Newsjournal of the Society for Industrial and Applied Mathematics

siam news

Volume 48/ Number 1
January/February 2015

Obama Honors Three Math Scientists in White House Ceremony

Photos courtesy of the National Science & Technology Medals Foundation

On November 20, in awarding the 2014 National Medal of Science to ten distinguished scientists and engineers, President Barack Obama recognized the achievements of three mathematical scientists.

Alexandre Chorin (left-hand photo), a University Professor at the University of California, Berkeley, was credited with "the development of revolutionary methods for realistic fluid flow simulation, now ubiquitous in the modeling and design of engines, aircraft wings, and heart valves," as well as in the analysis of natural flows.

Citing Thomas Kailath (right-hand photo), Hitachi America Professor of Engineering Emeritus at Stanford University, "for transformative contributions to the fields of information and systems science," Obama also recognized his "distinctive and sustained mentoring of young scholars," as well as his "translation of scientific ideas into entrepreneurial ventures that have had a significant impact on industry."

David Blackwell (1919–2010), who had been a professor emeritus at UC Berkeley, was honored with a posthumous medal "for fundamental contributions to probability theory, mathematical statistics, information theory, mathematical logic, and Blackwell games, which have had a lasting impact on critical endeavors such as drug testing, computer communications, and manufacturing."

More on the recipients can be found on page 3 in this issue and in an upcoming issue of SIAM News.

Traditions and Transitions for SIAM in 2015

TALK OF THE SOCIETY

By James Crowley

New years are always times of transition. This year, Pam Cook becomes president of SIAM on January 1, and Irene Fonseca transitions to the position of past president, which she'll occupy for one year. By the end of 2015, we will have elected the next president of SIAM, and that person will become president-elect, starting the cycle once again.

Irene Fonseca has been an energetic president, representing SIAM around the globe and encouraging the development of SIAM student chapters at many universities. She has also taken a keen interest in serving our industrial members, and many of her

See **SIAM 2015** *on page 2*

Making the transition from high-profile publishing positions within SIAM, Pam Cook (second from left) begins a two-year term as SIAM president on January 1. She succeeds Irene Fonseca (second from right), some of whose world travels on behalf of SIAM are documented in this and previous issues of SIAM News. *Cook and Fonseca are shown here with predecessors, from left, Gil Strang (1999–2000), Doug Arnold (2009–10), and Nick Trefethen (2011–12). Photo by David Sytsma, Corporate Chicago Photography.*

Modeling Lipoprotein Metabolism

Is "Good Cholesterol" Always "Good"?

In an invited presentation at the 2014 SIAM Conference on the Life Sciences, Norman Mazer began by rewording the question in the subtitle: Is a larger amount of cholesterol in high-density lipoprotein (HDL) particles invariably associated with a smaller risk of cardiovascular disease? He cited epidemiological studies showing that individuals with higher endogenous plasma levels of HDL cholesterol (HDL-C) have statistically lower risk of cardiovascular disease [2]. By contrast, he pointed to a number of recent clinical studies in which cholesteryl-ester transfer protein (CETP) inhibitors (and other compounds) were administered to raise HDL-C levels; those studies found the risk of cardiovascular disease to be either unchanged or increased in comparison to placebo treatments [1,6].

To understand the apparent paradox of HDL-C–raising therapy, Mazer and colleagues James Lu, Katrin Hübner, M. Nazeem Nanjee, and Eliot Brinton developed the LMK model of lipoprotein metabolism and kinetics [3]. Their model-based answer to the question is that raising HDL-C levels is "good" when it is associated with an increase in the rate of reverse cholesterol transport (RCT), the rate at which cholesterol is transferred from peripheral tissues to HDL particles in the bloodstream. The LMK model further showed that not all HDL-C–raising therapies raise the RCT rate.

The schematic of the LMK model (Figure 1) illustrates the steps in the RCT pathway. In the first step the ABCA1 transporter loads cellular cholesterol and phospholipid molecules onto lipid-poor ApoA-I protein dimers to create nascent discs. The discs are then converted to nascent spheres by the LCAT enzyme, which esterifies cholesterol molecules to create a lipid core within the particle. The nascent spheres typically fuse with the mature α-HDL particles, which undergo a number of metabolic processes that either remove cholesteryl-ester (CE) molecules from the lipid core (SRB1 pathway), transfer CE to VLDL and LDL particles (CETP pathway), or remove entire HDL particles from the plasma (holo-particle uptake pathway). As a consequence of resulting changes in the surface-to-volume ratio of the HDL particles, excess ApoA-I in the surface is shed from the particles to regenerate lipid-poor ApoA-I (the HDL remodeling flux).

The LMK model represents these various processes in eight ordinary differential equations with 16 parameters (Figure 2). Equations (1)–(3) describe the kinetic processes for ApoA-I in its lipid-poor and α-HDL states; (4) and (5) describe the fusion of the nascent spheres with mature α-HDL particles and the size-dependent holo-particle uptake mechanism; (6)–(8) describe the CE fluxes in the system. The key challenge in developing the LMK model, Mazer said, is representing the remodeling flux of ApoA-I by (3), which is based on the geometrical constraints imposed by the updated Shen model of HDL structure [3,5]. The group derived prior estimates of 14 of the model parameters from various literature sources. They obtained posterior estimates of all 16 parameters by calibrating the model to lipoprotein data from healthy subjects and from patients with heterozygous and homozygous CETP deficiency, using the maximum a posteriori method [3], thereby producing the parameter values for a nominal healthy subject.

To validate the model the group showed that it correctly predicted the effects of ABCA1 and ApoA-I gene mutations on HDL-C and ApoA-I levels and reproduced the bi-phasic kinetics observed in ApoA-I tracer kinetic experiments [3]. From the implementation perspective, Mazer noted that the ApoA-I tracer experiment can be simulated by adding an imaginary amount

See **HDL Modeling** *on page 4*

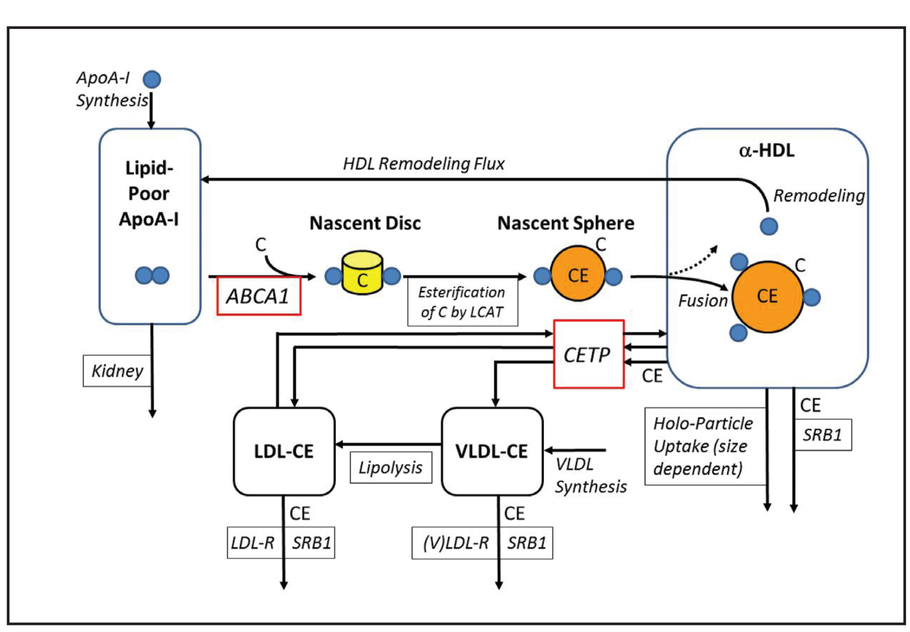
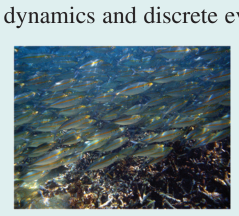


Figure 1. *Schematic diagram of LMK model by J. Lu et al. [3]. See text for details of HDL formation and HDL-C–raising mechanisms (CETP inhibition and ABCA1 up-regulation).*

Nonprofit Org
U.S. Postage
PAID
Permit No 360
Bellmawr, NJ

SOCIETY for INDUSTRIAL and APPLIED MATHEMATICS
3600 Market Street, 6th Floor
Philadelphia, PA 19104-2688 USA

siam news
Volume 48/ Number 1/ January/February 2015



SIAM 2015

continued from page 1

initiatives in that area will continue to be developed over the coming years.

This year SIAM welcomes just one new member to the Board of Trustees: Russ Calflisch, whose three-year term begins January 1. In the fall elections the SIAM membership also returned Mary Ann Horn and Tammy Kolda to the board for an additional term. We take this opportunity to thank Kathryn Brenan, who completes her final term on the board at the end of 2014, having provided thoughtful service on several board committees.

As to the Council, Rachel Kuske returns for a second term, and Raymond Chan, Geoff McFadden, and Padma Raghavan were elected to open seats. We have three retiring Council members to thank: The final terms of Bruce Hendrickson, Michele Benzi, and Tom Hou all draw to a close at the end of 2014.

In Philadelphia for the December meeting of the SIAM Board of Trustees were departing member Kathryn Brenan and Tim Kelley, who was elected at the meeting to a third one-year term as board chair. Photo by Lois Sellers.

SIAM is grateful to all who agreed to run for office in our 2014 elections, and to those who agreed to serve. A special thanks to those who completed multiple terms in office; as we hope the remarks in the remainder of this article show, SIAM's officers and committee members give generously of their time and expertise, and their efforts are greatly appreciated.

■■■

Members of the Board of Trustees and at-large (elected) members of the Council make up the governing bodies of SIAM; their responsibility is to ensure that SIAM remains healthy and responsive to the membership. It is the vice presidents who work directly, on a daily basis, with the portfolios of programs they oversee. As VP for education, Peter Turner has led an active Education Committee and initiated several new programs, notably the Modeling Across the Curriculum workshops as well as participation with our sister societies in several key activities in mathematics education. Turner completes his final term as VP for education at the end of 2014, with Rachel Levy succeeding him in that position.

At its December meeting, the Board of Trustees dealt mostly with routine (but consequential!) matters, such as appointments to board committees, including the Financial Management Committee, and approval of a SIAM budget for 2015. The group elected Tim Kelley to another term as board chair.

As part of its routine business, the board reviewed reports from officers—in areas including publications, programs, and members—and from the executive director. The board approved the creation of the SIAM Activity Group on the Mathematics of Planet Earth, based on a petition received from a large group of SIAM members and submitted by Hans Kaper, who will serve as the group's founding chair.

David Levermore. Photo by David Sytsma.

Discussion topics ranged from how SIAM should respond to the Department of Energy's recently released policy on providing public access to journals to how we might implement suggestions from the Joint Committee on Women in the Mathematical Sciences about ensuring a welcoming environment at SIAM conferences.

One additional area the board takes up is science policy. Like all the SIAM VPs, the VP for science policy (currently David Levermore) reports to the board on activities he oversees.

■■■

As VP for science policy, Levermore runs the biannual meetings of the Committee on Science Policy. The group met most recently in Washington, DC, November 24 and 25, following the tradition of a fall meeting devoted to visits from representatives of agencies with programs of interest to SIAM.

Among the visitors this year were Michael Vogelius, director of the Division of Mathematical Sciences at the National Science Foundation, and Steve Binkley, associate director of ASCR (Advanced Scientific Computing Research) in DOE's Office of Science. NSF and DOE, which together provide a large portion of funding for research in applied math and computational science, play a major role in charting the direction of science.

Vogelius highlighted a few NSF programs of interest, among them the new Enriched Doctoral Training Program (EDT). Recognizing that many students in the mathematical sciences eventually take jobs outside academia, this program provides grants for pilot projects to train students for a broader range of activities. It is expected that EDT will continue next year.

Vogelius also discussed the MSII (Mathematical Sciences Innovation Incubator), which was created to support mathematical scientists who establish collaborations with researchers in other NSF-supported disciplines, such as data science. This program is in its second year and is expected to continue.

On the theme of cross-disciplinary programs, Vogelius mentioned an initiative in mathematics and materials science, a priority area of the Obama administration, to which our community to date has responded less vigorously than anticipated. See the item on this page for information about related activities planned for the March 2015 SIAM Conference on CSE.

Workshops or minisymposia on such cross-disciplinary topics can be a means of fostering interest and interactions among scientists and mathematicians in other areas as well. A likely priority area in the near future is optics and photonics, clearly an area in which the mathematical and computational sciences have an important role to play.

Discussing ASCR, Binkley focused on its dramatic growth in recent years, mainly because of DOE's exascale program. Much has been said about achieving exascale-level throughput with massive concurrency. As Binkley noted, though, it's not just the hardware—advances in computer science and mathematics research are essential to achieve the program goals.

In a bit of history of ASCR's applied math program, Binkley mentioned that data-intensive computing was recently added to the list of research topics covered, while pointing out that the program has always been rooted in numerical PDEs and solvers, along with linear algebra and optimization. Consistent with the DOE mission, topics like multiscale mathematics and multiphysics, stochastic systems, and uncertainty quantification have become important parts of the program. DOE tries to maintain a strong coupling of mathematics to applications within its mission, including subsurface phenomena, climate modeling, energy efficiency, and the electric power grid.

Also visiting the CSP were representatives from the Office of Naval Research (Wen Masters) and DARPA (Fariba Fahroo, who had recently left the Air Force Office of Scientific Research to join DARPA), as well as the Intelligence Advanced Research Projects Agency (Peter Highnam). And the CSP's continuing interest in data science and the National Institutes of Health came together in the person of Phil Bourne, associate director for data science at NIH (an article based on his presentation appears on page 5).

As mentioned previously in these pages, big data, data science, and data analytics seem to be themes that cross many programs.

NSF and SIAM Plan Symposium on Math in Materials Science for CSE '15

Are you interested in the application of mathematics to challenging problems in materials science but don't know where to start? Or where to apply for funding?

If so, join us at the SIAM Conference on Computational Science and Engineering in Salt Lake City, March 14–18, and reserve Saturday, March 14, for the one-day NSF–SIAM Symposium on Mathematical and Computational Aspects of Materials Science. Ten leading researchers from the materials science and mathematical sciences communities will offer their perspective on areas of research in which mathematicians and materials scientists can find exciting opportunities for significant collaboration. At a panel session during the symposium, the directors of the National Science Foundation's Divisions of Mathematical Sciences (DMS) and Materials Research (DMR) will describe existing mechanisms for funding collaborations.—*Hans Kaper*

siam news

ISSN 1557–9573.

Perpetual Motion and the Theorem of Cosines

What follows is the first installment of a regular column by Mark Levi of the Pennsylvania State University. As proposed a few months ago, the column will consist of "short mathematical/physical morsels which should be of interest to any curious person, including graduate students, and requiring the attention span of a few minutes only . . . and always with pictures." At SIAM News *we liked the idea immediately, based in part on Levi's recent article presenting a newly discovered connection between bicycle tracks and the stationary Schrödinger equation (http://bit.ly/1zk59VF), which was based in turn on his invited talk at SIAM's 2013 conference on dynamical systems (http://bit.ly/12jkd95). We were also favorably impressed by a category labelled "Some Nifty Things."*

MATHEMATICAL CURIOSITIES

By Mark Levi

The impossibility of creating a perpetual motion machine is a sad fact of life for most people (especially those who are still trying to invent such machines). But this fact has a silver lining: Among other things, it implies some mathematical theorems. As a quick example, here is a derivation of the theorem of cosines.

The "machine" is a rigid triangular container in flatland, free to pivot on a vertex P (Figure 1). As a thought experiment, we fill the triangle with compressed gas. The trapped gas tries to rotate each side of the rigid frame around P. The sum of the three torques is zero (the alternative would be a functioning perpetual motion machine)—and this is the theorem of cosines in disguise. Indeed, deciphering the zero-torque statement we have, according to Figure 1:

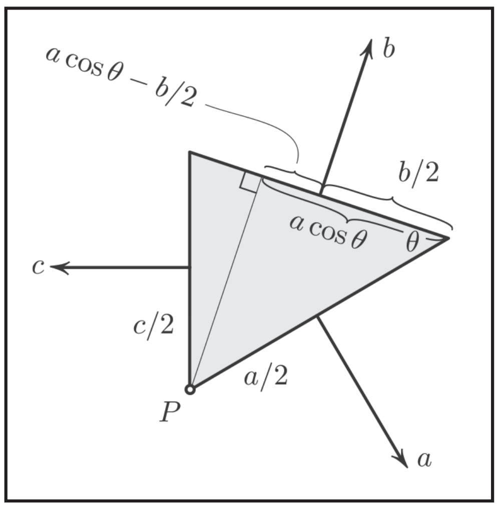


Figure 1. *Proof of the theorem of cosines. Pressure p = 1 (in units of force per unit of length), so that the forces are a, b, and c. Equidistributed force on each side was replaced by the force applied at the midpoint.*

$$c\,c/2 + b(a\cos\theta - b/2) = a\,a/2, \quad (1)$$

or, after a quick rearrangement:

$$c^2 = a^2 + b^2 - 2ab\cos\theta.$$

The same idea leads us to discover that for a right triangle we have

$$b^2 - a^2 = 2cd,$$

in the notation of Figure 2.

An amusing exercise in the same spirit is to translate the equilibrium statement for the half-disk shown at the right into a formula.

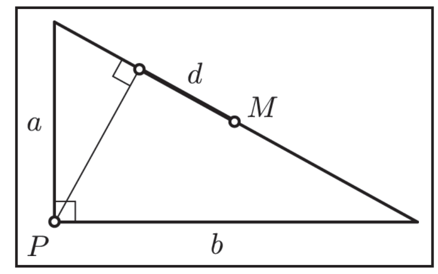
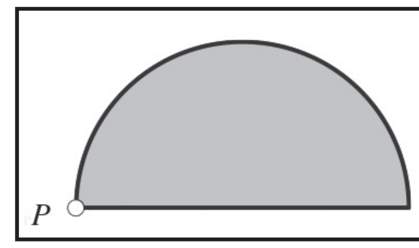


Figure 2. *M is the midpoint of the hypotenuse of length c, and d is the distance from M to the foot of the perpendicular.*



Answer to the exercise:

$$\int_0^{\pi/2} \sin\theta\cos\theta\, d\theta = 1/2$$

Mark Levi (levi@math.psu.edu) is a professor of mathematics at the Pennsylvania State University. The work from which these columns are drawn is funded by NSF grant DMS-1412542.

2014 National Medal of Science

Origins of a Lifelong Interest in Computation

Mention Alexandre Chorin and many readers would immediately reply "computational fluid mechanics." Those readers, and in fact anyone in the SIAM community, should be interested in a 2013 interview* with Chorin by his former PhD student and Berkeley colleague James Sethian. It would be hard to top the interview—for which "Is Turbulence Solvable?" would be an apt title—as a survey of Chorin's life, career, research, and thoughts on the elusive goal of much of his research. The following highlights are offered in the hope that readers, including and perhaps especially students, will visit the Simons Foundation website and access the interview themselves.

*Part of the Simons Foundation's Science Lives collection, in which prominent members of the mathematical sciences community are profiled in essays, taped interviews, or both (in the case of Chorin); www.simons.org.

Born in Poland less than two years before Hitler invaded, Chorin left with his family for Israel (his first two languages were Polish and Hebrew). Happy in Israel, he resented his family's move to Geneva (where he picked up his third language: French), and lost his early motivation to be a good student but with his interest in becoming a mathematician (a geometer) intact. After graduating from École Polytechnique Fédérale de Lausanne with a degree in engineering, he returned to Israel, where he was drafted and ended up as a programmer at the Weizmann Institute. Sethian is good at drawing out details about the conditions of computers and computing at the time (the early 1960s), and about inconsistencies in institutional policies, eliciting more than one "It's complicated" from Chorin.

This was the birth of Chorin's unswerving lifelong interest in computation, which really took off when he enrolled in a doctoral program at the Courant Institute. He soon settled in at Courant as a student of Peter Lax and had the opportunity to put his programming experience to work on the CDC 6400. As to the evolution of his research, Chorin describes some very early work at Weizmann in which he used the Laplace tidal equation to calculate the height of tides—"a gigantic linear algebra problem"—which affects the motion of satellites, which affects satellite communications. Later, his attention settled on thermal convection, of interest at the time to the U.S. weather bureau, which wanted to predict when thermal inversion would occur and fail to sweep away pollutants near the ground.

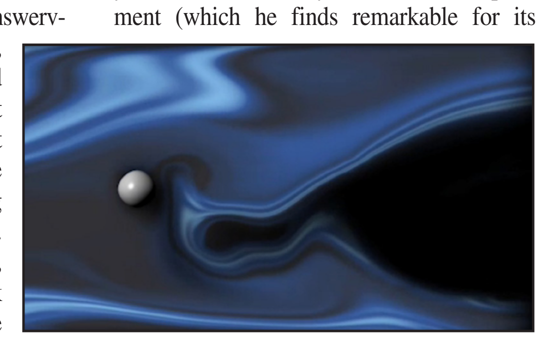
Of his classes at Courant, Chorin recalls thinking that "For the first time in my life, I'm taking a class in something I actually want to know." Of New York, Greenwich Village: "It was a ball." An unexpected but very welcome three-year postdoc at Courant had the effect of delaying the start of his teaching career. As he recalls his earliest teaching experience, a graduate course in numerical analysis at Courant, he covered the entire textbook in three weeks!

Throughout his 42 years at Berkeley, he has modulated the pace of his teaching, in courses ranging from beginning undergraduate mathematics through advanced graduate topics. Commenting on the inevitable proliferation of programs in computational science, he worries that students may not learn enough mathematics to be innovative in their work.

Turbulence is the subject of the longest section of the interview. For Chorin, the challenge is nothing less than to compute turbulence from first principles. The Navier–Stokes equations have been known for a century and a half, he points out; what's needed is a new idea—an idea on the newness scale of chaos. Unwilling to speculate on where that idea will come from, he says only that it is without doubt a mathematics problem.

Recently, he has used some of the tools he learned in fluid mechanics to consider the problem of statistical inference from unreliable models and noisy data, as in weather and economic forecasting—problems that also involve an interaction between probability and differential equations.

We encourage readers to follow Chorin's years in the Berkeley mathematics department (which he finds remarkable for its absence of rigid boundaries between pure and applied mathematics), and the equally supportive Lawrence Berkeley National Lab, which he considers critical to his happiness at Berkeley.



Images captured from the Simons Foundation interview.

Jim Crowley, in the midst of preparations for the December meeting of the SIAM Board of Trustees, happened on a draft of this article. Twenty years ago, he pointed out, Alexandre Chorin was a member of the SIAM board. For Crowley, who became SIAM executive director in the fall of 1994, it was his first board meeting. For Chorin, it was the mid-point of a three-year term on the SIAM board—part of a long association with SIAM that has been marked by several honors, including the Norbert Wiener Prize (2000) and in 2009, election to the first class of SIAM Fellows.

Inspiration for a Devoted Wordsmith

Origins of Mathematical Words: A Comprehensive Dictionary of Latin, Greek, and Arabic Roots. *By Anthony Lo Bello, Johns Hopkins University Press, 2013, 368 pages, $49.95.*

BOOK REVIEW
By Philip J. Davis

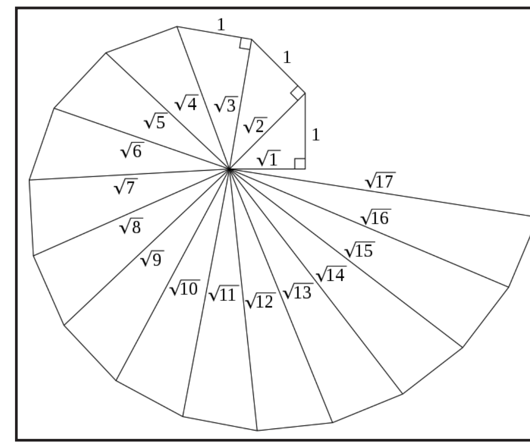
Once in a blue moon, the U.S. mail brings a book that is a great pleasure for me to review. Anthony Lo Bello of Allegheny College has written such a work. I am an old-time wordsmith: The bookcase next to my bed contains a half dozen dictionaries and concordances in five languages. In my living room I have the whole Compact Edition of the OED in microtype: two volumes, boxed, complete with a magnifying glass. For a few coins, as an act of pious admiration, I visited lexicographer Samuel Johnson's house in London and was allowed to flip (lightly) a few pages of his famous 1755 *Dictionary*. And I wish I owned a copy of C.T. Onions's *English Etymology*. Thus, Lo Bello's *Origins* was meat and potatoes for me.

The key mathematical words in Lo Bello's book are listed alphabetically from "a-" to "zero." Browsing at random, I learned the origins of *mantissa*, *equiangular*, *interpolate*, *sigma-field*, *contragredient*, *scalene*, *homoscedasticity*. The number six hundred sixty-six, famous from the Apocalypse in the Book of Revelation, makes a cameo appearance. Some terms, such as *extouch triangle* and *approximoscope*, were absolutely new to me. All in all, I estimate that the book provides genealogies for more than 1500 words.

The entries run from one-line explanations, as in "The F-Distribution of mathematical statistics is due to Snedecor [1881–1974]," to an extensive Wikipedia-type lecture on the entry "Cartesian," which runs to six pages and beats out "Euclid" by four pages. Among other things, I learned that the Empress Elizabeth Petrovna of Russia owned porcelain plates decorated with equiangular spirals in gold and magenta.

A book of this quality carries the possibility of a "vergroesserte und verbesserte Auflage," an enlarged and improved edition (a German publisher is reputed to have put out such a translation of Shakespeare). I suggest therefore that the overlooked word *syzygy* be added (although this single addition would not be grounds for a new edition). But assuming that computer science is a subset of mathematics, what about adding *cyber*,* *byte*, *virus*, *avatar*, *pixel*, *crash*, and a further dozen such words?

The book is larded with quotations—from Plutarch, Bertrand Russell, Plato, Rousseau, Euler, Herodotus, John Aubrey, Abelard of Bath, Voltaire, Dean Milman, Paul Halmos, and other worthies. Incidentally, Aubrey's *Brief Lives* (1680–1693) contains a great and entertaining collection of odd bits about mathematicians and scientists. Lo Bello has also included a few letters he has received, from, for example, W.E. Deming of NYU, on the teaching of mathematics, and J. Freund, on the uses of plot diagrams.



The spiral of Theodorus up to the triangle with a hypotenuse of $\sqrt{17}$. Image from Wikipedia.

I've thought of two personal items that might be included. If the author would care to join me in Providence for a glass of Narragansett ale, I would relate to him the deep and extensive origins of two phrases for which I've blown the kazoo for some years: *Quadratwurzel Schnecke* (the square root snail or spiral, or a sweet roll: your choice) and the *Schwartz function* (q.v. *Carus Mathematical Monographs*, No. 17).

Olé, Anthony Lo Bello! Good Job! Your book is full of much more interesting material than I can describe and stuff into my allotted space.

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.

*See my review in *SIAM News*, Vol. 38, No. 5, June 2005, for the Wiener story.

HDL Modeling

continued from page 1

of ApoA-I ($i \times h$) into the lipid-poor ApoA-I compartment, using MATLAB functions to numerically compute the analytic continuation of the model over the complex plane and dividing the imaginary part of the total ApoA-I level by h. He credited Lu for the application of this novel approach, which is analogous to computing the derivative of the ApoA-I concentration by a complex-step derivative approximation [4].

The key insights provided by the LMK model on HDL-C–raising therapy were based on simulation of the relationship between the whole-body RCT rate and the HDL-C concentration in a virtual population of 2000 subjects (Figure 3). In this virtual population (whose model parameters were drawn from a multivariate normal distribution, with a standard deviation of 15% of the nominal subject's values), a strong positive correlation was observed between the RCT rate and HDL-C (r = 0.95). Based on the assumption that the removal of cholesterol from atherosclerotic plaque lowers the risk of cardiovascular disease and that its rate parallels the whole-body RCT rate, the LMK model simulation would be consistent with the inverse relationship between HDL-C levels and cardiovascular disease risk seen in the epidemiological studies [2].

The group then used the model to simulate two different HDL-C–raising therapies in the subset of virtual subjects with HDL-C levels below 40 mg/dL. In the first case (Figure 3, top), inhibition of CETP activity by 80% was found to increase HDL-C levels by approximately 50%; the simulated RCT rates decreased slightly, however, rather than following the trend of the underlying virtual population. In the second case (Figure 3, bottom), up-regulating ABCA1 transporter activity by 100% also increased the HDL-C levels by about 50%; the RCT rates increased markedly, however, consistent with the trend of the underlying virtual population. Based on these simulations, the model suggests that CETP inhibition would neither increase RCT nor lower cardiovascular disease risk by this mechanism, whereas ABCA1 up-regulation would be expected to raise RCT rate and lower cardiovascular disease risk accordingly.

Mazer concluded that the LMK model provides a quantitative tool for evaluating the effects of different HDL-C–raising therapies and suggested that despite recent failures, some HDL-C–raising therapies may have the potential to lower cardiovascular disease risk.

Eq. 1: Lipid-Poor ApoA-I

$$\frac{dA_{lp}(t)}{dt} = \underset{1}{r_{\mathrm{in}}^{lp}} - \underset{2}{k_{\mathrm{ABCA1}}} A_{lp}(t) - \underset{3}{k_{\mathrm{kidney}}} A_{lp}(t) + \underset{4}{k_{\mathrm{dissoc}}} F_{\mathrm{rem}}(\mathrm{CE}_\alpha(t), A_\alpha(t), N_\alpha(t))$$

Eq. 2: α-HDL ApoA-I

$$\frac{dA_\alpha(t)}{dt} = k_{\mathrm{ABCA1}} A_{lp}(t) - k_{\mathrm{dissoc}} F_{\mathrm{rem}}(\mathrm{CE}_\alpha(t), A_\alpha(t), N_\alpha(t)) - k_{\mathrm{holo}}(d) A_\alpha(t)$$

Eq. 3: Remodeling Flux of ApoA-I

$$F_{\mathrm{rem}}(\mathrm{CE}_\alpha(t), A_\alpha(t), N_\alpha(t)) = m_A \times N_\alpha \times \left(n_{\mathrm{ApoA-I}}^{\mathrm{particle}} - n_{\mathrm{ApoA-I}}^{\mathrm{Shen}}\right)$$

Eq. 4: α-HDL Particle Number
(fusion of nascent spheres)

$$\frac{dN_\alpha(t)}{dt} = \frac{k_{\mathrm{ABCA1}}}{2m_A} \frac{1}{1 + \underset{5}{k_f} N_\alpha(t)} A_{lp}(t) - k_{\mathrm{holo}}(d) N_\alpha(t)$$

Eq. 5: HDL holo-uptake
(size dependent)

$$k_{\mathrm{holo}}(d) = \underset{6}{k_{\mathrm{holo}}^{c}} + \underset{7}{k_{\mathrm{holo}}^{l}} \times \left(\frac{d}{10} - 7\,\mathrm{nm}\right)$$

Eq. 6: α-HDL CE

$$\frac{d\mathrm{CE}_\alpha(t)}{dt} = \underset{8}{\gamma} \frac{m_C}{m_A} k_{\mathrm{ABCA1}} A_{lp}(t) + \underset{9}{k_{\mathrm{LH}}^{\mathrm{CETP}}} \mathrm{CE}_{\mathrm{LDL}}(t) - \left[\underset{10}{k_{\mathrm{HV}}^{\mathrm{CETP}}} + \underset{11}{k_{\mathrm{HL}}^{\mathrm{CETP}}} + \underset{12}{k_{\mathrm{SRB1}}^{\mathrm{HDL}}} + k_{\mathrm{holo}}(d)\right] \mathrm{CE}_\alpha(t)$$

Eq. 7: LDL CE

$$\frac{d\mathrm{CE}_{\mathrm{LDL}}(t)}{dt} = \underset{13}{k_{\mathrm{VL}}} \mathrm{CE}_{\mathrm{VLDL}}(t) + k_{\mathrm{HL}}^{\mathrm{CETP}} \mathrm{CE}_\alpha(t) - (k_{\mathrm{LH}}^{\mathrm{CETP}} + \underset{14}{k_{\mathrm{out}}^{\mathrm{LDL}}}) \mathrm{CE}_{\mathrm{LDL}}(t)$$

Eq. 8: VLDL CE

$$\frac{d\mathrm{CE}_{\mathrm{VLDL}}(t)}{dt} = \underset{15}{r_{\mathrm{in}}^{\mathrm{VLDL}}} + k_{\mathrm{HV}}^{\mathrm{CETP}} \mathrm{CE}_\alpha(t) - (k_{\mathrm{VL}} + \underset{16}{k_{\mathrm{out}}^{\mathrm{VLDL}}}) \mathrm{CE}_{\mathrm{VLDL}}(t)$$

Figure 2. *Equations and parameters (numbered in red) in the LMK model; details can be found in [3].*

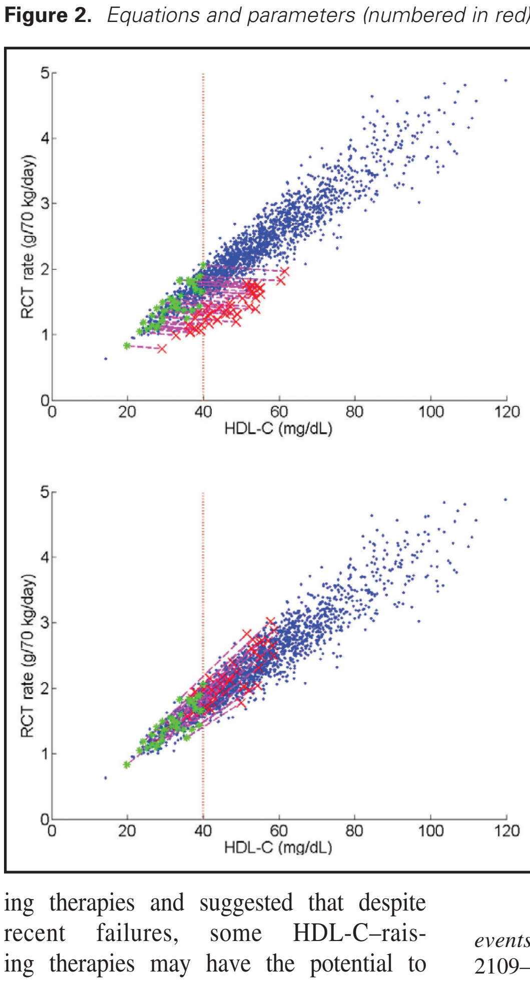


Figure 3. *Simulation of the relationship between the whole-body RCT rate and HDL-C in a virtual population (n=2000; blue). A subset of virtual subjects with HDL-C < 40 mg/dL (n=390; green) was subjected to 80% CETP inhibition (top) and 100% ABCA1 up-regulation (bottom; red). The purple dashed lines connect the asterisks with the X's for each individual subject during the respective treatments. While both treatments raise HDL-C levels by about 50%, CETP inhibition results in a slight decrease of RCT rate; ABCA1 up-regulation raises RCT rate markedly following the trend of the underlying virtual population.*

Acknowledgments

The invited presentation and this article are dedicated to Ed Block, a founding member of SIAM and long-time friend of the speaker's parents, Edy and Bob Mazer.

References

[1] P.J. Barter, M. Caulfield, M. Eriksson, et al., ILLUMINATE Investigators, *Effects of torcetrapib in patients at high risk for coronary events*, N. Engl. J. Med., 357:21 (2007), 2109–2122.

[2] Emerging Risk Factors Collaboration, *Major lipids, apolipoproteins, and risk of vascular disease*, JAMA, 302:18 (2009), 1993–2000.

[3] J. Lu, K. Hübner, M.N. Nanjee, E.A. Brinton, and N.A. Mazer, *An in-silico model of lipoprotein metabolism and kinetics for the evaluation of targets and biomarkers in the reverse cholesterol transport pathway*, PLoS Comput. Biol., 10:3 (2014), e1003509.

[4] J.R.R.A. Martins, P. Sturdza, and J.J. Alonso, *The complex-step derivative approximation*, ACM Trans. Math. Software, 29:3 (2003), 245–262.

[5] N.A. Mazer, F. Giulianini, N.P. Paynter, P. Jordan, and S. Mora, *A comparison of the theoretical relationship between HDL size and the ratio of HDL cholesterol to apolipoprotein A-I with experimental results from the Women's Health Study*, Clin. Chem., 59:6 (2013), 949–958; doi: 10.1373/clinchem.2012.196949.

[6] G.G. Schwartz, A.G. Olsson, M. Abt, et al., dal-OUTCOMES Investigators, *Effects of dalcetrapib in patients with a recent acute coronary syndrome*, N. Engl. J. Med., 367:22 (2012), 2089–2099; doi: 10.1056/NEJMoa1206797.

Norman Mazer is the Disease Modeling Leader in Ophthalmology & Rare Diseases, Clinical Pharmacology, at Roche Pharma Research and Early Development, Roche Innovation Center, Basel, Switzerland. An interview conducted at the SIAM meeting can be seen at http://bit.ly/1s4U22n.

Switching Diffusion Models and Their Many Applications

By George Yin and Chao Zhu

The current emphasis on modeling and analysis of many real-world applications has led to a resurgence of interest in switching diffusion. Such models, in contrast to existing differential equation-based dynamical systems models, are characterized by the coexistence of continuous dynamics and discrete events, as well as their interactions.

As an illustration, we consider the switching dynamical system shown in Figure 1. In it, three continuous dynamical systems sit on three parallel planes. An additional random switching process takes three possible values. Corresponding to the discrete state $i \in \{1, 2, 3\}$, the continuous state evolves on plane i. The pair of processes (continuous process, discrete event) = $(X(t), \alpha(t))$. Suppose that initially, the process is at $(X(0), \alpha(0)) = (x, 1)$. The discrete-event process stays in discrete state 1 for a random amount of time; during this time, the continuous component evolves according to the continuous process specified by the dynamics associated with discrete state 1 until a jump in the discrete component occurs. At random moment τ_1, a jump to discrete state 3 occurs. The continuous component then evolves according to a continuous process whose dynamics are associated with discrete state 3. The process wanders around the third plane until another random jump at time τ_2. At τ_2, the system switches to the second parallel plane, and so on.

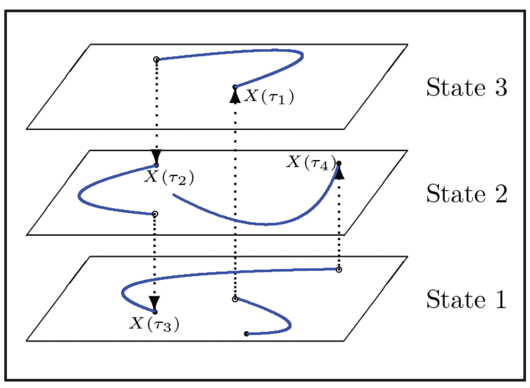


Figure 1. *Sample path for switching system (X(t), α(t)).*

A switching diffusion is schematically like the illustration shown in Figure 1. However, the dynamic system on each parallel plane is a stochastic differential equation with different drift and diffusion coefficients. Thus, a switching diffusion can be regarded as a coupled system of diffusion processes. Mathematically, a switching diffusion can be described by

$$\begin{aligned} dX(t) &= b(X(t), \alpha(t))dt + \sigma(X(t), \alpha(t))dW(t), \\ &(X(0), \alpha(0)) = (x, \alpha), \\ \mathbb{P}\{\alpha(t+\Delta) &= j | \alpha(t) = i, X(s), \alpha(s), s \leq t\} \\ &= q_{ij}(X(t))\Delta + o(\Delta). \end{aligned} \tag{1}$$

Here, $X(t)$, residing in $\mathbb{R}^r$, is the component representing the continuous state; $\alpha(t)$ is the discrete-event process taking values in a finite set $\mathcal{M} = \{1, \ldots, m\}$ and having a generator $Q(x) = (q_{ij}(x))$ that satisfies $q_{ij}(x) \geq 0$ and $\Sigma_j\, q_{ij}(x) = 0$ for each $i \in \mathcal{M}$; $b(\cdot,\cdot) : \mathbb{R}^r \times \mathcal{M} \mapsto \mathbb{R}^r$ and $\sigma(\cdot,\cdot) : \mathbb{R}^r \times \mathcal{M} \mapsto \mathbb{R}^{r\times r}$ are suitable functions; and $W(\cdot)$ is a standard r-dimensional Brownian motion. When $Q(x) = Q$, $\alpha(t)$ becomes a Markov chain independent of the Brownian motion.

In the more general setting, $\alpha(t)$ depends on the continuous state x and so is not itself a Markov chain; only the two-component process $(X(t), \alpha(t))$ is a Markov process. Switching diffusions have drawn attention and become popular because of their ability to depict random environments via the switching process. Such models have been used in the stabilization of partially observed systems with hidden switching processes [2], hedging of options [4], mean-variance portfolio selections [20], discrete optimization and wireless communication [15], flexible manufacturing and production planning [10], optimal harvesting problems in random environments [11], ecological models [21], real options and irreversible investment decisions in duopoly games with a variable economic climate stopping-time game under Stackelberg leader–follower competition [1], among others.

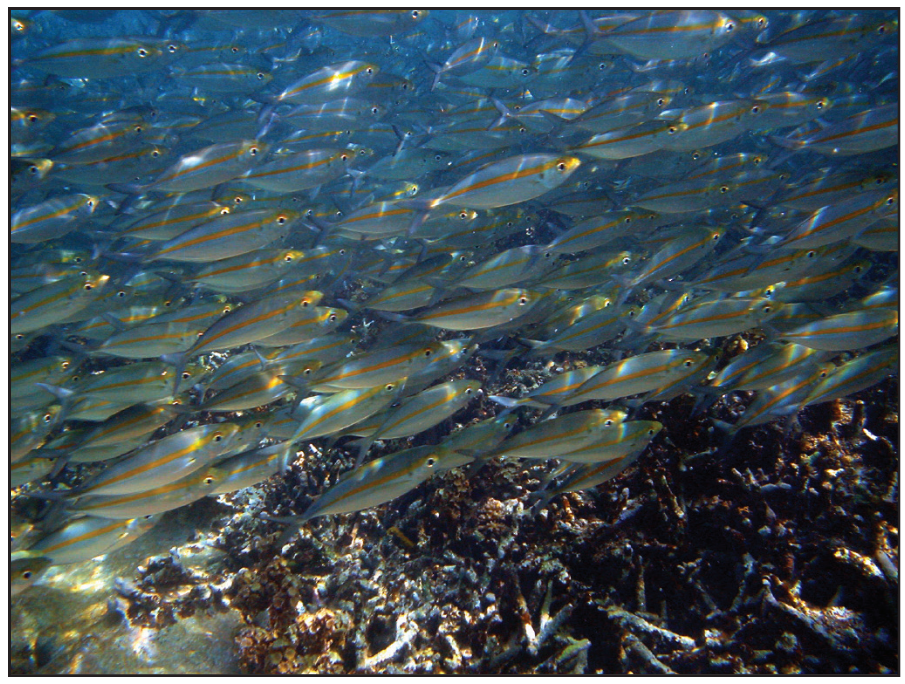


Figure 2. *A school of fish (goldband fusilier,* Pterocaesio chrysozona*) swim in a coordinated manner in a picture taken in Papua New Guinea by Brocken Inaglory. From http://en.wikipedia.org/wiki/File:School of Pterocaesio chrysozona in Papua New Guinea 2.jpg.*

Further applications include consensus control of multi-agent systems. In recent efforts, a number of processors (called mobile agents) participate in a task, with the goal of achieving a common objective, such as position, speed, or load distribution. In [14], in a proposed discrete-time model of autonomous agents, the agents can be viewed as points or particles, all moving in the plane at the same speed but in different directions. Each agent updates its direction using a local rule based on the average of its own and its neighbors' directions. This is a version of a model introduced in [12] for simulating flocking and schooling behaviors; see also [3, 13]. Figure 2 shows the collective behavior of a school of fish. If, in lieu of a fixed configuration, the topology is allowed to vary randomly according to a continuous-time Markov chain, the result is a switching diffusion limit of a suitably scaled sequence [16]. The random switching is used to model inherent uncertainties, the time-varying nature of the system, and random environments.

Although seemingly similar to the usual stochastic differential equations, the behaviors of the underlying systems are quite different. Consider, for instance, the following switching ordinary differential equation, even without the Brownian perturbations. Suppose that we have two linear systems, both stable in the usual sense. When we combine them using a switching device, is the resulting switched system stable? The answer, in general, is no. To understand this, we consider the randomly switched linear system

$$dX(t)/dt = A(\alpha(t))\, X(t), \tag{2}$$

where

See **Switching Systems** *on page 8*

Mathematical Problems Lie at the Heart of Biomedical Science

At its twice-yearly meetings in Washington, the SIAM Committee on Science Policy welcomes visitors from agencies with programs related to the mathematical sciences. At the November 2014 meeting, Philip E. Bourne, the associate director for data science at the National Institutes of Health, described some NIH programs that could benefit from the participation of mathematical scientists. The following article, by Bourne and his NIH colleague Michelle C. Dunn, is based on his CSP presentation.

The ongoing explosion in the quantity of biomedical data has put the spotlight on the importance of data analysis to the future of biomedicine and healthcare. These data cover all biological scales—from molecules, to cells, to patients, yet they share the properties of sparseness and noise. Given their volume and complexity, the data provide new challenges as well as opportunities for applied mathematicians to engage in the biomedical enterprise. The National Institutes of Health is keen to enable this engagement. What follows are examples of problem areas that can be addressed through the NIH Big Data to Knowledge (BD2K) initiative,* in which the 3 "V"s—volume, velocity, and variety—are all in play. Opportunities abound for all data types with which biomedicine is faced, including those described below.

Clinical data. Based on the American Recovery and Reinvestment Act of 2009, more than $19 billion has been invested in efforts to motivate hospitals and healthcare providers to convert from paper to electronic health records. Inconsistencies in the ways in which EHRs capture structured data (e.g., vital signs and lab results) and unstructured data (e.g., physicians' free-form text notes) become evident when a large cohort of patients is examined. Yet we are beginning to see promise. Analyzing these data needs rigorous statistical approaches across large, sparse noisy datasets for which feature extraction requires, for example, improved Natural Language Processing (NLP) tools.

Phenotype data. Challenges remain even for data that are routinely collected with a controlled vocabulary and in a standard format. Phenotype data, whether in a clinical or a laboratory setting, pose visualization and analysis challenges. With many more predictors than observations, even linear models are challenging because of drastically underdetermined systems of equations. Complex models are all the more challenging.

Image data. Mathematical problems arise with image data both in processing, via feature mapping, and analysis, through multiple, repeated comparisons. Feature mapping is the extraction from an image of useful summaries that describe the structure of interest, which can be represented as a manifold in a high-dimensional space. Multiple comparisons are made when, for example, hypothesis tests are performed on each pixel of an image to search for anomalies. Radiological image data are a prime example of the obvious benefit of early and reliable detection of anomalies.

Genomic data. High-throughput sequencing technologies will shortly make genomic data a standard feature of an EHR. Genomic data include not only a patient's genome, but also the genomic composition of the patient's microbiome. It is estimated that trillions of cells in a human being are not human cells, but rather from bacteria and viruses and other microorganisms. Our extensive microbiome is vital for normal health; change in its composition is a valuable diagnostic tool. New approaches will be required for reliably reconciling genomic data within health records and for performing comparative analyses of such multiscale records.

Network data. Graphs are used to model networks of connections, including those between molecules, genes, neurons, people, care providers, and hospitals. Discovery from large-scale, dynamic networks relies heavily on the field of graph theory. Goals include understanding the evolution of networks and inferring causality through mechanistic modeling.

Streaming data. Longitudinal studies are commonplace, but the granularity with respect to time and the volume of data are changing rapidly. For example, the potential exists for patients to continuously input into their EHRs through the use of mobile devices. As data are measured on increasingly fine time scales, data production will outpace the ability to write the data to disk or to do the desired computations in real time. In these cases, lightweight, real-time, online processing and analysis of streaming data become important, with decisions made after each observation.

These diverse data types are just the beginning. Individually, they produce tough computational and quantitative challenges. Their combination results in even tougher challenges—in data standardization, manipulation, modeling, and analysis. These challenges must be overcome, as advances in the biomedical sciences will become possible through data integration. Data integration includes combining diverse types of data, as well as combining data with prior information from expert knowledge. Integrating expert opinion, particularly important in a clinical setting, could be equally valuable in a biological one.

Once data are combined, the biomedical problem often boils down to inference (drawing conclusions about the population) or prediction (predicting the outcome for a particular individual). Both require a mathematical and biomedical understanding of confidence achieved through an estimation of associated noise. Predictions made without consideration of confidence will lead to unnecessary risks. Currently, many scalable prediction algorithms do not estimate errors associated with the predictions, and many prediction methods for which error is understood are not scalable. Therefore, a challenge is to combine the two in a biomedical context—to produce scalable algorithms that implement principled approaches for prediction and inference through the joint consideration of statistical risk and algorithmic runtime.

■■■

Achieving the promise of benefit from digital data requires a team effort. Computational and quantitative scientists are needed to address pressing problems alongside biomedical scientists. Building a collaborative relationship takes time and energy as both partners work to understand a new language and scientific context. The NIH is committed to bringing down barriers to the formation of collaborations between biomedical scientists and computational/quantitative scientists through investments in team science; teams with diverse expertise, including mathematical, have the skills to unlock biomedical discoveries for the benefit of humankind.

* The NIH Big Data to Knowledge initiative was created in 2012 to encourage the development of new approaches, standards, methods, tools, software, and competencies that will enhance the use of biomedical data. It includes support for research, implementation, and training in data science and other relevant fields. Information can be found at http://www.bd2k.nih.gov.

KSIAM Celebrates 10th Anniversary

The Korean Society for Industrial and Applied Mathematics held its 10th-anniversary conference on the tropical Jeju Island, November 20–22, 2014. The conference was jointly organized by KSIAM and the A3 Foresight Programs (a Chinese/Japanese/Korean research consortium). Among the approximately 300 participants were 75 Chinese and Japanese scholars from the A3 meeting.

SIAM president Irene Fonseca, one of three plenary speakers—with Zhiming Chen (Chinese Academy of Sciences) and Haesun Park (Georgia Institute of Technology)—also participated in a panel discussion, "Vision and Global Challenges for 2024 KSIAM." Min-Jae Tahk of Korea Advanced Institute of Science and Technology, recipient of the annual KSIAM–Kumkok Award, gave a lecture, and Chang-Ock Lee, also of KAIST, gave a public lecture.

KSIAM was formed in 1997 to encourage interactions of Korean applied mathematicians with their counterparts worldwide. In 2004, the society merged with the more informal, local Applied Mathematics Forum. Since the unification under the name KSIAM, the society has grown to a total of 554 members and 13 academic sections. Conferences are held twice yearly, and the quarterly KSIAM journal is now in its 18th volume. Goals for the coming decade include more active participation of people from industry and engineering, and expansion of reciprocal activities with international organizations, among them SIAM, ICIAM, and neighboring societies.—*Hyung-Chun Lee, president of KSIAM, and professor of mathematics at Ajou University.*

Professional Opportunities

Send copy for classified advertisements to: Advertising Coordinator, SIAM News, *3600 Market Street, 6th Floor, Philadelphia, PA 19104–2688; (215) 382–9800; fax: (215) 386–7999; marketing@siam.org. The rate is $3.00 per word (minimum $375.00). Display advertising rates are available on request.*

Advertising copy must be received at least four weeks before publication (e.g., the deadline for the March 2014 issue is January 31, 2014).

Advertisements with application deadlines falling within the month of publication will not be accepted (e.g., an advertisement published in the March issue must show an application deadline of April 1 or later).

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

www.siam.org/careers

The Milwaukee School of Engineering
Mathematics Faculty

The Milwaukee School of Engineering (MSOE) invites applications for a full-time mathematics faculty position starting in Fall 2015. The department has new and growing programs in actuarial science and operations research.

The successful candidate is expected to teach the mathematics courses in the undergraduate curriculum. Applicants should possess an appropriate doctoral degree at the time of hiring, and those with expertise in areas such as probability, applied probability models, and game theory will be given preference.

MSOE offers degrees in engineering, engineering technology, construction management, business, actuarial science, operations research, technical communications, and nursing. The school is located in the heart of downtown Milwaukee and is recognized in several national publications for its "applications-oriented" approach. Faculty is judged primarily on excellence in teaching. MSOE graduates are in high demand, as evidenced by the school's strong job placement rate.

The review of candidates will begin immediately and continue until the position is filled. To apply, applicants should submit a single file that includes a detailed resume, evidence of teaching excellence, and three reference letters. For more information and to apply, applicants should visit http://www.msoe.edu.

EEO Employer F/M/Vet/Disabled.

ICERM NSF BROWN

Institute for Computational and Experimental Research in Mathematics

ICERM Director Search Announcement

The Board of Trustees of the Institute for Computational and Experimental Research in Mathematics and Brown University seek a new institute Director for an appointment to begin between August 2015 and July 2016. The Director will serve as the scientific and administrative leader of ICERM and will be a distinguished member of the Brown faculty.

The successful candidate will possess outstanding scholarly credentials, including a Ph.D., as well as demonstrated academic leadership experience. The Director will hold a tenured position at Brown University in the Department of Mathematics or the Division of Applied Mathematics, or jointly in at least one of these departments. Preference will be given to applicants whose research interests align with the mission of ICERM. Although the Director will have no formal teaching obligations, the Director's faculty appointment will carry some expectation of service both to the department(s) in which the Director is appointed and to the university. The term of the appointment as Director of ICERM ends August 2020, and may be renewed.

The search committee consists of members of the ICERM Board of Trustees and faculty in Mathematics and Applied Mathematics. Review of applications will begin January 15, 2015.

For more information go to:
http://icerm.brown.edu/home/index.php#jobs

Brown University is committed to fostering a diverse and inclusive academic global community; as an EEO/AA employer, Brown considers applicants for employment without regard to, and does not discriminate on the basis of, gender, race, protected veteran status, disability, or any other legally protected status.

Texas Tech University
Department of Mathematics and Statistics

The Department of Mathematics and Statistics (M&S) at Texas Tech University invites applications for four tenure-track assistant professor positions beginning in fall 2015. M&S has active research groups in both pure and applied mathematics as well as in statistics (see http://www.math.ttu.edu/FacultyStaff/research.shtml). The department fosters a spirit of interdisciplinary collaboration across areas of mathematics and statistics as well as with engineering and the physical and biological sciences.

M&S is seeking candidates who will be engaged in nationally visible scholarship, establish externally funded research programs, interact with the existing research groups in the department, participate in interdisciplinary collaborations and service, involve graduate students in their research, and show excellence in teaching at the graduate and undergraduate levels. A PhD at the time of appointment is required.

One position will be in statistics, with a preference for applicants in probability theory/stochastic processes. The second position will be in biostatistics, with a preference for applicants who will collaborate with researchers in environmental toxicology, biological sciences, and/or public health. The third position will be in complex analysis and/or applications of complex analysis. The fourth position will be in mathematical and computational modeling, with a preference for applicants who will collaborate with researchers in biomathematics, applied mathematics, and/or computational mathematics. Applicants with very strong records who will bring externally sponsored research to Texas Tech will be considered for associate or full professor ranks.

Applicants should apply at http://www.texastech.edu/careers/, using the Requisition ID 1818BR. A completed AMS standard cover sheet and a curriculum vitae should be included. Three letters of reference plus any material in addition to that completed online should be sent to: Alex Wang, Hiring Committee Chair, Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409-1042; alex.wang@ttu.edu. Review of applications will begin immediately.

Texas Tech University is committed to diversity among its faculty. The university strongly encourages applications from women, minorities, persons with disabilities, and veterans, and it considers the needs of dual-career couples.

Texas Tech University is an Affirmative Action/Equal Opportunity Employer.

The Chinese University of Hong Kong, Shenzhen
The School of Science and Engineering

Located in the Longgang District of Shenzhen, The Chinese University of Hong Kong, Shenzhen—CUHK(SZ)—is a research-intensive university established through a Mainland–Hong Kong collaboration, with campus and infrastructure provided by the Shenzhen government. It will develop its academic programmes in phases and will offer courses in schools of management and economics, science and engineering, and humanities and social science. The faculty will be recruited internationally, as will some of the students. The languages of instruction will be English and Chinese, and the students will receive degrees from The Chinese University of Hong Kong.

The School of Science and Engineering at CUHK(SZ) will begin to admit students in four programmes starting in 2015: computer science and engineering, electronic information engineering, new energy science and engineering, and statistics. Other new programmes will be introduced gradually in the next few years. The school's mission is to develop innovative and forward-thinking science and technology leaders for the rapidly expanding economy of China and to become a top science and engineering school nationally and internationally.

The school invites applications for faculty positions in all related fields, including (but not limited to) the following areas:

- Computer science and engineering
  - computer systems
  - computer interfaces
  - cloud and distributed computing
  - databases and information systems
  - machine learning
  - robotics
  - theoretical computer science
- Statistical and data sciences
  - mathematical statistics
  - big data
  - optimization
  - financial statistics
  - risk analysis and control

Applications in areas such as mathematics, design and manufacturing systems, mechanical and automation engineering, industrial engineering and operations research, material science and engineering will also be considered.

Junior applicants are expected to have a PhD and strong potential in teaching and research. Applicants for associate and full professor positions should have demonstrated leadership and strong commitment to the highest international standards of excellence. Salary will be comparable to international standards and commensurate with experience and accomplishments. The university will provide comprehensive fringe benefits, including housing and medical care, for qualified candidates.

Applications (with curriculum vitae and at least three references) should be sent by email to hr-1@cuhk.edu.cn. Applications/nominations will be considered until the positions are filled.

See **Opportunities** *on page 7*

Opportunities

continued from page 6

Woods Hole Oceanographic Institution

Since 1959 the geophysical fluid dynamics (GFD) program at Woods Hole Oceanographic Institution has brought together graduate students and researchers from a variety of fields who share a common interest in the nonlinear dynamics of fluids. The 2015 program runs from June 15 through August 21. The theme is "Stochastic Processes in Atmospheric and Oceanic Dynamics," and principal lectures will be given by Charles Doering and Henk Dijkstra. Daily lectures, given by staff and visitors on a wide range of GFD and related topics, will follow.

Graduate research fellows undertake a ten-week research project, delivering a lecture and a written report for a proceedings volume at the summer's close. Fellows receive a stipend of $5,985 and a travel allowance. The application deadline is February 15, 2015. Applicants should visit http://gfd.whoi.edu/ for further information and applications.

An additional professional opportunity ad appears on page 8.

Announcements

Send copy for announcements to: Advertising Coordinator, SIAM News, *3600 Market Street, 6th Floor, Philadelphia, PA 19104–2688; (215) 382–9800; marketing@siam.org. The rate is $1.95 per word (minimum $275.00). Announcements must be received at least one month before publication (e.g., the deadline for the April 2015 issue is February 27, 2015).*

Call for Nominations for the Ostrowski Prize, 2015

The aim of the Ostrowski Foundation is to promote the mathematical sciences. Every second year it provides a prize for recent outstanding achievements in pure mathematics and in the foundations of numerical mathematics. The value of the prize for 2015 is 100,000 Swiss francs.

The prize has been awarded every two years since 1989. The most recent winners are Ben Green and Terence Tao in 2005; Oded Schramm in 2007; Sorin Popa in 2009; Ib Madsen, David Preiss, and Kannan Soundararajan in 2011; and Yitang Zhang in 2013. See http://www.ostrowski.ch/index_e.php?ifile=preis for the complete list and further details.

The jury invites nominations for candidates for the 2015 Ostrowski Prize. Nominations should include a curriculum vitae of the candidate, a letter of nomination, and 2–3 letters of reference. The Chair of the jury for 2015 is Christian Berg of the University of Copenhagen, Denmark. Nominations should be sent to berg@math.ku.dk by April 15, 2015.

Switching Systems

continued from page 5

$$A(1) = \begin{pmatrix} -10 & 2 \\ 20 & -10 \end{pmatrix},$$

$A(2)$ is the transpose of $A(1)$, and $\alpha(t)$ is a continuous-time Markov chain with generator

$$Q = \begin{pmatrix} -100 & 100 \\ 100 & -100 \end{pmatrix}.$$

It is easy to check that $(d/dt)X(t) = A(1)X(t)$ and $(d/dt)X(t) = A(2)X(t)$ are both stable. System (2), however, is unstable (see Figure 3). The system just described was presented in [18]; its behavior can be explained by the "averaging" effect. It is easy to see that $(A(1) + A(2))/2$ is an unstable matrix, one of whose eigenvalues has a positive real part. More detailed justification, using a perturbed Lyapunov function argument, can be found in [17, Section 5.6, pp. 229–233], in which it is also shown that two unstable systems combined with a switching process can produce a stable system; see also [5]. Similar behavior can be observed with the addition of a Brownian motion.

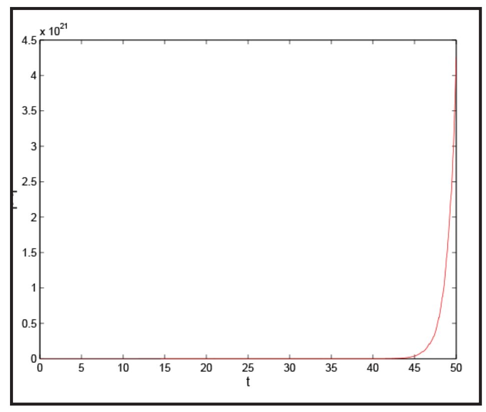


Figure 3. *Trajectory of the Euclidean norm |X(t)| as a function of t for system (2).*

The study of stochastic stability can be traced back to [6] for systems with Markov chains. That line of study was substantially extended in [7] and [8] for stochastic differential equations driven by Brownian motion. As mentioned earlier, switching diffusion models have drawn increasing attention because of the wide range of applications; see [9, 19] and references therein, especially in control and optimization. Apart from the existence and uniqueness of solutions, properties of crucial importance include the following:

(1) To ensure well posedness, we want to know under what conditions the solutions of the switched stochastic differential equations will possess continuous and smooth dependence properties on the initial data. (2) For initial data $(X(0), \alpha(0)) = (x, i)$, with $i \in \mathcal{M}$ and x in the exterior of an open set D with compact closure, we want to know if the system will return to the open set, which is known as "recurrence." (3) The first return time is a random variable τ; if $\mathbb{E}\tau < \infty$, then $(X(t), \alpha(t))$ is said to be "positive recurrent." An important problem concerns necessary and sufficient conditions for positive recurrence, which can be shown to imply ergodicity. (4) With the invariant measure, we can study many long-term average optimization and control problems that require the use of invariant measures. (5) Can we design suitable feedback controls that will make the resulting systems stable? And that will ensure positive recurrence? (6) Can we design efficient algorithms to solve the switching stochastic differential equations? Can we design good algorithms for approximating many optimal control problems with dynamics represented by switching diffusions?

Much of the recent work in this direction is driven by pressing needs in modeling, analysis, and numerical computation. In addition to the applications of switching diffusion models identified earlier, numerous applications arise in multi-agent systems, management of power systems under random environments, cyber-physical systems with switching topology, system identification with a hidden switching process, and social network modeling and analysis. Given the diversity in application domains, detailed system descriptions vary substantially and diverse methodologies are needed to treat such systems. A common feature of the underlying problems, however, is the interaction of continuous dynamics and discrete events. It is conceivable that the many diverse applications will motivate new research in switching diffusion and related complex models with jumps of the discrete component to new levels and open new avenues for further applications.

References

[1] A. Bensoussan, S. Hoe, Z. Yan, and G. Yin, *Real options with competition and regime switching*, to appear in Math. Finance.

[2] B. Bercu, F. Dufour, and G. Yin, *Almost sure stabilization for feedback controls of regime-switching linear systems with a hidden Markov chain*, IEEE Trans. Automat. Control, 54 (2009), 2114–2125.

[3] I.D. Couzin, J. Krause, N.R. Franks, and S.A. Levin, *Effective leadership and decision-making in animal groups on the move*, Nature, 43 (2005), 513–516.

[4] G.B. Di Masi, Y.M. Kabanov, and W.J. Runggaldier, *Mean variance hedging of options on stocks with Markov volatility*, Theory Probab. Appl., 39 (1994), 172–182.

[5] M.D. Fragoso and O.L.V. Costa, *A unified approach for stochastic and mean square stability of continuous-time linear systems with Markovian jumping parameters and additive disturbances*, SIAM J. Control Optim., 44 (2005), 1165–1191.

[6] I.I. Kac and N.N. Krasovskii, *On the stability of systems with random parameters*, J. Appl. Math. Mech., 24 (1960), 1225–1246.

[7] R.Z. Khasminskii, *Stochastic Stability of Differential Equations*, 2nd ed., Springer, New York, 2012.

[8] H.J. Kushner, *Stochastic Stability and Control*, Academic Press, New York, 1967.

[9] X. Mao and C. Yuan, *Stochastic Differential Equations with Markovian Switching*, Imperial College Press, London, 2006.

[10] S.P. Sethi and Q. Zhang, *Hierarchical Decision Making in Stochastic Manufacturing Systems*, Birkhauser, Boston, 1994.

[11] Q.S. Song, R. Stockbridge, and C. Zhu, *On optimal harvesting problems in random environments*, SIAM J. Control Optim., 49 (2011), 859–889.

[12] C.W. Reynolds, *Flocks, herds, and schools: A distributed behavioral model*, Computer Graphics, 21 (1987), 25–34.

[13] J. Toner and Y. Tu, *Flocks, herds, and schools: A quantitative theory of flocking*, Phys. Rev. E, 58 (1998), 4828–4858.

[14] T. Viseck, A. Czirook, E. Ben-Jacob, I. Cohen, and O. Shochet, *Novel type of phase transition in a system of self-driven particles*, Phys. Rev. Lett., 75 (1995), 1226–1229.

[15] G. Yin, V. Krishnamurthy, and C. Ion, *Regime switching stochastic approximation algorithms with application to adaptive discrete stochastic optimization*, SIAM J. Optim., 14 (2004), 1187–1215.

[16] G. Yin, L.Y. Wang, and Y. Sun, *Stochastic recursive algorithms for networked systems with delay and random switching: Multiscale formulations and asymptotic properties*, SIAM J. Multiscale Model. Simul., 9 (2011), 1087–1112.

[17] G. Yin and Q. Zhang, *Continuous-Time Markov Chains and Applications: A Two-Time-Scale Approach*, 2nd ed., Springer, New York, 2013.

[18] G. Yin, G. Zhao, and F. Wu, *Regularization and stabilization of randomly switching dynamic systems*, SIAM J. Appl. Math., 72 (2012), 1361–1382.

[19] G. Yin and C. Zhu, *Hybrid Switching Diffusions*, Springer, New York, 2010.

[20] X.Y. Zhou and G. Yin, *Markowitz mean-variance portfolio selection with regime switching: A continuous-time model*, SIAM J. Control Optim., 42 (2003), 1466–1482.

[21] C. Zhu and G. Yin, *On competitive Lotka–Volterra model in random environments* J. Math. Anal. Appl., 357 (2009), 154–170.

George Yin is a professor in the Department of Mathematics at Wayne State University. Chao Zhu is an associate professor in the Department of Mathematical Sciences at the University of Wisconsin–Milwaukee. The SIAM Activity Group on Control and Systems Theory provided this article.