 Most Influential People in the World by Time *magazine (2012) and one of America's Best Leaders by* U.S. News & World Report *(2008), he also received TIAA–CREF's Theodore M. Hesburgh Award for Leadership Excellence (2011), the Carnegie Corporation's Academic Leadership Award (2011), and the Heinz Award (2012) for his contributions to improving the "Human Condition." UMBC has been recognized as a model for academic innovation and inclusive excellence by such publications as* U.S. News & World Report, *which in each of the past four years ranked UMBC the #1 "Up and Coming" university in the nation.*

Sue Minkoff (sminkoff@utdallas.edu) of the University of Texas at Dallas is the editor of the Careers in the Math Sciences column.

The Meyerhoff Scholars Program

As we developed the Meyerhoff Scholars Program, we came up with and implemented the following components, which collectively have created an environment that continually challenges and supports students, from their pre-freshman summer through graduation and beyond: (1) recruiting top minority students in math and science, including a rigorous selection process; (2) conducting a six-week summer bridge program, including math, science, and humanities coursework, training in analytic problem-solving, group study, and social and cultural events; (3) offering comprehensive merit scholarship support; (4) actively involving faculty in recruiting, teaching, and mentoring the students; (5) emphasizing strong programmatic values, including outstanding academic achievement, study groups, collegiality, and preparation for graduate school; (6) involving the Meyerhoff Scholars in sustained, substantive research experiences during both the academic year and summers; (7) encouraging all students to take advantage of departmental and university tutoring resources in order to optimize their course performance; (8) ensuring the university administration's active involvement and support; (9) providing academic advising and personal counseling; (10) linking the Meyerhoff Scholars with professional and academic mentors in science and engineering; (11) building a strong sense of community among the students; (12) encouraging the students to engage in service in the larger community; (13) involving the students' parents and other relatives who can be supportive; and (14) conducting sustained, rigorous evaluation of the program's components and outcomes.

What Can Markets Do?

Letters to the Editor

To the Editor:

The article "The Interdisciplinary Quest for New Ideas in Economics" (James Case, *SIAM News*, July/August 2013) reports unanimity among attendees at the Perimeter Conference "that economic theory is inadequate." In such statements, it is never clear to me for what purpose an adequate theory is required.

Markets relate to society essentially as useful parasites justified by the hypothesis that well-informed, self-interested agents will act to redistribute wealth in ways that benefit society at large. From a societal standpoint, these benefits are the sole purpose of markets, and provide the only context in which notions of theoretical adequacy make any sense. But from the viewpoint of market traders, the purpose of markets is simply to enable profit-making, with only lip service paid to social benefit; from this perspective, the notion and purpose of adequacy become very different.

The differences can be expressed mathematically, and one important distinction is that market activity today has both low-frequency and high-frequency components. The low frequencies are perceptible by humans and are therefore able to make their way through the feedback loops that bring general benefit. The high frequencies exist only as noise in the computer, and it is hard to see how they bring benefit to anyone but the nimblest of traders.

If the multidisciplinary "Manhattan Project" that was described is ever launched, I hope that the team will include thermodynamicists who appreciate that energy may exist in various forms, not all of them equally able to perform useful work. The stage would then be set to pose the questions: What can markets do? What can they not do?—*Phil Roe, Aerospace Engineering, University of Michigan.*

Reply:

If the proposed multidisciplinary effort is ever launched, it will doubtless include a thermodynamicist. I suspect that it will fail anyway, for a whole host of reasons!—*James Case*

Student Days at the 2013 SIAM Annual Meeting

"What I enjoyed the most about the 2013 SIAM Annual Meeting was the opportunity to reconnect with fellow students and professors that I met at other conferences and workshops," said Diego Torrejon of George Mason University. "Besides the great talks, such as the I.E. Block Community Lecture, the numerous social and networking events allowed me to catch up with friends and make new contacts." One of several students who agreed to help *SIAM News* present a student's-eye view of the meeting, Torrejon spoke for many in choosing Anette (Peko) Hosoi's Block Lecture as a high point, and in appreciating the abundant networking opportunities.

Officially, the student activities got under way early Tuesday morning, when invited representatives of SIAM student chapters met with SIAM leaders over breakfast. The annual event has grown over the years, without losing its warm, friendly ambiance. As shown in the photo at the upper right, some of the chapter representatives had prepared slides to accompany short presentations of their groups' innovative activities.

"The Student Days activities were great for connecting with other student chapters across the world," said Siân Jenkins of the University of Bath. "I'll be returning to the UK with many new friends."

"I learned about some outreach other chapters were doing," wrote Olga Trichtchenko from the University of Washington. "I actually did not know that so many chapters

See **Student Days** *on page 7*

Anna Lieb, a graduate student at the University of California, Berkeley, discussed her poster, "Optimizing Intermittent Water Supply," with AWM executive director Magnhild Lien at the poster session in San Diego.

Over breakfast, students exchanged ideas for creative chapter activities.

"I would recommend that any final year PhD student attend this meeting. I'll certainly be taking back with me inspiration for my research, my student chapter, and my career."—Siân Jenkins

Invited speakers shared the wisdom of experience with students. Photos from Student Days by Susan Whitehouse.

The SIAM Book Giveaway was a hit with many students, but a chance conversation elevated it above the everyday for Diego Torrejon: "One memorable moment was when Dr. Carlos Castillo-Chavez spent time talking to me when I was waiting in line."

"I had the chance to participate in a minisymposium and give a talk. As a graduate student, whenever I have the chance to give talks in sessions with more senior researchers, it is a great learning and networking opportunity. Another very important aspect was having the receptions organized by SIAM. This allowed people to make contacts and then explore the city together after the talks were over for the day."—Olga Trichtchenko

Chicago-area SIAM Student Chapters Visit Argonne

A few questions come up again and again in student sessions at SIAM meetings: What's it like to work at a national lab? How does the environment at a national lab differ from that of academia?

Three Chicago-area SIAM chapters banded together on April 12 to find some answers for themselves in a one-day visit to the Mathematics and Computer Science Division at Argonne National Laboratory. MCS researchers greeted the 40 participating students and postdocs with a morning agenda devoted to ten "research vignettes."

"We chose these brief presentations to give young scholars a flavor of the problems we are investigating—from new analytical and numerical methods, to cutting-edge software, to practical applications," said Stefan Wild, an MCS computational mathematician and co-organizer of the visit. The topics presented were:

- Scalable power grid dynamics simulation (Shrirang Abhyankar)
- Data science for scientific computing: Learning and intelligent optimization (Prasanna Balaprakash)
- Parallel multigrid solvers (Jed Brown)
- Large-scale Gaussian process calculation without matrix factorizations (Jie Chen)
- Scaling computational fluid dynamics beyond a million cores (Paul Fischer)
- High-resolution, non-oscillatory schemes for hyperbolic PDEs (Debo Ghosh)
- PDE-constrained optimization under uncertainty (Drew Kouri)
- Algorithmic differentiation (Sri Hari Krishna Narayanan)
- Phase-field modeling for heterogeneous materials (Lei Wang)
- Stochastic optimization for complex network systems (Victor Zavala).

The students appreciated the carefully crafted introduction to MCS research. This was the first visit to Argonne for a number of the Northwestern students, said NU–SIAM president Thomas Wytock. "They jumped at the opportunity to explore the research opportunities offered there."

Xuan Zhou, president of the SIAM chapter at the Illinois Institute of Technology, found in the ten morning presentations an introduction to "exciting projects which applied mathematics to real world problems."

At lunchtime, the students divided into groups based on their research interests—including optimization, linear algebra, and PDEs. Over lunch, the Argonne researchers gave the students a more personal view of life at the lab, and the visitors had the chance to learn about career opportunities and projects, as well as new research directions in applied mathematics and computational science.

The afternoon featured tours of two research facilities at the laboratory: the Advanced Photon Source and the Argonne Leadership Computing Facility, home to several of the fastest supercomputers in the world.

"The Advanced Photon Source was amazing," Zhou said. "Seeing the most advanced technology with my own eyes was completely different from watching it on TV. And what can I say about the Blue Gene? The entire building was built for the supercomputer, and the power to keep it running alone cost 1 million dollars each year."

April in Chicago. After a warm welcome from Argonne research staff, members of three visiting SIAM student chapters learned about ongoing research projects in applied math/computational science before touring two high-profile research facilities at the lab. Later in the month, the three chapters ran the first-ever Chicago-area SIAM Student Conference. Photo by Andjelka Herman.

"A personal highlight for me," Wytock said, "was the tour of the Advanced Photon Source. Being able to see a world-class facility up-close and in action was exciting. I enjoyed learning about how the synchrotron accelerator functioned."

Concluding the visit, Sven Leyffer, SIAM vice president for programs and Argonne senior computational mathematician, emphasized the important role students play in SIAM. In addition to student activities like the Argonne visit, he said, SIAM supports career fairs and travel to a range of conferences. (For an update on SIAM Student Travel Awards, see page 5.)

Leyffer encouraged the students to apply for internships at Argonne, pointing to Argonne's recent designation in an annual survey by *The Scientist* as one of the top five "best places for postdocs to work."

Noting that the visiting students represented three local chapters—the University of Illinois at Chicago, in addition to IIT and Northwestern—Leyffer looked ahead to the 2014 SIAM Annual Meeting, which will be held in Chicago. "We hope that your chapters will join Argonne in providing lively input to the meeting."—*Gail Pieper, Argonne National Laboratory.*

A Second Doubling for SIAM's Student Travel Fund

FROM THE SIAM PRESIDENT

By Irene Fonseca

Each year, SIAM awards grants to hundreds of students for travel to SIAM conferences around the world, as part of its ongoing commitment to cultivating and training a new generation of mathematical scientists.

When it was launched several years ago, the Student Travel Fund relied primarily on National Science Foundation grants and donations of royalties by generous SIAM book authors. From there, it grew to include donations from the general SIAM membership (via a checkbox on the membership renewal form).

In 2011, under the leadership of my predecessor, then-SIAM president Nick Trefethen, the SIAM Board of Trustees decided to allocate $100,000 each year to the Student Travel Fund.

Joscha Gedicke of Humboldt University of Berlin accepted a 2013 SIAM Student Paper Prize from Irene Fonseca. The two other recipients were Keiichi Morikuni of the Graduate University of Advanced Studies (Sokendai), Japan, and Vladislav Voroninski of the University of California, Berkeley; all three gave talks based on their papers in a minisymposium at the SIAM Annual Meeting.

SIAM's commitment to its student network continues: Most notably, at its July 2013 meeting, the Board elected to double the annual investment, to $200,000, starting in 2014. As of January 2014, SIAM will make approximately $250,000–$275,000 available each year for Student Travel Awards.

Practically speaking, students anywhere in the world can apply for SIAM Student Travel Awards; preference is given to active meeting participants (speakers, poster presenters). Only the NSF portion of the fund is restricted—to students enrolled in U.S. institutions.

If you are interested in applying for a SIAM Student Travel Award, please check the eligibility criteria at http://www.siam.org/prizes/sponsored/travel.php. (Funds are also available for postdocs and early-career professionals; these awards, currently much more limited than the Student Travel Awards, are supported only by an NSF grant to SIAM.)

At the root of the Board's generosity is SIAM's mission of encouraging students to participate in SIAM conferences. To motivate award recipients' institutions to help cofinance their students' participation in SIAM events, the awards are generally limited in size. Nevertheless, SIAM hopes that these funds will make a real difference, enabling a growing number of mathematical scientists at the very beginning of their careers to play active roles in our conferences and in SIAM.

SIURO: A Flourishing Home for Undergraduate Research

SIAM Undergraduate Research Online (SIURO) was created in 2008 to provide a venue for articles presenting high-quality undergraduate research in industrial and applied mathematics. So far, more than 60 articles have appeared in SIURO's six volumes.

What kinds of articles does SIURO publish?

Most SIURO articles present original research in industrial and applied mathematics performed and written up by undergraduates. Research articles published to date have covered a wide range of topics, such as modeling invasive brain tumors, probing the eigenstructure of triangles, and simulating European option pricing. Many articles result from work done in REU (Research Experiences for Undergraduates) programs, senior capstone projects and theses, and, on occasion, projects from a course.

What should be submitted?

Unsolicited articles, both research-based and expository, are accepted year-round. The manuscript, supplemental files, a cover letter, and a letter from an adviser or sponsor should be submitted at http://www.siam.org/students/siuro/submit. The letter from the faculty sponsor verifies that the students were the primary researchers/writers and that they performed the research as undergraduates. Instructions for authors can be found at http://www.siam.org/students/siuro/authors.php.

What is the review process?

SIURO provides undergraduates with a review process similar to that of a standard journal. To begin, the editor must accept the paper for review. An associate editor then sends the paper to reviewers, who provide written reviews and recommendations regarding publication. Reviewers' comments generally give students guidance on both the exposition and the mathematics. If the associate editor decides that the article shows promise, students receive the reviews and suggestions for revision. The review process for SIURO is rapid—reviews are generally sent in a couple of months—to help students publish their work as soon as possible.

From Emily Beylerian, "Finding a Needle in a Haystack: An Image Processing Approach," SIURO, Volume 6, May 29, 2013.

Expository articles by undergraduates can be submitted to SIURO as well. The journal will also consider outstanding expository papers on a survey topic or a subject of historical interest written for an undergraduate audience by a faculty member or researcher.

All SIURO articles are freely available at http://www.siam.org/students/siuro/published.php.

Who can submit to SIURO?

The authors of research articles in SIURO must be undergraduates, and the research must have been conducted before the students' graduation. Faculty advisers on a project are recognized as mentors, but as the authors, students take primary responsibility for the research, writing, and communication during the review process.

How long will articles be available online?

SIURO is archived by SIAM, and each paper has a DOI.

Whom should I contact if I have questions about SIURO?

You can contact Brittni M. Holland, editorial associate at SIAM (holland@siam.org), or SIURO editor-in-chief Rachel Levy (levy@hmc.edu).

PAC: A Universal Framework for Learning?

Probably Approximately Correct. *By Leslie Valiant, Basic Books, New York, 2013, 208 pages, $26.99.*

BOOK REVIEW

By Ernest Davis

In 2010, Leslie Valiant received the Turing Award, the "Nobel prize of computer science." The citation mentioned a number of contributions, the best known of which is the theory of probably approximately correct (PAC) learning, which Valiant first proposed in the early 1980s. In his new book *Probably Approximately Correct*, Valiant discusses the theory of PAC learning and its applications to artificial intelligence; he also introduces a more specialized concept—"evolvable learning"—which, he claims, characterizes Darwinian evolution.

PAC learning is an elegant framework that characterizes the objective and the computational difficulty of carrying out certain kinds of learning. Imagine a person or a computer program that is trying to determine the characteristics of mammals by viewing a sample of individual animals, each correctly labeled either "a mammal" or "not a mammal." Suppose, as is likely, that the sample does not include any platypuses or echidnas. The learner might then come up with a rule like "hair, warm-blooded, suckles their young, live-bearing." Although not quite correct, because platypuses and echidnas are mammals that lay eggs, this rule is *approximately* correct, because it works correctly for every animal except platypuses and echidnas.

Given a large enough random sample, can we develop a learning algorithm that always generates an approximately correct answer? No, because we could be very unlucky in the constitution of our sample. For instance, there is a small but non-zero chance that in a random sample of animals, all the mammals will be platypuses and echidnas. If so, the learner might reasonably posit the additional condition that mammals are egg-laying; that rule would not be approximately correct. So what we can hope for is an algorithm that is *probably* approximately correct—an algorithm that, given a random sample, will probably come up with a rule that is approximately correct.

One particularly elegant feature of PAC learning is that, because the same distribution is used in the "probably" and the "approximately," the algorithm does not have to make any prior assumptions about the distribution used to select the sample. Consider, for example, an anomalous distribution over mammals that chooses platypuses and echidnas 99.9% of the time. If samples are being generated according to that distribution, the learner is likely to come up with a rule that requires mammals to be egg-laying. But now that rule is approximately correct, relative to this anomalous distribution.

Another attractive feature of the definition, from the standpoint of mathematical analysis, is that it provides a number of numerical parameters to play with. There is $1 - \delta$, the accuracy of the rule; $1 - \varepsilon$, the probability of attaining an approximately correct rule; n, the number of samples; s, the size of an individual instance; and t, the running time. *PAC-learnability* is a property of a collection $\mathcal{C}$ of categories in some space of instances $\mathcal{X}$; for example, the collection of all categories definable by a simple conjunction of unary properties like "warm-blooded and hairy and suckles-young." The collection $\mathcal{C}$ is *PAC-learnable* if there is an algorithm that, given large enough values of n and t, will probably find an approximately correct definition of each category in $\mathcal{C}$ for any distribution over $\mathcal{X}$ and for arbitrarily small δ and ε. Finally, following standard practice in complexity theory, Valiant characterizes a problem as "tractable" if it is solvable by an algorithm whose running time is bounded by a polynomial function of the parameters. Thus, the collection $\mathcal{C}$ is *efficiently PAC-learnable* if the running time t and the number of samples n are bounded by a polynomial in $1/\varepsilon$, $1/\delta$, and s. Valiant and other researchers have proved a rather small number of learning problems to be efficiently PAC-learnable.

■ ■ ■

Despite the title, the focus of Valiant's book is not PAC learning, but rather a question motivated by Darwinian evolution: Is it plausible that life could have evolved to its current state within the time that the earth has existed, if the mechanism for evolution is Darwinian? Valiant approaches the analysis of this problem by identifying Darwinian evolution with a narrow class of algorithms called "statistical query" algorithms. Algorithms in this class can use only statistical information about the sample as a whole; they are not allowed to use information about individual instances. A class of learning problems is considered evolvable if it satisfies the conditions of PAC learning when the class of algorithms under consideration is limited to statistical query algorithms. The theory of evolvable learning is much more recent and less developed than the theory of PAC learning, but some theoretical results have been obtained.

Valiant applies this theory to the question of the plausibility of Darwinism as follows. The terrestrial environment confronts each species with the challenge of maximizing its "performance" (essentially its fitness). The adaptation of a species through evolution is conceptualized as the execution of a learning algorithm (Valiant calls this an "ecorithm") to solve that problem. The terrestrial environment, indeed, has a collection of problems that it could set to the species, and the ecorithm must be such that the species will successfully use it to solve any problem in the collection. Valiant is not very explicit about the exact relation of the complexity classes to the theories of evolution. Presumably, if the class of problems set by the environment is found to be evolvable, then Darwinism is plausible; if the collection is PAC-learnable but not evolvable, then some other evolutionary mechanism, such as Lamarckianism, should be sought; if it is not even PAC-learnable, then we must fall back on intelligent design, or on the anthropic principle. This kind of analysis presumably could not distinguish an evolutionary theory that requires 40 million years from one that requires 4 billion years, but it might distinguish these theories from those requiring $10^{20,000}$ years.

I am not at all an expert, but it does not seem to me that Valiant makes a very cogent case that this is a useful abstract model for this question. To what extent is it reasonable to view adaptation as the execution of an algorithm, and specifically a statistical query algorithm? In particular, to what extent is this a reasonable view of the early stages in the emergence of life, the formation of self-replicating biological chemicals? To what extent is it reasonable to view the environment as potentially posing any of the problems in a collection, and to require that the ecorithm be able to solve all of them? How is one to find a characterization of the class of problems that the environment could potentially present? Moreover, the devil is very much in the details in this kind of analysis: Small changes to the formulation of a problem can make a large difference in its learnability. Unless the abstraction reflects reality with high fidelity, an analysis based on that abstraction may well be useless.

See **Learning** *on page 8*

MPE2013

continued from page 1

rials, and maintains a collection of posters and other educational materials.

The dual mission of MPE2013—stimulating the mathematics research community and reaching out to the general public—is reflected in the Daily Blogs (one in English, the other in French), each of which has already featured more than 200 posts on a wide variety of topics. Conference announcements and workshop reports can be found in the blogs, as well as short articles on topics from astronomy to uncertainty quantification.

Matching the Zeitgeist

The level of effort and cooperation demonstrated by MPE2013 is unprecedented in the annals of mathematics. Why has the MPE2103 movement been so popular with mathematicians? Undoubtedly, one of the reasons is the increased awareness among the general public, shared by the mathematics community, that our planet is in trouble. For too long, we have conducted an uncontrolled experiment, using natural resources as if they were infinite. Mathematicians, like the majority of the general public, agree that it is time to get a better understanding of our place and role within the Earth system. Mathematics has something to contribute to the discussion, whether on the subject of resource management, climate change, risk assessment, or any of the other issues related to Planet Earth.

Another reason for the popularity of the MPE2013 movement is that mathematical scientists are increasingly collaborative. Fifty years ago, the average number of co-authors of a mathematics paper was 1.3; now it is more than 2. Whereas dozens of or even a hundred co-authors are common on a single publication in the experimental sciences, the record in pure mathematics until a few years ago was surely fewer than ten. This new degree of collaboration can undoubtedly be attributed to the Internet, the ubiquity and ever-increasing power of computing resources, and the proliferation of workshops devoted to creating and promoting collaborations. In this sense, MPE2013 matches the spirit of the time. The issues related to Planet Earth require collaborative efforts more extensive than ever before, and the mathematics community is prepared to respond.

Because of the many opportunities for networking and interdisciplinary research, MPE2013 has drawn the attention of other disciplines as well. Among its partners are the American Geophysical Union, the International Association for Mathematical Geosciences, and the International Union of Geodesy and Geophysics.

Looking Ahead: MPE2013+

All this leads to a natural follow-up question: What will happen after 2013? Clearly, identifying the research problems is not enough. Mathematics moves slowly, and we cannot expect great results in just one year. But MPE2013 has been a great start. With support from the National Science Foundation, we plan to sustain MPE activities in 2014 and beyond. Specifically, plans are in place for (1) five research workshops, each of which will define a set of future research challenges; (2) a Research and Education Forum (REF) associated with each workshop, with smaller follow-up group meetings held to flesh out the challenges, identify potential follow-up activities, and begin collaborations; (3) an education workshop that helps identify ways to integrate themes identified in the research workshops into undergraduate and graduate curricula; (4) a search for ways to involve the next generation of mathematical scientists, with special emphasis on under-represented minorities, in the MPE workforce of the future; and (5) dissemination of information about MPE via a website and other publicity materials for the project. MPE2013+ will be organized under the auspices of DIMACS, the Center for Discrete Mathematics and Theoretical Computer Science (dimacs.rutgers.edu).—*Hans Kaper, on behalf of the MPE2013 Steering Committee.*

Christiane Rousseau of the University of Montreal chairs the Steering Committee, and various working groups coordinate MPE2013 activities. The program receives financial support from NSF and the Simons Foundation, is carried out under the patronage of UNESCO, and is endorsed by the International Council for Science (ICSU), the International Mathematical Union (IMU), and the International Council for Industrial and Applied Mathematics (ICIAM).

Student Days

continued from page 4

existed all over the world and so many were involved in outreach—I thought maybe our chapter was unique in that way. The downside was there were too many of us to actually be able to say anything more than a brief introduction. We did get a chance later on in the day though, when we broke into smaller groups."

Pictured on the first page of this issue of *SIAM News* and in the photo at bottom right on page 4 is a now-traditional event that gives interested students the chance to chat with invited speakers at the meeting. The setting was simultaneously relaxed and charged, in part because participating students asked good questions, in part because the speakers seemed to have no difficulty imagining themselves back in their own early-career situations.

For Siân Jenkins, the opportunity to meet with academics across many different fields of research and ask them about their research and careers was invaluable. "Choosing a direction after your PhD can be quite a daunting process," she said, "and knowing that they had felt the same was really reassuring."

For many students, attending the meeting was serious business: They had come primarily to give talks, in some cases prize talks (undergraduate and graduate student prize recipients are recognized on page 12), or to present posters. Xue Jiang of the Chinese Academy of Sciences said of what was his first SIAM meeting that he was "very happy to have the opportunity to present my paper at the conference." He also benefited from other activities, including the poster session and outdoor receptions, which "provided good chances to share ideas, provoke discussions, and seek collaboration with others."

Charles Brett of the University of Warwick found "countless interesting talks" at the meeting and "really appreciated the activities and events targeted at students. The industry panel and career fair informed me on some of the exciting opportunities for applied mathematicians in industry, and the professional development evening gave me insights on how to find them. I now feel much better informed about my options."

Students can find out more about chapter activities and resources for students at http://www.siam.org/students/.

Super-resolution

continued from page 1

and solving a tractable convex program. When applied to our model of interest, compressed-sensing theory guarantees that we can reconstruct any sequence of k spikes from approximately Ck random Fourier coefficients by solving the ℓ_1-norm minimization problem

$$\min_x \|x\|_{\ell_1}$$

among all signals x consistent with the data. Moreover, the recovery scheme can be stable in the presence of noise. This is possible because the random-sensing operator is well conditioned when its domain is restricted to the class of sparse signals. Intuitively, such a condition is necessary for recovery by any method in a realistic setting; otherwise, the signal could be completely lost in the measurement process.

Returning to the problem of super-resolution: As a first step, we should investigate whether the low-pass operator is well conditioned when acting on sparse signals. This does not follow at all from compressed-sensing theory, which ensures that it is possible to *interpolate* the spectrum of a sparse signal from random samples, but says nothing about *extrapolating* the higher end of the spectrum from low-frequency samples. The second row of Figure 2 illustrates the difference between the two measurement schemes: In both cases we subsample in the frequency domain, but compressed sensing gives us access to the entire spectrum, whereas in super-resolution we are restricted to the low-pass frequencies. It turns out that low-pass filtering of sparse signals, unlike randomized spectral sampling, can be very badly conditioned. A simple example helps make this important point. The signal in the left column of Figure 2 is very sparse, but the fraction of its energy located in the lower quarter of its spectrum is only about 10^{-8}! No recovery scheme—no matter how sophisticated—could possibly estimate this signal from low-pass measurements in the presence of even the slightest perturbation. In sharp contrast, if the whole spectrum is sampled at random, the measurements do capture a sizable fraction of the energy of the signal. Indeed, compressed sensing recovers the highly clustered signal from a quarter of its discrete spectrum, as shown at the lower left in Figure 2.

A careful reader might wonder whether the example on the left of Figure 2 is pathological, in the sense that the spectrum of most sparse signals might not be as concentrated in the high frequencies. We can do a simple experiment to test whether this is so. Consider the vectors of length 5000 that end in 4950 zeros. This defines a vector space of dimension 50 composed entirely of very sparse signals, to which we apply a low-pass filter retaining a quarter of the spectrum. Taking the singular value decomposition of the filter restricted to this vector space reveals that a subspace S of dimension 22 is almost completely destroyed; the fraction of the remaining energy for any signal in S is at most 10^{-10}! This phenomenon was characterized theoretically by Slepian in the 1970s. His work on prolate spheroidal sequences confirms that, asymptotically, most tightly clustered sparse signals are almost completely annihilated by low-pass filtering.

Does this mean that super-resolution of sparse signals is completely hopeless? Not if we are willing to add some further structure to our model. We must impose conditions on the support of the signal to preclude its being too clustered. The right column of Figure 2 shows a signal that is identical to the one in the left column, except that its support is more spread out. Spacing out the spikes results in a spectrum that is not as concentrated in the higher frequencies. For such signals super-resolution from low-pass measurements is no longer hopeless. In fact, as shown at the lower right in the figure, ℓ_1-norm minimization succeeds in reconstructing the signal exactly from the lower quarter of its spectrum.

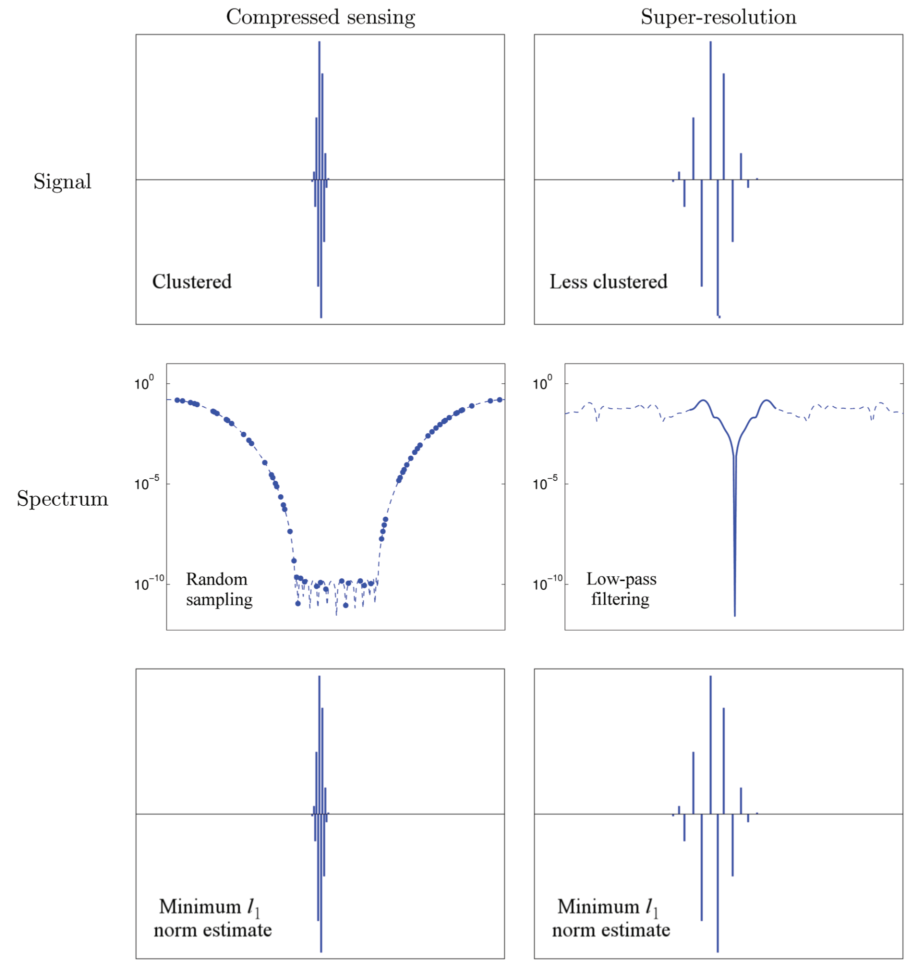

Figure 2. *Compressed sensing recovers any sparse signal, even highly clustered ones, from random spectral samples. Super-resolution via ℓ_1-norm minimization extrapolates the high frequencies of sparse signals that are not too clustered.*

The outcome of this example is encouraging, but is it typical? The answer is yes. Recent work has established that ℓ_1-norm minimization super-resolves any train of spikes as long as the separation between spikes is at least $2/f_c$, where f_c denotes the cut-off frequency of the measurements. Exact recovery is guaranteed even in a gridless setting, where the spikes may be supported at arbitrary points of a continuous interval. In that case, the recovery algorithm can be recast as a discrete semidefinite program, which locates the support of the signal with infinite precision. Furthermore, the method is provably robust to perturbations and can be adapted to signals of other types, such as piecewise-smooth functions.

To recapitulate, sparsity is not enough to characterize the problem of super-resolution. Refining the signal model to exclude highly clustered signals not only ensures that the problem is well posed in principle, it is actually sufficient to guarantee the success of a tractable method based on convex optimization. This illustrates a central theme in modern signal processing: Understanding the interaction between the sensing process and certain low-dimensional structures—such as sparse vectors or low-rank matrices—allows us to develop non-parametric algorithms that are remarkably successful at extracting information from high-dimensional data.

Acknowledgments

The author is grateful to Gilbert Strang for encouraging him to write this article and to his adviser, Emmanuel Candès, for his support.

Related Publication

E.J. Candès and C. Fernandez-Granda, *Towards a mathematical theory of super-resolution*, Comm. Pure Appl. Math., to appear.

Carlos Fernandez-Granda is a PhD student in the Department of Electrical Engineering at Stanford University.

Learning

continued from page 6

■■■

The book also includes an extended discussion of machine learning and artificial intelligence, although the view of machine learning is disappointingly narrow. PAC learning applies in a natural way to only a rather restricted, though very important, class of learning problems: learning categories from labeled data ("supervised" learning), in cases in which there is an exact definition (or at least arbitrarily good definitions). If PAC learning is to be viewed as a universal framework for learning, other forms of learning must then either be shoehorned into this form, declared unimportant, or ignored. Valiant does some of each. Most strikingly, he specifically denies that unsupervised learning (learning from unlabeled examples, as in grouping examples into clusters) is a useful concept in studying natural learning, though he concedes that it may have some value in machine learning. In one case an errant form of learning sneaks in behind Valiant's back, when he remarks in passing, in a discussion of learning from positive examples, "We may have figured out that each animal belongs to one species." On the whole, one suspects that the way we figured this out was by learning it, although the problem of learning propositions like "each animal belongs to one species" does not fit well into the framework of supervised learning of categories.*

PAC learning is only one of many general frameworks that have been proposed for learning, and in many ways, it is one of the most limited. Other frameworks include Bayesian learning, minimum description length learning, the Vapnik–Chervonenkis theory of learning, and classical frequentist statistics. V–C theory is mentioned in an endnote, the others not at all.

PAC learning is an elegant and useful approach to a specific class of learning problems. I am doubtful that an approach of this kind is useful in characterizing evolution; it is certainly not a universal framework applicable to all forms of either natural or machine learning.

*An observer in a state of nature does not directly perceive species; he perceives animals, their features, and their behaviors. Species are a higher-order construct. Learning the proposition "each animal belongs to one species" involves determining that the class of animals is partitioned into categories, that features and behavior of two animals in the same category are generally much more similar than features and behavior of two animals in different categories, and that animals breed only within the same category.

Ernest Davis is a professor of computer science at the Courant Institute of Mathematical Sciences, NYU.

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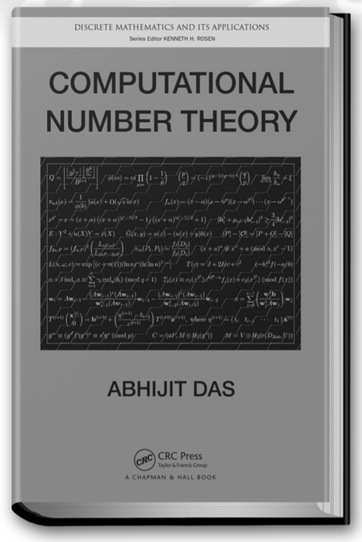

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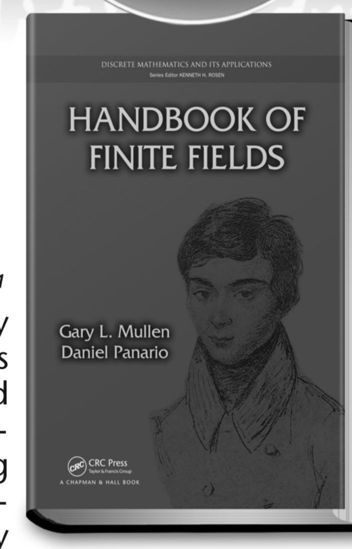

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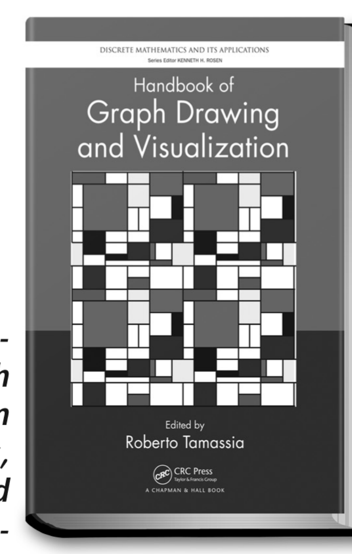

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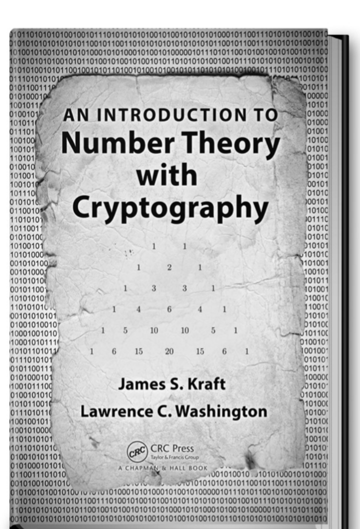

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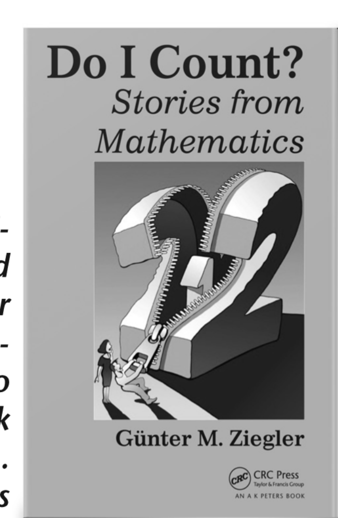

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National University of Singapore

Department of Mathematics

The Department of Mathematics at the National University of Singapore invites applications for tenured, tenure-track, and visiting positions at all levels, beginning in August 2014. The department seeks promising scholars and established mathematicians with outstanding track records in any field of pure and applied mathematics. The department, housed in a newly renovated building equipped with state-of-the-art facilities, offers internationally competitive salaries with start-up research grants, as well as an environment conducive to active research, with ample opportunities for career development. The teaching load for junior faculty is kept especially light. The department is particularly interested in, but not restricted to, considering applicants specializing in any of the following areas: Ergodic theory and dynamical systems; partial differential equations and applied analysis; computational science, imaging, and data science; operations research and financial mathematics; and probability and stochastic processes.

NUS is a research-intensive university that provides quality undergraduate and graduate education. The Department of Mathematics has about 65 faculty members and teaching staff, whose expertise cover major areas of contemporary mathematical research. For further information about the department, applicants should visit http://www.math.nus.edu.sg.

Application materials should be sent via e-mail (as PDF files) to the Search Committee at: search@math.nus.edu.sg. Applicants should include the following supporting documentation in an application: (1) an American Mathematical Society Standard Cover Sheet; (2) a detailed CV, including a list of publications; (3) a statement (maximum of three pages) of research accomplishments and plans; and (4) a statement (maximum of two pages) of teaching philosophy and methodology. Applicants should attach evaluations of teaching from faculty members or students at their current institutions, where applicable, and arrange for at least three letters of recommendation, including one that indicates effectiveness in and commitment to teaching. Applicants should ask their referees to send their letters directly to: search@math.nus.edu.sg; inquiries can also be sent to this e-mail address. The review process will begin on October 15, 2013, and will continue until the positions are filled.

Southern Methodist University

Dedman College
Department of Mathematics

Applications are invited for the Clements Chair of Mathematics (Position No. 00050961), to begin in the fall semester of 2014. The department is searching for senior scholars with outstanding records of research in computational and applied mathematics as well as a strong commitment to teaching, including an established history of advising doctoral students. The department is seeking candidates whose interests align with those of the department and who would contribute in a substantial way to the university's initiatives in high performance computing and interdisciplinary research. A PhD in applied mathematics or a related field is required.

SMU, a private university with active graduate and undergraduate programs in the sciences and engineering, is situated in a quiet residential section of Dallas. The Dallas–Fort Worth Metroplex is America's fourth largest metropolitan area, and residents enjoy access to world-class cultural and entertainment activities.

The Department of Mathematics offers graduate degrees in computational and applied mathematics and includes 16 tenured or tenure-track faculty researchers, all of whom work in application areas. Applicants should visit http://www.smu.edu/math/ for more information about the department.

Applicants should send a letter of application, a curriculum vitae, a list of publications, research and teaching statements, and the names of three references to: Faculty Search Committee, Department of Mathematics, Southern Methodist University, P.O. Box 750156, Dallas, TX 75275–0156. The Search Committee can also be contacted at: (214) 768–2452; fax: (214) 768–2355; mathsearch@mail.smu.edu. Applications received by November 1, 2013, will receive full consideration; however, applications will continue to be accepted until the position is filled. Applicants will be notified when the search is concluded.

SMU will not discriminate on the basis of race, color, religion, national origin, sex, age, disability, genetic information, or veteran status. SMU's commitment to equal opportunity includes nondiscrimination on the basis of sexual orientation and gender identity and expression. Hiring is contingent on the satisfactory completion of a background check.

University of Nebraska–Lincoln

Department of Mathematics

The Department of Mathematics at the University of Nebraska–Lincoln invites applications for one tenure-track assistant professor position in scientific computing/computational mathematics, to begin in August 2014. The successful candidate will have a PhD in mathematics or in a field with strong interdisciplinary ties to mathematics and a demonstrated potential to conduct a research program and teach mathematics at a research university. Preference will be given to applicants who (i) have a documented research background in some area of computational mathematics, i.e., some mathematical research area in which computation is a prominent feature. Such an area would include, but is not limited to, scientific computation, numerical analysis, and computational geometry; (ii) have the potential to interact with, and strengthen, existing research groups within the Department of Mathematics; and (iii) have the potential to strengthen cross-disciplinary ties with other departments by connecting mathematical research and computational capability to applications. Applications from entry-level people as well as from those with prior postdoctoral experience are encouraged.

More information about this position, including instructions on how to apply, can be found at: http://www.math.unl.edu/department/jobs/. The review of applications will begin November 15, 2013, and will continue until the position is filled or the search is closed.

The University of Nebraska is committed to a pluralistic campus community through affirmative action, equal opportunity, work–life balance, and dual careers.

University of Cincinnati

Department of Electrical Engineering and Computing Systems

The University of Cincinnati's EECS department invites applications for two full-time tenure-track faculty positions in computer science at the assistant/associate professor level. Areas of expertise include, but are not limited to, software engineering, cyber-security, and scalable data management and analytics. Requirements include a PhD in computer science or a closely related discipline by the date of appointment.

Applicants can view a detailed job description (see Position #213UC5559) and apply at: http://www.jobsatuc.com. The review of applications will continue until both positions are filled.

The University of Cincinnati is an affirmative action/equal opportunity employer. UC is a smoke-free work environment.

University of Colorado Boulder

Department of Applied Mathematics

The Department of Applied Mathematics at the University of Colorado Boulder expects to hire a tenure-track assistant professor, to begin in August 2014. The position is in the area of nonlinear mathematics and applications; however, exceptional candidates in all fields of applied mathematics can be considered. A PhD in applied mathematics, mathematics, or a related discipline is required.

A more detailed posting can be found and applications are accepted electronically at: https://www.jobsatcu.com, posting #F00595. The review of applications began October 1, 2013, and will continue until finalists are identified.

The University of Colorado is an equal opportunity employer.

University of Colorado Boulder

Department of Applied Mathematics

The Department of Applied Mathematics at the University of Colorado Boulder expects to hire a tenure-track assistant professor, to begin in August 2014. The position is in the area of computational/numerical mathematics and applications; however, exceptional candidates in all fields of applied mathematics can be considered. A PhD in applied mathematics, mathematics, or a related discipline is required.

A more detailed posting can be found and applications are accepted electronically at: https://www.jobsatcu.com, posting #F00596. The review of applications began October 1, 2013, and will continue until finalists are identified.

The University of Colorado is an equal opportunity employer.

Dartmouth College

Department of Mathematics

Applications are invited for John Wesley Young Research Instructorships. These positions are for new or recent PhD recipients whose research overlaps a department member's and are available for two to three years. Instructors teach three ten-week courses spread over three terms; appointment is for 26 months, with possible renewal for 12 months. Monthly salary is $5100, including a two-month research stipend for instructors in residence during two of three summer months; for those not in residence for 11 months, salary is adjusted accordingly.

Applicants should apply online at: http://www.mathjobs.org, Position ID: JWY #4928. Applicants can also access an application through a link at http://www.math.dartmouth.edu/activities/recruiting/. General inquiries can be directed to Tracy Moloney, administrator, Department of Mathematics, tfmoloney@math.dartmouth.edu. Applications completed by January 5, 2014, will be considered first.

Dartmouth College is committed to diversity and strongly encourages applications from women and minorities.

Georgia Institute of Technology

School of Mathematics

The School of Mathematics at Georgia Tech is accepting applications for faculty positions at all ranks and in all areas of pure and applied mathematics and statistics. Applications by highly qualified candidates, and especially those from groups underrepresented in the mathematical sciences, are particularly encouraged.

Applicants should see http://www.math.gatech.edu/resources/employment for more details and application instructions.

Rutgers University–New Brunswick

Department of Mathematics

The Department of Mathematics at Rutgers University–New Brunswick invites applications for an opening at the level of tenured associate professor or tenured full professor in numerical analysis/scientific computation, subject to the availability of funding, starting in September 2014. Candidates must have a PhD, show a strong record of research accomplishments, and have a concern for teaching. The normal annual teaching load for research-active faculty is 2–1, that is, two courses for one semester, plus one course for the other semester. The review of applications will begin immediately.

Updates on these positions will appear on the Rutgers mathematics department webpage at http://www.math.rutgers.edu.

Applicants should submit a curriculum vitae (including a list of publications) and arrange for four letters of reference to be submitted, one of which evaluates teaching, to: https://www.mathjobs.org/jobs. Applicants should first go to the website and fill out the AMS Cover Sheet electronically. It is essential to fill out the cover sheet completely, including naming the position being applied for (namely, TAP), giving the AMS Subject Classification numbers of areas of specialization, and answering the question about how materials are being submitted. The strongly preferred way to submit a CV, references, and any other application materials is online at: https://www.mathjobs.org/jobs; however, if necessary, application materials can instead be mailed to: Search Committee, Department of Mathematics, Hill Center, Rutgers University, 110 Frelinghuysen Road, Piscataway, NJ 08854–8019. The review of applications will begin immediately and will continue until the openings are filled.

Rutgers is an affirmative action/equal opportunity employer.

INSTITUTE FOR COMPUTATIONAL ENGINEERING & SCIENCES

The *Institute for Computational Engineering and Sciences (ICES)* at *The University of Texas at Austin* is searching for exceptional candidates with expertise in computational science and engineering to fill several Moncrief endowed faculty positions at the Associate Professor level and higher. These endowed positions will provide the resources and environment needed to tackle frontier problems in science and engineering via advanced modeling and simulation. This initiative builds on the world-leading programs at ICES in Computational Science, Engineering, and Mathematics (CSEM), which feature 16 research centers and groups as well as a graduate degree program in CSEM. Candidates are expected to have an exceptional record in interdisciplinary research and evidence of work involving applied mathematics and computational techniques targeting meaningful problems in engineering and science. For more information and application instructions, please visit: www.ices.utexas.edu/moncrief-endowed-positions-app/. This is a security sensitive position. The University of Texas at Austin is an Equal Employment Opportunity/Affirmative Action Employer.

THE UNIVERSITY OF TEXAS AT AUSTIN

INSTITUTE FOR COMPUTATIONAL ENGINEERING & SCIENCES

POSTDOCTORAL RESEARCH FELLOWSHIPS

Research areas include, but are not limited to, inverse analysis, differential equations, kinetic theory, remediation of groundwater contaminants, tidal surges in coastal environments, drug design, damage and failure of composite materials, patient-specific surgical procedures, dynamics of polar ice, and the human ear.

Annual Stipend of $60,000 plus benefits for up to two years

DEADLINE: **JANUARY 6, 2014**
Apply at: www.ices.utexas.edu/programs/postdoc/

See **Opportunities** *on page 11*

Opportunities

continued from page 10

University of Pennsylvania

School of Arts and Sciences

The School of Arts and Sciences at the University of Pennsylvania seeks to add to the faculty of its newly formed Evolution Cluster. The school invites applicants for a tenure-track assistant professor appointment in evolution, broadly interpreted. The school is interested in exceptional scientists who will establish a research program to empirically study the evolution of dynamical processes using field or laboratory experiments or the construction and analysis of massive data sets. Areas of interest include, but are not limited to: the evolution of neural, social, ecological or linguistic dynamics and networks; evolution of early life or exobiology; biochemical, neuronal, or cooperative interactions and exchange of information at the molecular, cellular, human, or ecosystems scales; directed evolution of organisms or processes; and the analysis of extant structures and networks, from molecules to populations, along with their evolutionary trajectories, including the development of new modalities to extract data from the geologic, genetic, or linguistic historical records. The successful candidate's primary appointment will be in a single department in the natural sciences: biology, chemistry, Earth and environmental science, linguistics, mathematics, physics and astronomy, or psychology. Secondary appointments in other departments can be arranged, as appropriate. The successful candidate will have a strong interest in building a program that generates interaction with researchers from other disciplines who are working within the overarching theme of evolution and will teach courses in his or her home department and participate in the development of curricula pertinent to the Evolution Cluster; applicants should see http://evolutioncluster.sas.upenn.edu for more information.

Applications should be submitted online at: http://facultysearches.provost.upenn.edu/postings/23. They should include a curriculum vitae, a research statement that includes a candidate's perspective on how she or he fits into one of the core departments, links to no more than three journal publications, and the contact information for three individuals who will provide letters of recommendation. The review of applications will begin November 3, 2013, and will continue until the position is filled.

The University of Pennsylvania is an affirmative action/equal opportunity employer and is strongly committed to establishing a diverse faculty; http://www.upenn.edu/almanac/volumes/v58/n02/diversityplan.html.

San Diego State University

Department of Mathematics and Statistics

The Department of Mathematics and Statistics at San Diego State University invites applications for a position as a tenure-track assistant professor in mathematics, beginning in August 2014. The department seeks a harmonic analyst with a strong background in core mathematics, and a research program that includes applied or interdisciplinary work. Candidates must have a doctorate, or equivalent degree, in mathematics or applied mathematics, and demonstrate outstanding research potential. The new faculty member will contribute to the department's program in the Mathematics of Communications Systems, and is encouraged to participate in the SDSU Computational Science Research Center. Preference may be given to candidates who would augment or interact with existing research programs in the department or with key university programs. Candidates must demonstrate enthusiasm and ability to teach undergraduate- and graduate-level courses in pure and applied mathematics.

Applications should include a cover letter, a curriculum vitae, a description of a research program, a statement of teaching philosophy, and three letters of recommendation, which should be sent directly to the search committee. Applications should be addressed to: Peter Blomgren, Chair: Search Committee, Department of Mathematics and Statistics, San Diego State University, San Diego, CA 92182–7720. The review of applications will begin on October 15, 2013, and will continue until the position is filled.

SDSU is an equal opportunity employer and does not discriminate against persons on the basis of race, religion, national origin, sexual orientation, gender, gender identity and expression, marital status, age, disability, pregnancy, medical condition, or covered veteran status. The person holding this position is considered a "mandated reporter" under the California Child Abuse and Neglect Reporting Act and is required to comply with the requirements set forth in CSU Executive Order 1083 as a condition of employment.

North Carolina State University

Department of Mathematics

The Department of Mathematics at North Carolina State University invites applications for tenure-track positions, depending on the availability of funding, to begin in the fall of 2014. The department is seeking exceptionally well-qualified individuals with research interests compatible with those in the department, and in particular in areas of numerical linear algebra, or control; operations research; and personalized medicine/mathematical modeling and health system analysis. For position requirements, applicants should see the position listings at http://www.mathjobs.org.

The Department of Mathematics has strong research programs in applied and pure mathematics. Information about the department is available at http://www.math.ncsu.edu.

Applicants should submit application materials to: http://www.mathjobs.org/jobs/ncsu. Applicants will then receive instructions to complete a faculty profile at http://jobs.ncsu.edu, using the link in the posting. Priority will be given to applications received by November 15, 2013.

NC State is an affirmative action/equal opportunity employer and welcomes all persons without regard to sexual orientation. The College of Sciences welcomes the opportunity to work with candidates to identify suitable employment opportunities for spouses or partners.

University of Toronto

Department of Mathematical and Computational Sciences, UT Mississauga
Department of Mathematics, UT St. George Campus

The Department of Mathematical and Computational Sciences, University of Toronto Mississauga, and the Department of Mathematics, University of Toronto, St. George campus, invite applications for two tenure-stream appointments at the rank of assistant professor in the area of applied mathematics. The expected start date of the appointments is July 1, 2014.

All qualified applicants are invited to apply at the following link: https://www.mathjobs.org/jobs/jobs/4921. For full consideration, applications should be received by November 15, 2013.

The University of Toronto is strongly committed to diversity within its community and especially welcomes applications from visible minority-group members, women, Aboriginal persons, persons with disabilities, members of sexual minority groups, and others who can contribute to the further diversification of ideas. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

Institute for Advanced Study

School of Mathematics

The School of Mathematics at the Institute for Advanced Study, in Princeton, New Jersey, will have a limited number of one- and two-year memberships with financial support for research in mathematics and computer science at the institute for the 2014–15 academic year. The school frequently sponsors special programs; however, these programs comprise no more than one-third of the membership so that a wide range of mathematics can be supported each year. "The Topology of Algebraic Varieties" will be the topic of the special program in 2014–15. Claire Voisin, of the Institut de Mathématiques de Jussieu, will be the school's Distinguished Visiting Professor and lead the program. More information about the special program can be found on the school's homepage (http://www.math.ias.edu/).

Several years ago the school established the von Neumann Fellowships. Up to eight of these fellowships will be available for each academic year. To be eligible for a von Neumann fellowship, applicants should be at least five, but no more than 15, years after receipt of a PhD. Veblen Research Instructorships are three-year positions that were established in partnership with the Department of Mathematics at Princeton University in 1998. Three-year instructorships will be offered each year to candidates in pure and applied mathematics who have received a PhD within the last three years. Usually, Veblen research instructors spend their first and third years at Princeton University; these years will carry regular teaching responsibilities. The second year is spent at the institute and dedicated to independent research of the instructor's choice.

Candidates must have given evidence of ability in research comparable with at least that expected for a PhD degree. Postdoctoral applicants in computer science and discrete mathematics may be interested in applying for a joint (two-year) position with one of the following: Department of Computer Science at Princeton University, http://www.cs.princeton.edu; DIMACS at Rutgers, The State University of New Jersey, http://www.dimacs.rutgers.edu; or the Intractability Center, http://intractability.princeton.edu. For a joint appointment, applicants should apply to the School of Mathematics, as well as to one of the listed departments or centers, noting their interest in a joint appointment.

Applicants can request application materials from: Applications, School of Mathematics, Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540; applications@math.ias.edu. Applications can also be found online at: https://applications.ias.edu. The deadline for all applications is December 1, 2013.

The Institute for Advanced Study is committed to diversity and strongly encourages applications from women and minorities.

Read

Professional Opportunities

online:

jobs.siam.org/

Outstanding Research and Service Recognized at 2013 SIAM Annual Meeting

The following recipients of SIAM awards and prizes were recognized at the 2013 SIAM Annual Meeting and the SIAM Conference on Control and its Applications in San Diego on July 9.

I.E. Block Community Lecture. Anette Hosoi, Massachusetts Institute of Technology, "From Razor Clams to Robots: The Mathematics Behind Biologically Inspired Design."

AWM–SIAM Sonia Kovalevsky Lecture. Margaret Cheney, Colorado State University and Naval Postgraduate School, "Introduction to Radar Imaging."

Ralph E. Kleinman Prize. Anna C. Gilbert, University of Michigan.

W.T. and Idalia Reid Prize in Mathematics. Tyrone E. Duncan, University of Kansas, who gave a prize lecture titled "Solvability for Stochastic Control Problems."

SIAM Activity Group on Control and Systems Theory Prize. Ricardo G. Sanfelice, University of Arizona, whose prize lecture was titled "Feedback Control of Hybrid Dynamical Systems: From Cells to Power Networks."

SIAG/CST Best SICON Paper Prize
2011 Recipients:
Jean-Pierre Raymond, Université Paul Sabatier (Toulouse III), France, for "Feedback Stabilization of a Fluid–Structure Model," *SIAM Journal on Control and Optimization*, Volume 48, Issue 8 (2010).

Mou-Hsiung Chang, U.S. Army Research Office, Tao Pang, North Carolina State University, and Jiongmin Yong, University of Central Florida, for "Optimal Stopping Problem for Stochastic Differential Equations with Random Coefficients," *SIAM Journal on Control and Optimization*, Volume 48, Issue 2 (2009).

2013 Recipients:
Francesco Bullo and Ruggero Carli, University of California, Santa Barbara, and Paolo Frasca, Politecnico di Torino, Italy, for "Gossip Coverage Control for Robotic Networks: Dynamical Systems on the Space of Partitions," *SIAM Journal on Control and Optimization*, Volume 50, Issue 1 (2012).

Bernard Chazelle, Princeton University, for "The Total s-Energy of a Multiagent System," *SIAM Journal on Control and Optimization*, Volume 49, Issue 4 (2011).

SIAM Award in the Mathematical Contest in Modeling
Problem A, The Continuous Problem: "The Ultimate Brownie Pan"
Solution: "The Best Rounded Rectangle for Ultimate Brownies"
Students: Christopher Aicher, Tracy Babb, and Fiona Pigott
Faculty Adviser: Anne Dougherty
University of Colorado at Boulder.

Problem B, The Discrete Problem: "Water, Water, Everywhere"
Solution: "Quenching China's Thirst in 2025: A Min-Cost–Max-Flow Network Model"
Students: Pengfei Gao, Boshuo He, and Tianxin Zou
Faculty Adviser: Hao Wu
Tsinghua University, PRC.

Student Paper Prizes
Joscha Gedicke, Humboldt University of Berlin, Germany, for "An Adaptive Finite Element Eigenvalue Solver of Asymptotic Quasi-Optimal Computational Complexity," *SIAM Journal on Numerical Analysis*, Volume 50, Issue 3 (2012). (Co-Author: Carsten Carstensen, Humboldt University of Berlin, Germany.)

Keiichi Morikuni, The Graduate University of Advanced Studies (Sokendai), Japan, for "Inner-Iteration Krylov Subspace Methods for Least Squares Problems," *SIAM Journal on Matrix Analysis and Applications*, Volume 34, Issue 1 (2013). (Co-Author: Ken Hayami, The Graduate University of Advanced Studies (Sokendai), Japan.)

Vladislav Voroninski, University of California, Berkeley, for "PhaseLift: Exact and Stable Signal Recovery from Magnitude Measurements via Convex Programming," *Communications on Pure and Applied Mathematics*, Volume 66, Issue 8 (2013). (Co-Authors: Emmanuel Candès, Stanford University, and Thomas Strohmer, University of California, Davis.)

Outstanding Paper Prizes
Andrew J. Bernoff, Harvey Mudd College, and Chad M. Topaz, Macalester College, for "A Primer of Swarm Equilibria," *SIAM Journal on Applied Dynamical Systems*, Volume 10, Issue 1 (2011), 212–250.

Daniel Kressner and Christine Tobler, Ecole Polytechnique Fédérale de Lausanne, Switzerland, for "Krylov Subspace Methods for Linear Systems with Tensor Product Structure," *SIAM Journal on Matrix Analysis and Applications*, Volume 31, Issue 4 (2010), 1688–1714.

Alexander V. Shapeev, University of Minnesota, for "Consistent Energy-Based Atomistic/Continuum Coupling for Two-Body Potentials in One and Two Dimensions, *Multiscale Modeling and Simulation*, Volume 9, Issue 3 (2011), 905–932.

SIAM/ACM Prize in Computational Science and Engineering
Linda R. Petzold, University of California, Santa Barbara.

SIAM Prize for Distinguished Service to the Profession
Douglas N. Arnold, University of Minnesota.

The John von Neumann Lecture. Stanley Osher, University of California, Los Angeles, "What Sparsity and ℓ_1 Optimization Can Do For You."

James H. Wilkinson Prize in Numerical Analysis and Scientific Computing. Lexing Ying, Stanford University; he titled his lecture "Interpolative Decomposition and Novel Operator Factorizations."

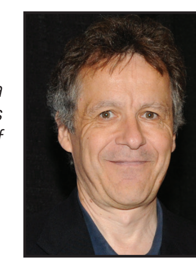
2012 SIGEST Authors
Each issue of SIAM Review*'s SIGEST section features the slightly modified version of a paper originally published in one of SIAM's research journals. SIGEST papers are judged to be of exceptional quality and of potential significance to the entire SIAM community.*

Péter Csorba, Cor A.J. Hurkens, and Gerhard J. Woeginger, TU Eindhoven, The Netherlands, "The Alcuin Number of a Graph and Its Connections to the Vertex Cover Number," *SIAM Review*, Volume 54, Issue 1 (2012), 141–154; published originally in *SIAM Journal on Discrete Mathematics*.

Mark A. Peletier, TU Eindhoven, The Netherlands, and Giuseppe Savaré and Marco Veneroni, Universita di Pavia, Italy, "Chemical Reactions as Γ-Limit of Diffusion," *SIAM Review*, Volume 54, Issue 2 (2012), 327–352; published originally in *SIAM Journal on Mathematical Analysis*.

SIAM president Irene Fonseca presented the 2013 SIAM Activity Group on Control and Systems Theory Prize to Ricardo G. Sanfelice of the University of Arizona, who was recognized for his "contributions to analysis and synthesis of hybrid feedback control systems."

Receiving best SICON paper prizes for 2013 were Francesco Bullo (left) and Ruggero Carli of the University of California, Santa Barbara; their co-author, Paolo Frasca of the Politechnico di Torina, is not pictured. The paper prizes, first awarded in 2009, were given in San Diego at this year's joint control conference and SIAM Annual Meeting.



Also honored with a 2013 paper prize was Bernard Chazelle of Princeton University.

Jean-Pierre Raymond (left) of Université Paul Sabatier (Toulouse III), France, and Tao Pang of North Carolina State University received best SICON paper prizes for 2011 from Irene Fonseca at the prize lunch. Not pictured are Pang's co-authors, Mou-Hsiung Chang of the U.S. Army Research Office and Jiongmin Yong of the University of Central Florida.

T.T. Ngo and Y. Saad, University of Minnesota, and M. Bellalij, Université de Valenciennes et du Hainaut-Cambresis, France, "The Trace Ratio Optimization Problem," *SIAM Review*, Volume 54, Issue 3 (2012), 545–569; published originally in *SIAM Journal on Matrix Analysis and Applications*.

L. Borcea, Rice University, F. Gonzalez del Cueto, Shell Oil Bellaire Technology Center, Houston, G. Papanicolaou, Stanford University, and C. Tsogka, University of Crete and IACM/FORTH, "Filtering Deterministic Layer Effects in Imaging," *SIAM Review*, Volume 54, Issue 4 (2012), 757–798; published originally in *Multiscale Modeling and Simulation*.

SIAM Fellows, Class of 2013
Randolph E. Bank, University of California, San Diego
Kaushik Bhattacharya, California Institute of Technology
Jerry L. Bona, University of Illinois at Chicago
Oscar P. Bruno, California Institute of Technology
John A. Burns, Virginia Polytechnic Institute and State University
Raymond Honfu Chan, The Chinese University of Hong Kong
Andrew R. Conn, IBM T.J. Watson Research Center
Benoit Couet, Schlumberger-Doll Research Center
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Andrew V. Goldberg, Microsoft Research
Alan Hastings, University of California, Davis
Sze-Bi Hsu, National Tsing Hua University
Shi Jin, Shanghai Jiao Tong University and University of Wisconsin–Madison
David Kinderlehrer, Carnegie Mellon University
Edgar Knobloch, University of California, Berkeley
C. David Levermore, University of Maryland, College Park
Marc Mangel, University of California, Santa Cruz
Hans G. Othmer, University of Minnesota
Haesun Park, Georgia Institute of Technology
Robert J. Plemmons, Wake Forest University
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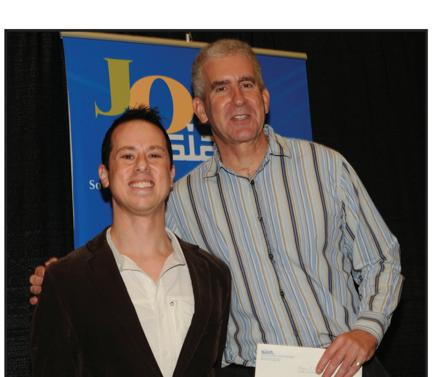
Horst D. Simon, Lawrence Berkeley National Laboratory
Peter R. Turner, Clarkson University
Pauline van den Driessche, University of Victoria
James A. Yorke, University of Maryland, College Park.



Honored at the prize lunch with SIAM Outstanding Paper Prizes were, from left, Chad Topaz of Macalaster College and Andrew Bernoff of Harvey Mudd College; Daniel Kressner (middle) and Christine Tobler (not pictured) of Ecole Polytechnique Fédérale de Lausanne; and Alexander V. Shapeev of the University of Minnesota. The SIAM Outstanding Paper Prizes, first awarded in 1999, are given for outstanding papers published in SIAM journals during the three years prior to the year in which awards are given. Papers are selected for their originality; preference is given to papers that take a fresh look at an existing field or open up new areas of applied mathematics.