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2013 Reid Prize Lecture: Some Solvable Stochastic Control Problems

Tyrone Duncan, a professor of mathematics at the University of Kansas, received the 2013 W.T. and Idalia Reid Prize for "fundamental contributions to nonlinear filtering, stochastic control, and the relation between probability and geometry." The prize was awarded at the SIAM Annual Meeting and control conference in San Diego, where Duncan gave the prize lecture, "Some Solvable Stochastic Control Problems." For readers who missed the talk, James Case considers highlights.

Optimal control theory began to diverge from the calculus of variations in the aftermath of World War II, when it was found that problems of the form

$$\text{minimize}_{u(\cdot)\in\mathfrak{U}} J = K(T,x(T)) + \int_0^T L(t,x(t),u(t))dt \qquad \text{(P)}$$

$$\dot{x}(t) = f(t,x(t),u(t));\ u(t) \in U$$

offered modeling flexibility unmatched by the older theory. If $f(t,x(t),u(t)) \equiv u(t)$, P reduces to a problem in the calculus of variations. Here T is the first instant at which $x(t)$ belongs to a specific "terminal manifold" $\mathfrak{M}$ in space–time, U is a (frequently compact) subset of Euclidean space, and $\mathfrak{U}$ is a class of admissible control histories $u(t); 0 \le t \le T$ taking values in U. Early milestones include Donald Bushaw's Princeton thesis (1953), in which he devised a method for solving a narrow class of two-dimensional "bang-bang" control problems, L.S. Pontryagin's multidimensional maximum principle (published in the West in 1962), and R.E. Kalman's solution of the (also multidimensional) linear-quadratic "tracking" problem (1960). Initially, the problems considered were all deterministic. Only later was it realized that quite similar methods could be used to treat stochastic problems, in which a random process—most commonly Gaussian white noise $W(t)$—is included among the arguments of f.

Kalman's linear-quadratic problems form the most exhaustively (and fruitfully) studied class of optimal control problems. In them one seeks—for a fixed termination time T—to keep the output "history" $y(t)$; $0 \le t \le T$ of a specific system from wandering uncomfortably far from a predetermined path $z(t)$; $0 \le t \le T$ without recourse to unduly costly control histories $u(t)$; $0 \le t \le T$. The instantaneous output $y(t)$ is related to the instantaneous state $x(t)$ of a linear system $\dot{x}(t) = A(t)x(t) + B(t)u(t)$ by the relation $y(t) = C(t)x(t)$, where x, y, and u are column vectors of (constant) dimension N, n, and m, respectively; for each $t \in [0,T]$, $A(t)$, $B(t)$, and $C(t)$ are conformable real matrices. In this case

$$L(t,x(t),u(t)) = \tfrac{1}{2} < [y(t) - z(t)], Q(t)[y(t) - z(t)] > + \tfrac{1}{2} < u(t),R(t)u(t) > \qquad (1)$$

while

$$K(T,x(T)) = \tfrac{1}{2} < [y(T) - z(T)], M[y(T) - z(T)] >. \qquad (2)$$

This reduces to (2) when $y(t)$ is replaced by $C(t)x(t)$ in K and L. The latter evidently grows with the vectors to be multiplied by the symmetric matrices $Q(t)$, $R(t)$, and M,

See **Reid Prize** *on page 8*

Shaw Prize Goes to Statistician/Mathematician David Donoho

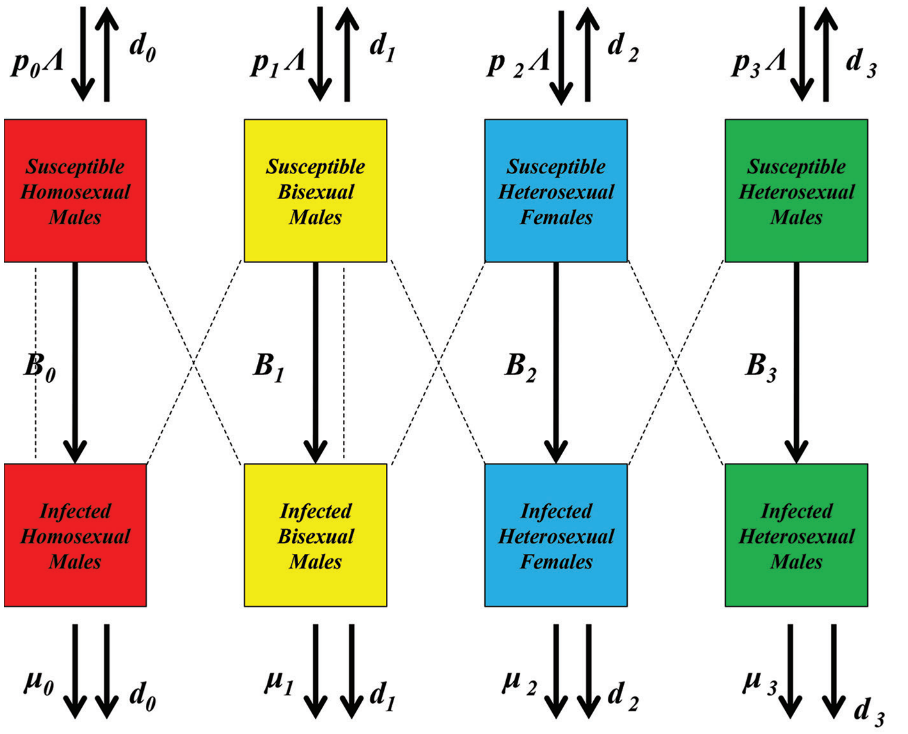
For more than two decades, according to the selection committee for the 2013 Shaw Prize in Mathematical Sciences, David Donoho of Stanford University has been a leading figure in mathematical statistics. Donoho, shown here (left) with Hong Kong Chief Executive C.Y. Leung, was cited by the committee for novel mathematical tools and ideas that have helped shape both the theoretical and applied sides of modern statistics. His work is characterized by the development of fast computational algorithms, together with rigorous mathematical analysis for a wide range of statistical and engineering problems. See page 3. Photos courtesy of David Donoho.

Social Engagement Shapes a Mathematical Career

For the year from July 1, 2011, to June 30, 2012 (the latest year for which statistics are available), exactly 16 PhDs in the mathematical sciences were awarded to black/African-American women in the entire U.S. Evelyn Thomas, now a postdoctoral fellow at the University of Maryland, Baltimore County, is one of them. UMBC mathematician and novelist Manil Suri profiles her for SIAM News, *with the aim of shedding light on challenges and opportunities she has encountered along her career path.*

The first defining event in Evelyn Thomas's career was 9/11, when she was a sophomore at Spelman College. She spent all morning with her friends, watching the grim events unfold on TV. Most professors cancelled classes or held discussions to address the emotional trauma of students. But Thomas's set theory professor conducted his afternoon class as usual, without the slightest reference to the attacks. It felt so surreal that Thomas decided never again to let her love for mathematics cut her off from the real world like this. She began to envisage a research career in mathematics rooted in the humanistic field of sociology, which was her minor.

The second defining moment came in April 2004. Thomas was watching Oprah Winfrey interview the writer J.L. King, who announced that he was on the "down low." This is the term used of African-American men who secretly engage in sex with other men, without telling their wives or girlfriends. Her friends were as shocked as she was. "What if a partner or spouse was having unprotected sex with a man? The level of deception would be amazing," Thomas says. Back then, she decided to do something unusual about it—make it the topic of her PhD thesis.



Effects of bisexuals on the spread of HIV/AIDS: A simplification in a model she studied led Evelyn Thomas to construct a model for her PhD thesis that included the four distinct populations shown here.

The idea of choosing one's own thesis topic in mathematics is almost unheard of. Thomas's quest eventually led her to enlist Katharine Gurski of Howard University as her adviser. Gurski suggested bringing in Kathleen Hoffman of UMBC as co-adviser. "Both had expertise in applied mathematics," Thomas says, "but each offered a different perspective, adding to the substance of the work." Thomas successfully defended her thesis, *The Effect of Bisexual Males on the Spread of Incurable Sexually Transmitted Diseases*, in April 2012.

Perhaps more than any other factor, Thomas attributes her success to her parents: "Both their families realized education was the great equalizer—my maternal grandmother even obtained a college degree in the 1940s." It helped that Thomas grew up in a stable middle-class family in Washington, DC, and attended public schools in relatively affluent areas. Still, she recalls feeling odd as the only black girl from her grade level enrolled in most of her advanced math courses.

Spelman College, one of the HBCUs (historically black colleges and universities), changed that. Suddenly, she was surrounded by black women with similar backgrounds, freeing her from the distractions of race and gender. "I could no longer simply define myself as *the* 'smart black girl'—I had to find my own identity." The "outstanding" mentorship there was matched by high standards: "Women were expected to pursue graduate and professional degrees." Black female role models (like Monica Stephens Cooley) on the mathematics faculty offered living proof of a waiting world of possibility. "I absolutely think if I had not gone to an HBCU for my undergraduate degree, I would not have earned a PhD," Thomas says.

She continued to experience the benefits of HBCUs at Howard University. The mathematics department (under the leadership of Aziz Yakubu) was creating partnerships within mathematical biology, specifically with DIMACS (the Center for Discrete Mathematics and Theoretical

See **Evelyn Thomas** *on page 8*

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Meet SIAM's Science Policy Committee

For readers who would like to know more about SIAM's Committee on Science Policy, CSP members Hans Kaper and David Levermore (chair) offer highlights of recent projects and concerns pursued by the committee.

The SIAM Committee on Science Policy represents the interests of the SIAM membership in Washington, DC. SIAM is supported in this effort by a contract with Lewis–Burke Associates, a government-relations firm in Washington that specializes in advocacy for the public policy interests of universities and other research and education organizations. In 2013, the CSP worked to make SIAM's voice heard by the appropriate decision makers in a variety of areas, including federal funding for research, reauthorization of the America COMPETES Act, undergraduate mathematics education, and the Computational Science Graduate Fellowship program of the Department of Energy.

CSP Meetings

The CSP, whose 25 members are appointed by the SIAM president, meets twice a year in Washington, DC, to discuss legislative and policy issues that have the potential (real or perceived) to affect our disciplines. The agenda of a typical meeting includes an update on pending legislation from Lewis–Burke staff, discussions with invited guests from agencies that oversee funding in the mathematical and computational sciences (mainly the Departments of Defense and Energy, National Institutes of Health, National Science Foundation), and deliberation about priorities for future action.

The second day of the spring meeting is usually devoted to visits to Capitol Hill, where CSP members meet separately or in small groups with congressional staff (normally those connected to key committees). The schedule sometimes also includes visits to offices in the Administration, such as the Office of Management and Budget and the Office of Science and Technology Policy. The CSP met most recently on December 4 and 5, 2013.

A Sample of Recent Activities

Between meetings, CSP members engage in lively discussions via e-mail. Among the topics discussed between the spring and winter meetings in 2013 was a consolidation of federal STEM education programs proposed in the president's budget request for FY 2014. Of particular concern to the SIAM community, DOE's Computational Science Graduate Fellowship program would be terminated under the consolidation in favor of an expansion of NSF's Graduate Research Fellowship program. Given the strong support for the CSGF program among CSP members, and in the SIAM community at large, the CSP wrote to Senate and House majority and minority appropriators outlining the relevance of the program to specific research needs of DOE. The fate of the CSGF program remains uncertain.

A focus of earlier discussions was a February 2012 report of the President's Council of Advisors on Science and Technology (*Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*) and its potential impact on the teaching of mathematics at the college level. An important finding of the study was that increased student success in STEM disciplines would require improvements in mathematics education at the K–12 and undergraduate levels.

Many in the mathematical sciences community expressed concern about the report's suggestion that non-mathematicians be engaged in the teaching of undergraduate mathematics for non-majors. In response to the report, the SIAM Education Committee and the CSP joined to prepare a formal white paper, which was sent to the White House Office of Science and Technology Policy and NSF.

Following up on those efforts in 2013, CSP chair David Levermore participated in a presentation with Mark Green (co-chair, "Math 2025"), Eric Friedlander (former president of the American Mathematical Society), and David Bressoud (former president of the Mathematical Association of America) to PCAST on July 18. (See related statement on page 6.) Given the influential voice of PCAST on S&T matters, the CSP recognizes the importance of having the interests of our community represented on PCAST. We encourage qualified candidates to consider submitting their names for nomination.

Budget Drivers

Setting priorities means looking for budget drivers. In his proposed budget for FY 2014, President Obama called for an initiative in brain research. This is likely to be a major budget driver in future budgets of NSF and other agencies. The goals of the initiative include the development of imaging tools and the creation of "tools to influence the activity of every neuron individually." Most related to our area of science is the third-stated goal: "to understand circuit function." This includes methods for modeling and analyzing data. The CSP is actively considering how research in our field could support the initiative and encourages the SIAM membership to suggest ideas for a planned white paper.

Another budget driver lies in the realm of cybersecurity. The Networking and Information Technology Research and Development program, which operates under the umbrella of the National Science and Technology Council in the executive branch of the government, prepared a strategic plan for federal cybersecurity research and development activities. Late in 2012, the CSP responded to a request for feedback on the draft plan, emphasizing areas of applied mathematics that could be effective in advancing cybersecurity research. This is one example of SIAM's interaction with decision makers in shaping future R&D activities across agencies.

Policy Drivers

Setting priorities also means looking for policy drivers. Modernization of graduate education is emerging as an important priority area for the Administration and for a number of agencies, including NSF and NIH. The main aim is to ensure that graduate students acquire skills for the full range of STEM careers. In the course of meetings with NSF, OSTP, and OMB staff, SIAM has been invited to provide feedback on this topic; again, we invite readers to suggest ideas for a planned white paper.

Improving undergraduate education has also been a focus for the Administration. There is bipartisan concern about the cost of higher education. Silicon Valley has Washington's ear about ways in which technology can transform education. Educators tout evidence-based and inquiry-based teaching methods. SIAM continues to engage in discussions of these issues when they affect the membership, and the CSP is working with the SIAM Education Committee to ensure a greater voice in these matters for the SIAM community. Cooperative efforts are under way with other mathematical professional societies through the Joint Policy Board on

See **Science Policy** *on page 5*

Stay Informed: Follow the Debates on Science Policy

SIAM, like many professional organizations, regularly updates members on developments in the science policy arena. Some of the latest information on these developments, from SIAM and several other organizations, can be found at the following web links:

Society for Industrial and Applied Mathematics
Science Policy and Funding
siam.org/about/science

American Institute of Physics
FYI: The AIP Bulletin of Science Policy News
aip.org/fyi/
subscribe at aip.org/fyi/subfyi.html

American Geophysical Union
Science Policy Updates
agu.org/sci_pol/

American Mathematical Society
Policy and Advocacy News
ams.org/policy/govnews/govnews

American Physical Society
Capitol Hill Quarterly
aps.org/publications/capitolhillquarterly/index.cfm

American Society for Engineering Education
Capitol Shorts Newsletter
asee.org/papers-and-publications/blogs-and-newsletters/capitol-shorts-newsletter

Association for Computing Machinery/U.S. Public Policy Council
ACM Washington Update
usacm.acm.org/

Computing Research Association
Computing Research Policy Blog
cra.org/govaffairs/blog/

Many of these websites also provide information for readers interested in visiting their representatives in Washington, DC.

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From Wavelets to Compressed Sensing and Beyond: 2013 Shaw Prize Recognizes a Remarkable Mathematical Life

On September 23, in formal ceremonies in Hong Kong, David Donoho of Stanford University received the 2013 Shaw Prize in Mathematical Sciences. Citing "his profound contributions to modern mathematical statistics," the selection committee mentioned in particular his "development of optimal algorithms for statistical estimation in the presence of noise and of efficient techniques for sparse representation and recovery in large datasets."

Within the sweeping citation are references to some of the most important mathematical/statistical research advances of recent years, many rooted in the latter half of the 1980s. Mathematicians at that time, Donoho's Stanford colleague Iain Johnstone recalls, were crystallizing the theoretical and algorithmic possibilities of wavelets. Donoho, Johnstone says, "quickly saw implications of wavelets for statistical theory and statistical signal processing, where the presence of noisy and sometimes indirect observation is a defining feature."

He and Johnstone proposed thresholding algorithms that were both efficient and amenable to "detailed and elegant theoretical study using a blend of statistical decision theory, harmonic analysis, and approximation theory." In estimation theory, Johnstone says, "Donoho changed the paradigm from 'smoothness' to 'sparsity' by showing that sparsity was the more powerful concept. When sparsity reduced to smoothness, traditional linear methods of estimation such as splines, kernels and spectral cut-off were provably optimal. By contrast, when sparsity could be identified in non-smooth settings, suitable nonlinear methods were demonstrably superior."

Joining David Donoho (center) in Hong Kong during the 2013 Shaw Prize festivities were, from left, C.N. Yang, a 1957 Nobel laureate in physics; Miriam Donoho; Tony Chan, president of the Hong Kong University of Science and Technology; and Pak-Chung Ching, pro-vice-chancellor/vice-president of the Chinese University of Hong Kong. Donoho gave the prize lecture for the mathematical sciences, titled "Compressed Sensing: Past, Present, Future," at HKUST on September 24.

Many in the SIAM community heard about Donoho's subsequent interests in his invited talk at ICIAM 2003 and in his 2001 SIAM John von Neumann Lecture: "What Lies Beyond Wavelets? Explorations in Multiscale Thinking . . . ." Variants of multiscale thinking woven into the lecture ranged from Fourier integral operators to "ridgelets and curvelets for representation of edges in images, to beamlet detectors for filaments in noisy images." Applications abounded, in data compression, statistical estimation, and pattern analysis.

Recommended reading for those interested in these research areas, or in the trajectory of such a successful research career, is the "Autobiography" Donoho wrote for the Shaw Prize website.* In it, he paid tribute to a very early influence on his career: John Tukey, his undergraduate thesis adviser at Princeton, who advocated "robust statistical methods, such as fitting equations by minimizing the ℓ_1 norm of residuals rather than the ℓ_2 norm." Tukey, Donoho wrote, "criticized 'classical' mathematical statistics as searching for polished answers to yesterday's problems."

In the course of his career, Donoho has worked with many colleagues and more than twenty-five PhD students, who have derived both practical and theoretical results in related work. Prominent among exciting recent directions is "compressed sensing," a term coined by Donoho for an area that he described in a 2004 paper of the same name. "Because the wavelet transform sparsifies images," he explained in the paper, "images can be recovered from relatively few random measurements via ℓ_1-minimization."

In a concluding twist to his autobiographical statement, Donoho commented on a new approach to the sparsity/undersampling tradeoff that he and colleagues had developed: "Solving random underdetermined systems by ℓ_1-minimization was revealed as *identical to* denoising of sparse signals embedded in noise [his emphasis]. Two separate threads of my research life became unified."

In the statement, Donoho credited many people, both mathematical forebears and colleagues and students. Sure to play a role in any future autobiographical statement is Run Run Shaw, Hong Kong philanthropist, entertainment tycoon, and co-founder of Shaw Brothers, one of the world's largest film studios. In 2002 he established the Shaw Prizes, which honor outstanding work in research and applications in the mathematical sciences, life science and medicine, and astronomy; presented annually, the prize in each field carries a cash award of U.S. $1 million. Shaw died in January 2014, at the age of 106.

*shawprize.org/en/shaw.php?tmp=3&twoid=94&threeid=220&fourid=387&fiveid=185.

Reaching for Success, One Word at a Time

By Ellen Lê

What is joy if you can't communicate it to others? It's my belief that many mathematicians and scientists, particularly applied mathematicians, feel a need to communicate their work to others—to the public, to lay people, to those not privileged to do mathematics for a living, to their children, to their non-scientist friends. For them, and for me, just talking to the same circle of collaborators day after day is not fulfilling. So when I was offered a AAAS Mass Media Fellowship through SIAM to do science writing at *The Sacramento Bee*, the newspaper where famed science writer Deborah Blum wrote her Pulitzer Prize-winning series "The Monkey Wars," I jumped at the opportunity.

It made no sense, and also made perfect sense at the time. It was the summer between finishing my master's degree at the University of Iowa (in the Applied Mathematics and Computational Science program) and embarking on a PhD at ICES (the Institute for Computational Engineering and Sciences at the University of Texas). I had no newspaper or media experience, except for a satirical math department fashion column that I wrote for my graduate student newsletter. (You read that correctly.) I hadn't written anything serious and non-math-related in two years.

But I loved science writing and media—how, when done well, it can be so pleasurable, educational, inspiring, powerful, and relevant all at once. I believed in it. Could I become a part of it? By the end of the summer, would I be able to rightfully call myself a mathematician/science writer?

Arriving at the fellows orientation in Washington, DC, I quickly realized that I was in way over my head. I did not love, eat, and breathe science journalism the way other fellows did. They did not simply aspire to the scientist/journalist title—some had already earned that status. Three people had popular science podcasts, and two were famous on Twitter. How was I even allowed to be in the same room?

Then it was off to *The Sacramento Bee*, where my editors quickly demoralized me further by showing me impressive clips from the previous two AAAS interns, one a hard-hitting physicist and the other a biologist with a passion for bees and tomatoes. The editors had great expectations for me, they said. Oh dear.

The first day, I sat clicking at my computer, looking for a story, optimistically hoping for an editor to throw me an assignment. The second day, the same thing happened. I re-read the "advice to future interns" essay that the previous intern had written, the one they had all loved; she said it took her two weeks to get her first story out! But during those two weeks, it seemed that all she did was work up the courage to pitch a story, and from then on it got much easier.

So the third day, hiding my nervousness and complete lack of an idea of what I was doing, I pitched a weather story—having noticed strange patterns in the national weather. I made frantic calls to meteorology and climate professors at UC Davis. One particularly charismatic and brash professor called me back and gave me some fantastic quotes. I wrote the story, and it ran the next day.

The same day my first article ran, one of the editors, Maury, told me to go investigate a foul odor rumored to be coming from a city park pond. I biked down to the park, talked to some locals, and found out that two city garbage trucks filled with dead fish had just left. I wrote a well-received pair of back-to-back articles investigating and

"By the end of the summer," wondered AAAS media fellow Ellen Lê, "would I be able to rightfully call myself a mathematician/science writer?"

explaining the science of that mysterious fish kill, earning Maury's trust.

From then on, he gave me wonderful assignments and was always eager to hear my pitches. Over the course of ten weeks, I managed to publish 14 articles and shoot and edit three videos. The topics I covered ranged from Snapchat to the eventual flooding of the world's coastal cities to urban bat populations. I'm proud of what I managed to accomplish in such a small amount of time.

As much as I enjoyed being a science writer, and as much as I embarrassingly enjoyed the compliments about my writing and potential as a journalist, the summer at *The Sacramento Bee* made me reaffirm my goal of becoming a mathematician. Was the summer a waste? Far from it. There are so many lessons that I carry forward, but the most important is the idea that to become an expert in anything, you have to be a novice in it first.

You have to be eager to absorb information and ask questions, and not pretend that you already know everything; otherwise, you might not get those great quotes for your article. Similarly, in mathematics, you have to figure out what concepts you're stuck on and get help, and not pretend that you already know everything; otherwise, you might soon find yourself in a bad place.

But you can't allow your novice-ness to paralyze you. Success is achieved one word at a time, one proof at a time, one day at a time. So what are you waiting for? Apply for the Mass Media fellowship already. If you have any questions at all, don't hesitate to contact me (ellenle@utexas.ices.edu).

Readers can learn more about the AAAS Mass Media Fellowship program at aaas.org/mmfellowship.

De Moivre Revealed

Abraham de Moivre: Setting the Stage for Classical Probability and its Applications. *By David R. Bellhouse, A.K. Peters/CRC Press, Boca Raton, Florida, 2011, 266 pages (with extensive notes and bibliography and numerous illustrations), $45.00.*

BOOK REVIEW
By Philip J. Davis

Over the past decades, not a few mathematicians have been forced out of their homes, exiled, persecuted, or worse. During the heyday (1947–1954) of the House Un-American Activities Committee, mathematical friends who were social activists fled to Canada or to Sweden. And, of course, during the Hitler years European mathematicians sought refuge in all parts of the globe. Such harassment was due not to the mathematical content of their work, but to their political opinions, their actions, or their genealogies.

Harassment is an old story. The first historical case I know of is that of the brilliant neo-Platonist mathematician Hypatia (c. 370–415 CE), daughter of the mathematician Theon Alexandricus. Involved in a controversy between the Christians and non-Christians of Alexandria, Hypatia was brutally murdered. Hypatia's life has become a legend, a paradigm for feminists, and it has been much elaborated via artistic renditions, novels, plays, and a journal. Harassment of women mathematicians continues today.

I turn now to the French Huguenot mathematician Abraham de Moivre (1667–1754), who, during the intolerance and dragonade that accompanied the revocation by Louis XIV of the Edict of Nantes, fled to liberal England. Established in England, earning a meager living as a tutor to upper-crust Whigs, getting to know Edmund Halley, the Astronomer Royal, and several years later Isaac Newton, de Moivre became part of the British scientific coffeehouse community. In 1697, with his mathematical talents and bona fides established by his generalization of Newton's binomial theorem, he was elected a Fellow of the Royal Society.

Who were de Moivre's scientific contemporaries? Citing only major works, we should list Leibniz, *Acta Eruditorum*, 1684; Newton, *Principia Mathematica*, 1687; Brook Taylor, *Methodus Incrementorum Directa et Inversa*, 1715; Roger Cotes, *Harmonia mensurarum*, 1722 (posthumous); A.C. Clairaut, *Recherches sur les courbes*, 1731. We must certainly not forget Leonhard Euler (1701–1783), of whose works, from a myriad of possibilities, I mention *Introductio in Analysin Infinitorum* of 1748. De Moivre was familiar with some of Euler's results. What a splendid pantheon of talent and what a heady and fundamental brew of mathematics these fellows created!

In 1721, a challenge was thrown out to de Moivre by a certain Alexander Cuming, "an interesting character who had a checkered career," in the words of David Bellhouse. This challenge, Bellhouse writes, "resulted in one of de Moivre's major accomplishments . . . : the normal approximation to binomial probabilities." The book traces de Moivre's development of that work.

I would conjecture that to most mathematicians not in the probability business (a group in which I include myself), the name de Moivre brings immediately to mind his formula $(\cos z + i\sin z)^n = \cos(nz) + i\sin(nz)$ or, in its later and deeper Eulerian formulation, $\exp(iz) = \cos(z) + i\sin(z)$. As a matter of fact, de Moivre's oeuvre goes beyond combinatorics, probability, and actuarial mathematics to what might be called the foundations and the early developments of analytic power and trigonometric series.

Though neglected or downplayed in most histories of mathematics, theology and its relation to mathematics have been in the minds and in the writings of numerous mathematicians of all periods.* As an author famous for his mathematization of chance (his *Doctrine of Chances* appeared in 1718), what did de Moivre think of chance philosophically, so to speak? In a paragraph that has theological overtones, he wrote:

"And thus in all cases it will be found, that although Chance produces irregularities, still the Odds will be infinitely great, that in process of Time, those Irregularities will bear no proportion to the recurrency of that Order which naturally results from Original Design. . . . Again, as it is thus demonstrable that there are, in the constitution of things, certain Laws according to which Events happen, it is no less evident from Observation, that these Laws serve to wise, useful and beneficent purposes, to preserve the steadfast Order of the Universe, to propagate the several Species of Beings, and furnish to the sentient Kind such degrees of happiness as are suited to their State. . . ."

We have here an early statement that fits in with today's rampant controversy on "intelligent design," the theory that the universe and all that is in it could not have originated and developed randomly, but was the work of an intelligent designer. It would be interesting to know how or whether de Moivre's Huguenot Calvinist background entered into his views. Is intelligent design an aspect of predestination, which was a Calvinist tenet?

Bellhouse, a professor of statistics at Western University, in London, Ontario, has given us in this book a splendidly detailed, background-rich, and well-referenced coverage of de Moivre's work and life. His presentation is topped off by three pages on a long-neglected fellow: the Reverend Thomas Bayes, of inverse probability fame and notoriety—a subject now all the rage. Bayes espoused the notion of Divine Benevolence, and his theorems have been employed to arrive at the probability that Christian theology is true.

*See P.J. Davis, "A Brief Look at Mathematics and Theology," *The Humanistic Mathematics Network Journal Online*, Vol. 27, 2004.

Philip J. Davis, professor emeritus of applied mathematics at Brown University, is an independent writer, scholar, and lecturer. He lives in Providence, Rhode Island, and can be reached at philip_davis@brown.edu.

Big Data Meets The Wisdom of the Crowd

Who's Bigger? Where Historical Figures *Really* Rank. *By Steven Skiena and Charles Ward, Cambridge University Press, Cambridge, UK, 2013, 408 pages, $27.99.*

BOOK REVIEW
By Ernest Davis

Who was more important historically—Mary, Queen of Scots, Mary Tudor, Queen of England, or Marie Antoinette? Copernicus or Freud? Charlie Chaplin or Steven Spielberg? Wonder no longer. Thanks to the power combo of Big Data and the Wisdom of the Crowd, these and all such questions have been scientifically answered. Specifically, Steven Skiena and Charles Ward have produced a ranking of the historical importance of everyone with a Wikipedia entry—which, needless to say, is everyone who was ever anyone—from Jesus [#1] to Sagusa Ryusei [#843,790]. Consulting the index to the book, or the accompanying website (whoisbigger.com), we find that the battle of the Mary's was a photo finish: Marie Antoinette was the 125th-most-important person in history, Mary of England was 126th, and Mary, Queen of Scots, was 127th. Freud at 44 handily beat Copernicus at 74; and Chaplin at 295 clobbered Spielberg at 1079.

The list, as I mentioned, includes anyone with a Wikipedia article; for instance, my boss John Sexton, president of NYU, is the 69,747th-most-important person in the history of the world; my instructor in undergraduate topology, James Munkres, is the 195,642nd. One can easily imagine that after the next project of this kind—which would incorporate everyone with a web presence and constantly update the calculations—it would be de rigueur to list one's current ranking on one's CV, together with citation count, h-index, i10-index, and all the other numbers that reliably quantify one's life and labors.

To compute the ranking of Person X, Skiena and Ward start with six basic statistics:

1 and 2. The PageRank of X's Wikipedia page. This measure, famous as the basis of the Google search engine, is computed from the number of Wikipedia pages that contain a link to X, weighted by the importance of the pages linking to X. Two versions of PageRank are computed: One considers all Wikipedia pages, the other biographical pages only. For instance, Linnaeus (overall rank 31) scores very high on the first measure, because every species that he named links back to him; he scores less high if one considers only biographical pages.

3. The number of times the Wikipedia page has been viewed.

4. The number of times the Wikipedia page has been modified.

5. The length of the Wikipedia article.

6. The frequency with which X is mentioned in the news.

Applying a factor analysis to these numbers reveals that there were two primary factors. One, which Skiena and Ward call *celebrity*, is the person's current notoriety; hot rock stars, politicians in the news, and so on score high here. The other, called *gravitas*, is the measure of solid accomplishment; philosophers, scientists, classic historical figures score high here. A linear combination of celebrity and gravitas gives *fame*. Fame, however, is fleeting and declines over time; correcting for this effect, Skiena and Ward arrive at the final value for *historical significance*. They also discuss and analyze the evolution of fame over time, using the Google Ngrams tool that reports the number of times a given name was mentioned in publications within a given range of dates. In many ways, this diachronic analysis is more interesting and more informative, though less complete, than the ranking studies.

What Is Being Measured? Given that "historical significance" is obviously entirely vague and nonquantifiable, what do these numbers actually signify? Skiena and Ward make a number of claims. The most cautious claim is that the rankings measure "the strength of historical memes" and that their study of change over time analyzes the processes that cause figures to become more and less famous. Among their normative claims are that highly ranked figures are those who are "most worth knowing" and "really belong in history textbooks." They claim further that these numbers correlate strongly with the figures' "true" importance as measured by historians. Finally, there is the tongue-in-cheek claim of the subtitle: "Where Historical Figures *Really* Rank."

How Accurate Are the Rankings? That's harder to say. Skiena and Ward, naturally, are very enthusiastic about their ranking. They have validated it against quite

See **Rankings** *on page 5*

NJIT
New Jersey Institute of Technology

Eleventh Conference on Frontiers in Applied and Computational Mathematics (FACM '14)

May 22-23, 2014
New Jersey Institute of Technology
Newark, New Jersey

Program: The eleventh conference will focus on mathematics applied to problems in science and technology including nonlinear waves, completely integrable systems, mathematical biology and biostatistics. This conference will coincide with a celebration of Robert Miura's 75th birthday.

Plenary Speakers: Huaxiong Huang (York University), Peter Miller (University of Michigan), John Rinzel (New York University) and Jonathan Wylie (City University of Hong Kong).

Minisymposium Speakers (partial list): Mark Ablowitz (U Colorado), Ron Anafi (U Penn), Mickey Atwal (CSHL), Ernie Barretto (George Mason U), Richard Bertram (Florida State U), Gino Biondini (SUNY- Buffalo),Victoria Booth (U Michigan), Gerda De Vries (U Alberta), Daniel DeWoskin (U Michigan), Nick Ercolani (U Arizona), Adrian Granada (Harvard U), Zhezhen Jin (Columbia U), David Kaup (U Central Florida), Justin Kinney (CSHL), Christian Klein (U Bourgogne), Yuji Kodama (Ohio State U), Peter Kramer (RPI), Tanya Leise (Amherst), Yue-Xian Li (UBC), Qing Nie (UC-Irvine), Demetrios Papageorgiou (Imperial), Linda Petzold (UC-Santa Barbara), Vipul Periwal (NIDDK), Jonathan Rubin (U Pittsburgh), Constance Schober (U Central Florida), Harvey Segur (U Colorado), Mona Singh (Princeton U), Greg Smith (William & Mary), David Terman (Ohio State U) and Michael Ward (UBC).

Organizers: Amitabha Bose (Chair), Gerda DeVries, Roy Goodman, Victor Matveev, Michael Siegel and Antai Wang.

Sponsored and Supported by: Department of Mathematical Sciences, NJIT; Center for Applied Mathematics and Statistics, NJIT; National Science Foundation (pending).

Travel Awards: Applications are solicited for contributed talks from postdoctoral fellows and graduate students. Selected applicants will receive full support for travel. Other contributed papers for the conference will be presented as posters. Funds are available for partial support of travel expenses for graduate students, postdoctoral fellows, and junior faculty poster presenters. The deadline for all applications and submission of titles and short abstracts is April 15, 2014.

Contact: See the FACM'14 URL for full details: http://m.njit.edu/Events/FACM14/. Local contact: Alison Boldero, Department of Mathematical Sciences, New Jersey Institute of Technology, Newark, NJ 07102, USA; email: alison.r.boldero@njit.edu, tel.: 973-596-5782.

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The Science & Technology University of New Jersey

Rankings

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a collection of existing measures: lists put together by others, prices of autographs, answers from people asked to compare pairs of historical figures, and so on. The authors report correlations of about 0.5 with these other measures, which they argue is as good as could be expected in that the different measures don't agree with one another better than that.

Looking over the list, I had mixed feelings. On the one hand, most of the rankings, especially the comparative rankings of people in the same field, are plausible. Jesus [1], Napoleon [2], Muhammad [3], Shakespeare [4], and Lincoln [5] were important people—check; Leonardo [29], Michelangelo [86], Raphael [140], Rembrandt [189], and Titian [319] were great painters—check; and so on. The work is also impressive in some technical respects; in particular, the distinction between celebrity and gravitas and the correction for time both seem, on the whole, to work very well. (Among intellectuals, in fact, it seems to me that they *over*-compensate for time and rank premodern figures higher than they deserve.)

On the other hand, there are a number of significant biases and numerous rankings that, I would argue, are just indisputably wrong. To the extent that comparisons of this type are meaningful at all, it is simply wrong to say that two of the top 20 and four of the top 41 most important people in history were Tudor or Stuart British monarchs; or that Queen Victoria, who had pretty much no political power, was the 16th-most-important person in history; or that Charles Babbage [273] and Ada Lovelace [994] were more important mathematicians than Noether [2523], Chebyshev [3571], or Grothendieck [7311]; or that all but one (Schiller [564]) of the 20 most important poets have been anglophone; or that Francis Scott Key [1050] was the 19th-most-important poet in history.

The category lists have apparently been manually assembled; in categories in which the authors are not experts, there can be major gaps. For example, the list of "American Religious Figures" includes Jimmy Swaggart [12,579] but not Dwight L. Moody [2915], Elijah Muhammad [4483], Reinhold Niebuhr [6453], Joseph Soloveitchik [7308], Richard Allen [7635], Mordecai Kaplan [11,346], Moshe Feinstein [11,761], Steven Wise [11,849], or Abraham J. Heschel [12,019].

As I was writing this review, the website was full of bugs. About a fifth of the pages did not display the statistics correctly. The web page for Queen Victoria strangely compared her ranking to New York, Toronto, San Francisco, and so on. The website included pages for "Knitting" (the activity) and for "December 6" (the date). Presumably, these are the results of misclassified pages in Wikipedia, but those who live by Wikipedia perish by Wikipedia.

A book of this kind reinforces the widespread and growing illusions that all questions can be answered by web mining; that fame is equivalent to a worthwhile life; and that the significance of a human life can be reduced to a number and a 25-word summary.

Biases: As expected for a collection based in the English-language Wikipedia, there are biases in favor of English-speakers, against women, and, in descending order, in favor of the U.S., the UK, Western Europe, classical Greece and Rome, Eastern Europe, the Middle East, the Far East. There are also striking biases in the categories: The top 200 figures include ten classical composers and five artists, but only one person known primarily as a historian (Herodotus [123]). In the top 1000, we find only 11 more historians, only two of whom are of the modern era (Gibbon [573] and Tocqueville [716]), and only one computer scientist (Bill Gates [904]). Jimmy Wales, who founded Wikipedia, is #3198; Tim Berners-Lee, who created the World Wide Web, is #3931.

What Is the Use of It? There is an inherent difficulty in finding an actual use for a project of this kind. To the extent that the rankings correspond to the conventional wisdom (Jesus, Napoleon, Muhammad), we don't need the study. To the extent that they contradict the conventional wisdom (Ada Lovelace, Queen Victoria), the study seems wrong. Of course, Skiena and Ward could argue the exact reverse: To the extent that they correspond, the rankings are validated; to the extent that they differ, they offer us new insights. The problem, though, is that the new insights—i.e., about the people who are more highly ranked than expected—do not seem particularly interesting or deep; they just concern people (Queen Victoria, Jules Verne, Ada Lovelace) who, for one reason and another, are much better known than their actual accomplishments would warrant.

Skiena and Ward suggest a number of uses for the rankings. One is for vetting history textbooks; Skiena discusses at length his daughter's fifth-grade history textbook, which includes some very obscure people. He proposes the substitution of other people, judged more important in his ranking. His suggestions mostly seem sensible; precisely because they are sensible, however, it is not clear why you would need the rankings to arrive at them (except to intimidate reluctant educationalists with numbers). The authors also suggest that the lower rankings of women collectively can be used to measure the neglect of women in the historical literature.

What Is the Harm in It? Against these uses, one has to weigh the harm done by a book of this kind in reinforcing the widespread and growing illusions that all questions can be answered by web mining; that fame is equivalent to a worthwhile life; and that the significance of a human life can be reduced to a number and a 25-word summary. We are awash in lists; the last thing we need is an exhaustive list of everyone judged on a single criterion, supported by pretenses to objectivity.

Bottom Line: All in all, the book seems to me bloated, both in its claims and in its length. The claim that it constitutes any kind of contribution to our understanding of what figures are historically significant seems to me entirely baseless. And the book is about ten times too long. It contains a variety of silly lists: Who is the most important person to die at age 57? Who is the most important person to be born on March 28? The discussion of the fifth-grade textbook mentioned earlier is sensible, but the point could have been made in one page rather than 30. A long history of the inductees into the "Hall of Fame for Great Americans" in the Bronx, with a year-by-year account of the honorees and the rejected candidates, is entirely uninteresting. If this book had been a 30-page research paper, with conclusions along the lines of, "We have shown that we can automatically compute historical importance using these kinds of techniques, and that the results are pretty good, with such and such kinds of bugs and biases," I would have said it was a fascinating, though useless, project, very well executed.

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

Science Policy

continued from page 2

Mathematics and through outreach to larger organizations, such as the AAAS and the Association of American Universities, that have related initiatives.

Outlook

Given the volatile political climate in Washington, members of the CSP and their friends at Lewis–Burke Associates will continue to keep their ears close to the ground to pick up any signals, positive or negative, from Congress and the Administration.

We encourage readers interested in receiving updates on policy issues and/or funding opportunities to sign up (at http://www.siam.org/about/science/sci_policy_form.php) for occasional e-mail alerts on matters of general interest to the mathematical and computational sciences community. Information about other policy alerts of interest to the SIAM community can be found in the sidebar on page 2.

Read
SIAM News online:
siam.org/news/

ICIAM 2015

August 10-14, 2015 Beijing, China

8th INTERNATIONAL CONGRESS ON INDUSTRIAL AND APPLIED MATHEMATICS

The International Congress on Industrial and Applied Mathematics (ICIAM) is the premier international congress in the field of applied mathematics held every four years under the auspices of the International Council for Industrial and Applied Mathematics. From August 10 to 14, 2015, mathematicians from around the world will gather in Beijing, China for the 8th ICIAM to be held at China National Convention Center inside the Beijing Olympic Green.

Organized by
International Council for Industrial and Applied Mathematics (ICIAM)
China Society for Industrial and Applied Mathematics (CSIAM)
Chinese Mathematical Society (CMS)
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Award lectures of ICIAM, SIAM, AWM
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Important Dates

Mini-symposium
2014-03-30 Mini-symposium online submission opens
2014-09-30 Deadline for submitting mini-symposiums

Contributed paper
2014-07-30 Contributed papers online submission opens
2014-10-30 Deadline for submitting contributed papers

Poster
2014-07-30 Poster online submission opens
2014-11-30 Deadline for submitting posters

Satellite conference
2014-01-01 Satellite conference online submission opens
2014-10-30 Deadline for submitting satellite conferences

ICIAM 2015

8th International Congress on Industrial and Applied Mathematics
ICIAM 2015
August 10-14 , 2015
Beijing , China

WWW.ICIAM2015.CN

Meeting the Challenges of Improved Post-Secondary Education in the Mathematical Sciences

In 2012, the President's Council of Advisors on Science and Technology (PCAST), which advises President Barack Obama, issued a report, Engage to Excel*, that raised many concerns about the teaching of the mathematical sciences in the first two years in our colleges and universities. On behalf of the Joint Policy Board for Mathematics—the umbrella organization of the American Mathematical Society, the American Statistical Association, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics—David Bressoud, Eric Friedlander, and David Levermore, with support from the leadership of all four societies, crafted a response. After participation in many discussions within our professional societies, JPBM, and PCAST, we were guided in formulating the following statement. We call upon the entire mathematical sciences community to achieve much needed change in undergraduate education in the mathematical sciences.*

By David M. Bressoud, Eric M. Friedlander, and C. David Levermore

The mathematical sciences play a foundational and crosscutting role in enabling substantial advances across a broad array of fields: medicine, engineering, technology, biology, chemistry, computer science, social sciences, and others. The delivery of excellent post-secondary mathematics education is essential to the present and future wellbeing of our nation and its citizens.

Whereas research in the mathematical sciences is flourishing, with dramatic advances regularly occurring in core mathematics and in applications, mathematics education needs **immediate attention**. We focus on the needs of students in two-year colleges, four-year colleges, and universities. Mathematics education is a critical component of all undergraduate Science, Technology, Engineering, or Mathematics (STEM) degrees and plays a key role in educating the next generation of leaders in our increasingly technological, data-driven, and scientific society.

The President's Council of Advisors on Science and Technology presented many challenges to the mathematics community as it addressed the needs of post-secondary mathematics education in its 2012 report *Engage to Excel*.[1] Answering these challenges will require collaboration among all of the scientific disciplines that are working to prepare the STEM workforce of the future. We acknowledge many of the shortcomings highlighted by the report. The *wake-up call* delivered by this PCAST report has underscored the immediacy of the need for intensive, broad-scale efforts to address these problems. Whereas efforts by a great many in the mathematical sciences community predate PCAST's report, now more than ever we need a broad community-wide effort to implement innovation in all of our college and university educational programs.

What are these challenges, why is this an especially critical time for the mathematical sciences community, what efforts are under way to meet them, and what do we ask of the mathematical community?

Among the challenges we face is the need to find new ways to educate students

See **Post-Secondary Education** *on page 7*

[1]www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf.

Institute for Computational and Experimental Research in Mathematics

CALL FOR PROPOSALS

The Institute for Computational and Experimental Research in Mathematics (ICERM) invites program proposals that support its mission to foster and broaden the relationship between mathematics and computation.

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ICERM hosts two semester programs per year. Each has 5-10 organizers and typically incorporates 3-4 weeklong associated workshops.

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ICERM hosts several topical workshops each year. They are scheduled outside of the dates of the semester programs (usually in December, January or May through August). Workshops typically last 5 days and focus on timely and exciting themes which align with ICERM's mission.

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ICERM hosts a weeklong summer program for 20 early career researchers. The program is organized around two or more exciting mission-related research topics and challenges.

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Ways to participate:
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Apply for a:
- semester program or workshop
- postdoctoral fellowship

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About ICERM: The Institute for Computational and Experimental Research in Mathematics is a National Science Foundation Mathematics Institute at Brown University in Providence, Rhode Island. Its mission is to broaden the relationship between mathematics and computation.

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BROWN

2014 CBMS-NSF Conference:

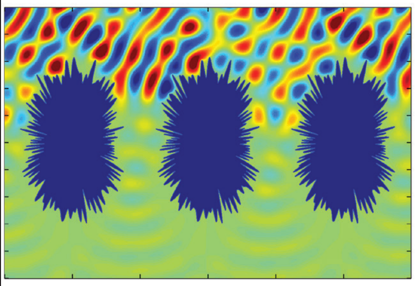
Fast Direct Solvers for Elliptic PDEs

June 23 – 27, 2014, at Dartmouth College, Hanover, NH

DARTMOUTH 1769

Lecturer:
Per-Gunnar Martinsson (U. Colorado Boulder)

Speakers:
Alex Barnett (Dartmouth)
Adrianna Gillman (Dartmouth)
Leslie Greengard (Simons Foundation and NYU)
Vladimir Rokhlin (Yale)



Conference themes:
- Direct solvers with $O(N)$ complexity.
- Randomized methods for linear algebra.
- High-accuracy discretizations.
- Communication minimizing algorithms.
- Integral equation formulations.

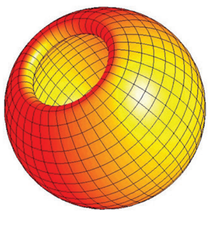
Application deadline: April 15th

Conference format: 10 lectures surveying the conference themes will be delivered by Per-Gunnar Martinsson of the University of Colorado. Participants will be given an opportunity to interact hands-on with the algorithms described through coding workshops using tutorial style software. Supplementary lectures on current research will be delivered by scientists in the field.

Workshop: The conference will be followed by a weekend workshop on the topic of fast analysis based methods for elliptic PDEs on June 28-29.

Support: Lodging, meals, and some travel expenses will be provided for up to 30 participants. Graduate students, junior researchers, and members of underrepresented groups are particularly encouraged to apply.

Website: http://www.math.dartmouth.edu/~fastdirect



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Students (and others) in search of information about careers in the mathematical sciences can click on "Careers and Jobs" at the SIAM website (www.siam.org) or proceed directly to

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Geisinger Health System

Position Available: Applied Mathematics Data Scientist

Applications are invited for the position of applied mathematics data scientist at Geisinger Health System in Danville, Pennsylvania. Requirements are a PhD in applied mathematics or a related field. The successful candidate will work under the direction of Dr. Nicholas Marko, a clinical neurosurgeon and data scientist, who directs a research group focused on data-science applications in clinical medicine and health-care delivery. This is an excellent and rare opportunity for investigators and early-career PhDs interested in applied research to use state-of-the-art methods in mathematics, computational intelligence, and data modeling to address real-world problems in clinical medicine (e.g., individualized risk prediction, clinical decision support, and personalization of medical care) and in optimization of health-care delivery.

Applicants can apply at: http://tinyurl.com/ppyr47j or contact Grace Onkst, IT recruiter, at gbonkst@geisinger.edu.

California Institute of Technology

Department of Computing and Mathematical Sciences

The Department of Computing and Mathematical Sciences at the California Institute of Technology invites applications for the position of lecturer in applied and computational mathematics. This is a full-time, non-tenure-track position, with primary responsibilities in teaching. The initial term of appointment can be up to three years. An advanced degree in applied mathematics or a related field and a track record of dedication to and excellence in teaching are required.

The successful candidate will teach courses in applied and computational mathematics and is expected to work closely with the CMS faculty on instructional matters. These courses will cover various methods of applied mathematics, such as but not limited to: complex analysis; ordinary and partial differential equations; real and functional analysis; linear algebra and applied operator theory; optimization; stochastic processes and modeling; applied statistics and data analysis; and numerical methods. The successful candidate may also assist in other aspects of the undergraduate program, including curriculum development and involvement in research projects with undergraduate students. He or she will have opportunities to be involved in ongoing research projects in the department; however, such involvement is not required. More importantly, the successful candidate is expected to be dedicated to and passionate about teaching at the upper-level undergraduate and graduate levels.

Applicants can view the instructions for application and apply online at: https://applications.caltech.edu/job/acmlect.

The California Institute of Technology is an affirmative action/equal opportunity employer. Women, minorities, veterans, and disabled persons are encouraged to apply.

Milwaukee School of Engineering

Mathematics Department

The Milwaukee School of Engineering invites applications for two full-time faculty positions in mathematics, starting in the fall of 2014. The department has just launched programs in actuarial science and operations research and is looking for candidates who have a strong background in one or both of these areas. Successful candidates should also be prepared to teach the standard mathematics courses in the first two years of the undergraduate curriculum. Applicants should possess an appropriate doctoral degree and related experience. Salary and rank will be commensurate with experience.

An institution that offers degrees in engineering, engineering technology, business, nursing, mathematics, and technical communication, MSOE is located on the beautiful east side of downtown Milwaukee, just blocks from Lake Michigan and within easy walking distance of the city's highly acclaimed fine arts and entertainment venues. With approximately 2400 full-time students, the campus maintains an intimate, small-town atmosphere.

Applicants should submit a file that includes: (1) a detailed resume; (2) a letter of interest; (3) evidence of successful teaching; and (4) three professional references. Applicants can visit the school's website at http://www.msoe.edu/hr/ for additional information about requirements and the application process; applicants can also apply by completing the form at http://www.milwaukeejobs.com/apply.asp?jid=5642529. The review of candidates will begin immediately and will continue until the positions are filled.

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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

Post-Secondary Education

continued from page 6

who are poorly prepared for post-secondary mathematics. This includes new teaching methodologies and technology, as well as changes in curricula at all levels. We must do more to adapt the mathematics we teach to the career needs of the students we teach. We must pursue cooperation ever more energetically with mathematics-intensive disciplines. For emphasis, we rephrase these challenges as explicit questions. How should mathematics educators improve developmental education in order to enable students to aspire to STEM careers? What methods of placement and advising best help students navigate through a STEM curriculum? How should mathematical scientists in colleges and universities augment their cooperative efforts with "partner disciplines" to best serve the needs of students needing basic university mathematics? How should mathematical sciences departments reshape their curricula to suit the needs of a well-educated workforce in the 21st century? How can technology be best used to serve educational needs?

We are at a critical juncture. Members of the academic mathematical sciences community should recognize that *change is coming rapidly* in their world. There is great pressure to reduce costs in order to relieve state budgets and student debt; this pressure will translate to "efficiencies" and new measures of effective teaching. Numerous agencies are identifying mathematics courses as a stumbling block for success in undergraduate programs leading to a STEM degree. Increasing numbers of students coming to colleges and universities seek STEM careers that require post-secondary mathematics, yet many of these are poorly prepared. There is much demand to make mathematics education directly relevant to STEM careers.

The mathematical sciences themselves are changing as the needs of big data and the challenges of modeling complex systems reveal the limits of traditional curricula. The National Research Council report *The Mathematical Sciences in 2025*[2] eloquently describes the opportunities and challenges of this shifting landscape. This well-received report can serve as one foundation for the change that is needed, providing a springboard for initiatives in mathematics education that more closely intertwine the learning of mathematics with the appreciation of its applications.

We mention a few of the national efforts under way to address these challenges. There are many, many efforts at individual institutions that we hope will be shaped into more coherent efforts as well. For two-year colleges, the New Mathways Project,[3] Statway,[4] and Quantway[5] programs are assisting under-prepared students. Project NExT[6] is now past its 20th year of introducing new faculty to effective strategies for teaching. MAA's national study of calculus has identified characteristics of successful programs.[7] Modeling Across the Curriculum[8] is working to embed computational learning and exposure to modeling and simulation in early STEM courses. CAUSE,[9] which grew out of an ASA initiative, provides resources, professional development, outreach, and research for the needs of modern undergraduate statistics education. At research universities, there is a new program of the Association of American Universities to implement more "evidence based" teaching practices and improve the quality of teaching and learning.[10] The INGenIoUS project[11] is a joint effort of AMS, ASA, MAA, and SIAM to develop strategies for future investments in training at the graduate and undergraduate levels. Carnegie Corporation of New York and the Sloan Foundation are supporting a broad-ranging initiative entitled Transforming Post Secondary Education in Mathematics.[12] These efforts are steps in the right direction, but much remains to be done.

We call upon all mathematical scientists in academia to renew their focus on post-secondary mathematics education. We challenge department chairs to incentivize innovation for the sake of their students and the health of our discipline. We encourage mathematics faculty to reach out to colleagues in mathematics-intensive disciplines in order to heighten the relevance of their courses to the careers of their students. And we urge departments as a whole to investigate with an open mind new teaching methodologies and technologies, keeping in mind the need to retain and motivate students.

[2]www.nap.edu/catalog.php?record_id=15269.

[3]www.utdanacenter.org/higher-education/new-mathways-project.

[4]www.carnegiefoundation.org/statway.

[5]www.carnegiefoundation.org/quantway.

[6]archives.math.utk.edu/projnext/.

[7]www.maa.org/cspcc.

[8]connect.siam.org/siam-nsf-workshop-on-modeling-across-the-curriculum.

[9]Consortium for the Advancement of Undergraduate Statistics Education, www.causeweb.org.

[10]AAU Undergraduate STEM Education Initiative, www.aau.edu/policy/article.aspx?id=12588.

[11]Investing in the Next Generation through Innovative and Outstanding Strategies, www.ingeniousmathstat.org.

[12]tpsemath.org.

Announcements

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GSMMC 2014: Graduate Student Mathematical Modeling Camp

June 17–20, 2014

Rensselaer Polytechnic Institute

The Department of Mathematical Sciences at RPI is pleased to announce the 11th annual GSMM Camp. The camp is a four-day informal workshop in which graduate students work in teams on problems brought by invited faculty mentors. The problems, inspired by real problems that arise in industrial applications, span a wide range of mathematics and are designed to promote problem-solving skills while the team approach is designed to promote scientific communication.

Graduate students at all levels are invited to participate. General information and an online application form can be found at http://www.rpi.edu/dept/math/GSMMCamp/. Financial support for travel and local accommodations is available. The application deadline is April 25, 2014.

Graduate students attending the GSMM Camp are also invited to participate in the Mathematical Problems in Industry (MPI) Workshop, to be held at the New Jersey Institute of Technology, June 23–27, 2014. For further information about MPI 2014, students should visit http://web.njit.edu/~rmoore/MPI2014/.

Project NExT Fellowships for 2014–2015

Applications are invited for the 2014–2015 class of Project NExT Fellows. Fellowships are intended for faculty members who will be in their first or second year of full-time teaching (post-PhD) at the college or university level in the 2014–2015 academic year; about 80 fellows are to be chosen from across the U.S.

Applications for this fellowship year (the project's 21st) are due April 11, 2014. More information can be found on the Project NExT website at http://archives.math.utk.edu/projnext/; applicants can also contact Aparna Higgins, the project's director, at Aparna.Higgins@udayton.edu.

Evelyn Thomas

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Computer Science at Rutgers) and MCMSC (the Mathematical, Computational and Modeling Sciences Center at Arizona State). Under a DIMACS initiative to forge relations between American and African students, Thomas was selected to visit mathematical conferences in both Johannesburg and Cape Town. (She also went to one in Israel.) In addition, she participated in an REU at Arizona State run by Carlos Castillo-Chavez, which specifically targeted Hispanics and Latinos. "It gave me a different perspective: conducting research at a predominantly white institution under a program aimed at other minorities," she says.

The HIV modeling talks at the Cape Town conference were particularly compelling to Thomas. For the first time, she saw the urgency of the problem: Some of the African researchers spoke movingly of relatives they'd personally lost to AIDS. "They weren't just creating HIV models for the sake of doing cool math, but to really solve problems that impacted their families and communities." Back at Howard, Thomas began studying a paper* written by

UMBC postdoc Evelyn Thomas hopes "to communicate to everyday people that if there are problems they see in their communities: HIV/AIDS, gun violence, racism, sexism, homophobia—anything—a solution does lie within mathematics."

a group of African mathematicians describing the effect of bisexuals on the dynamics of HIV/AIDS spread. The authors' SI (susceptible–infectious) model contained a crucial simplification: Bisexuals appeared in it only as infected individuals. At the point of infection, a certain proportion of both heterosexual and homosexual men were assumed to "switch" into this infected bisexual category.

Thomas believed that this dynamic was at odds with human sexuality. In her thesis, she therefore modeled the interactions between four distinct groups: heterosexual, homosexual, and bisexual males, and heterosexual females (see diagram on page 1). New analytic techniques were needed to investigate a system with so many parameters. One of Thomas's novel ideas was to use reduced models in which the value of the epidemic equilibrium of one subpopulation could be entered as a forcing term acting on other subpopulations. She was able to characterize precise conditions under which HIV would permeate the full system. To this end, she mathematically established something that might have been only suspected so far: The bridge between heterosexual females and bisexual males (in particular the down-low population) was the key determining factor.

Issues related to homosexuality can evoke strong reactions, but Thomas has encountered generally positive responses to her work. "People are surprised that math could be applied to such a sociological and topical problem," she says. "If I know I am speaking with someone who is homophobic, I try to avoid any confrontation and find common ground." A related question is how she feels working on mathematics that might affect people's lives. Given the sad state of LGBT rights in many countries, what if her results were used as a justification to persecute gay or bisexual people?

"If anything, the takeaway should be the consequences of oppressing people for being simply who they are innately. For countries like Uganda, Russia, or Nigeria, my study shows how their anti-gay policies can have a negative trickle-down effect on their heterosexual populations."

Since arriving at UMBC for her postdoc, Thomas has started a new epidemiological project based on the rise of cholera in Haiti after the devastating earthquake of 2010. She is also exploring the addition of age structure to her down-low model, which would make it a more computationally intensive PDE investigation. Her goal is to continue working on projects with social engagement. "I hope to communicate to everyday people that if there are problems they see in their communities: HIV/AIDS, gun violence, racism, sexism, homophobia—anything—a solution does lie within mathematics."

Manil Suri is a professor of mathematics at UMBC. His latest novel is The City of Devi. *His opinion piece "How to Fall in Love With Math" achieved "most emailed" status when it was published last year in* The New York Times.

*Z. Mukandavire et al., *Assessing the effects of homosexuals and bisexuals on the intrinsic dynamics of HIV/AIDS in heterosexual settings*, Mathematical and Computer Modelling, 49 (2009), 1869–1882.

Reid Prize

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of which $R(t)$ is assumed to be positive-definite for each $t \in [0,T]$, while M and $Q(t)$ need only be positive-semi-definite. Thus, J is invariably non-negative, vanishing only in contrived circumstances. Following Kalman, Duncan confined his remarks to the special case $z(t) \equiv 0$; $C(t) \equiv I$, so that the controller's conflicting aims are to make both $x(t)$ and $u(t)$ small.

To obtain the complete solution of such an optimal control problem, it suffices to solve the first-order (typically nonlinear) Hamilton–Jacobi partial differential equation

$$V_t + \min_{(u \in R^m)} H(t,x,u,\nabla V(t,x)) = 0 \quad (3)$$

satisfied by the value function $V(t,x) = \inf_{u(\cdot)\in\mathfrak{U}} J$. Ordinarily, the class $\mathfrak{U}$ of admissible control histories $u(t); 0 \le t \le T$ must include an abundance of discontinuous functions to transform the foregoing inf into an attained minimum. Here

$$H(t,x,u,p) = L(t,x,u) + < p, f(t,x,u) >, \quad (4)$$

and the HJE is to be solved subject to the boundary condition

$$V(t,x) = K(t,x) \quad (5)$$

for all $(t,x) \in \mathfrak{M}$. These linear-quadratic tracking problems are by far the largest class of optimal control problems for which the foregoing program can be carried to completion. For less tractable problems, it is usually necessary either to "synthesize" the complete solution from partial solutions obtained by satisfying, for example, Euler equations or the maximum principle, or to approximate.

As Kalman demonstrated, the solution of the HJE for the linear-quadratic tracking problem is $V(t,x) = ½ < x, P(t)x >$, where $P(t)$ is the unique positive-definite symmetric solution of the matrix Riccati initial value problem (IVP)

$$\dot{P} = -PA - A^T P + PBR^{-1}B^T P - Q$$
$$P(T) = M. \quad (6)$$

Accordingly, the optimal feedback control is $u^*(t) = -R^{-1}(t)B(t)P(t)x(t)$, and, once calculated, the solution $P(t)$; $0 \le t \le T$ can be used repeatedly to compute any number of optimal pairs $(x^*(t),u^*(t))$; $0 \le t \le T$ associated with initial states $x(0) = x_0$ of interest. Should the matrices A, B, C, Q, R, and M be composed entirely of constants, one can set $T = \infty$ and employ $u^*(t) = -R^{-1}BPx(t)$, where P is the unique positive-definite symmetric solution of the algebraic Riccati equation obtained from the above by setting $\dot{P} = 0$. In that case it turns out that—under suitable conditions—the eigenvalues of the matrix $\hat{A} = A - BR^{-1}BP$ all have negative real parts, so that the "controlled system" $\dot{x} = \hat{A}x$ is asymptotically stable.

Linear-quadratic models are better known for their tractability than for their ability to mimic real-world situations. Nevertheless, they are frequently employed in practice and have been generalized in countless directions. Among the most interesting generalizations are those in which the (now random) state variable $X(t)$ evolves according to the stochastic relation

$$dX(t) = (AX(t) + BU(t))\,dt + dW(t), \quad (7)$$

while the "objective functional" J is replaced by its expected value $\hat{J} = E(J)$. It is a remarkable fact—for which Duncan provided a partial explanation—that as long as W remains Markovian, the previous feedback control $u^*(t) = -R^{-1}(t)B(t)P(t)x(t)$ is again optimal! If, however, the noise process $W(t)$ is less well-behaved, the optimal control becomes

$$u^*(t) = -R^{-1}(t)B(t)P(t)x(t) + \Sigma(t), \quad (8)$$

where $\Sigma(t)$ is a certain linear functional (stochastic integral) of $W(t)$ representing the minimum least-squares expected error prediction of the response of the system in question to future noise. Duncan has developed explicit constructions for $\Sigma(t)$ under various assumptions on the noise process $W(t)$. If the noise is standard (Gaussian) Brownian motion, for instance, the value function $V(t,x)$ is again well defined and satisfies the (now second-order) Hamilton–Jacobi–Bellman PDE

$$V_t + tr(\nabla^2 V(t,x)) +$$
$$\min_{u \in R^m} H(t,x,u,\nabla V(t,x)) = 0, \quad (9)$$

along with the boundary condition $V(t,x) = K(t,x)$ for all $(t,x) \in \mathfrak{M}$. Solving for the unknown value function $V(\cdot,\cdot)$ is then feasible. But if W is an arbitrary square-integrable process with continuous sample paths and a "filtration" $\mathcal{F}(t); 0 \le t \le T$, other techniques are called for.

A few words on filtration: The study of stochastic differential equations—and thus of stochastic optimal control—ordinarily takes place in a measurable space $(\Omega, \mathcal{F})$ in which $\mathcal{F}$ denotes a σ-algebra of measurable subsets of Ω, to be thought of as "events" that might or might not occur. A filtration $\mathcal{F}(t); 0 \le t \le T$ on $\mathcal{F}$ is then a collection of σ-subalgebras of $\mathcal{F}$ indexed such that $\mathcal{F}(s) \subset \mathcal{F}(t)$ whenever $s < t$. $\mathcal{F}(t)$ is thus a collection of events—growing with the passage of time—that occur at or before time t. The requirement that $\mathfrak{U}$ consist of control histories $u(t)$; $0 \le t \le T$ that are $\mathcal{F}(t)$-measurable for each $0 \le t \le T$ then ensures that the elements of $\mathfrak{U}$ are "non-anticipative" in the sense that they do not employ as yet unavailable information.

Rather than solve more HJB equations, Duncan resorts to a variant of the age-old "complete the square" argument to establish the optimality of the feedback control $u^*(t)$ mentioned earlier, provided that

$$\Sigma(t) = \int_t^T \Phi_P(s,t)P(s)dW(s), \quad (10)$$

Φ_P being the solution to the (linear) matrix IVP

$$\dot{\Phi}_P(s,t) = -(A^T - P(t)BR^{-1}B^T)\,\Phi_P(s,t)$$
$$\Phi_P(s,s) = I. \quad (11)$$

Such solutions are often called "fundamental" solutions of (11).

Perhaps the most interesting special case of the foregoing result is one that Duncan has explored since 2006 in a series of papers with B. Pasik-Duncan, in which $W(t)$ is a "standard *fractional* Brownian motion." A real-valued process ($\mathbb{B}(t)$; $t \ge 0$) is a standard fractional Brownian motion with Hurst parameter $H \in (0,1)$ if it is a Gaussian process with continuous sample paths satisfying $E[\mathbb{B}(t)] = 0$ and $E[\mathbb{B}(s)\mathbb{B}(t)] = ½\,(t^{2H} + s^{2H} - |t-s|^{2H})$ for all $s, t > 0$. The formal derivative $d\mathbb{B}/dt$ is then called "fractional" Gaussian noise. Fractional Brownian motion differs from standard Brownian motion in that, for $r < s < t$, successive increments $\mathbb{B}(s) - \mathbb{B}(r)$ and $\mathbb{B}(t) - \mathbb{B}(s)$ are no longer independent. Increments are positively correlated with Hurst coefficients $H > ½$ and negatively correlated with $H < ½$. Duncan pointed out that time series with correlated increments occur in the empirical study of turbulence, hydrology, earthquakes, telecommunications, and economic data, to name but a few, and displayed a formula analogous to the above for $\Sigma(t)$ involving a fractional integral if $H > ½$ and a fractional derivative if $H < ½$. Stock market crashes seem to occur when the successive increments in key financial time series cease to be independent and become positively correlated.

Duncan also exhibited a few extensions of linear-quadratic regulator theory to infinite-dimensional state spaces, to cases in which the objective functional is $\hat{J} = \exp\left(\int_0^T L(t,x,u)dt\right)$, and to two-player, zero-sum linear-quadratic stochastic differential games. (He did not mention many-player differential game theory, either stochastic or deterministic, as developed during the 1960s and 1970s.) Finally, he considered the control of Brownian motions in rank-one symmetric spaces, such as the (compact) two-sphere and the (noncompact) real hyperbolic space of dimension 2. In the latter, the optimal feedback control involves the hyperbolic tangent of the state variable. In each case, he was able to give specific formulas for the main objects of interest, and argued by example that, though much is known, much remains to be learned about the control of even quite simple stochastic processes.

James Case writes from Baltimore, Maryland.

NSF's CyberSEES and Sustainability Research Networks Programs

NSF has released an updated solicitation for the Cyber-Innovation for Sustainability Science and Engineering program. The deadline for submission of proposals is April 8, 2014; the solicitation can be found at http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504829.

An updated solicitation for the Sustainability Research Networks competition is also available (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503645). Urban sustainability is the focus for 2014. Proposals are due by April 29, 2014.