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GRACE Satellite Data Delineates Changing Earth Surface

By James Case

It has been known since the time of the French Revolution that the plumb lines observed at different points on the Earth's surface are often "skew" to one another, meaning that they meet nowhere, much less at the planetary center of mass. Consequently, the Earth's gravitational field differs in kind from those generated by simple point masses, spheres, or ellipsoids of uniform density. Until the advent of satellite technology, however, there was no practical way to determine the actual shape of the field. That's why, in 1976, NASA launched the first LAGEOS satellite; it remains in orbit some 6000 kilometers above the Earth's surface to this day, providing laser-assisted range measurements of remarkable accuracy to points of interest on the Earth's surface. But because more accurate measurements can be made from satellites orbiting closer to ground level, NASA and the Deutsches Zentrum für Luft und Raumfahrt have joined forces in GRACE—the Gravity Recovery and Climate Experiment—which is designed to map the Earth's gravitational field with previously unattained precision.

This article is based on portions of a public lecture the author heard at the Aspen Center for Physics, Aspen, Colorado, in July 2012. The speaker, Ralph J. Cicerone, is an atmospheric scientist and current president of the U.S. National Academy of Sciences; the lecture was titled "Contemporary Climate Change as Seen Through Data."

The knowledge to be gained from such an undertaking should prove extremely valuable. It will, among other things, help scientists to decide whether rising sea levels are due mainly to melting ice sheets, thermal expansion of the ocean water, or increasing salinity. It will also help them to separate the effects of gravity and ocean currents, and so to decide which shorelines should prepare for the most rapidly rising sea levels. Models have long predicted (and measurements begun to confirm) that sea levels will rise about twice as fast along shores like those of Virginia and southern California, where ocean currents are directed landward, as elsewhere along the east and west coasts of the U.S.

Already GRACE data has revealed the existence of the 300-mile-wide Wilkes Land crater in Antarctica, believed to have formed about 250 million years ago. It offers new ways of calculating ocean bottom pressures—as important to oceanography as atmospheric pressure is to meteorology. GRACE data has also been used to determine the water content of the soil in various agricultural regions, to analyze the movements of the Earth's crust caused by the earthquake that created the 2004 tsunami in the Indian Ocean, and to measure "post-glacial rebound," the ongoing process whereby the Earth's crust is gradually returning to the shape it had before the last ice age, when "climate change" was responsible for coverage of much of the northern hemisphere with snow and ice to a depth of perhaps 200 miles.

The Earth's gravitational field is the gradient field of a potential $V(r,\theta,\lambda)$, where r, θ, λ represent the radial distance, latitude, and longitude of a point on or above the surface. The function V can be expanded in spherical harmonics as follows:

$$V(r,\theta,\lambda) = \frac{GM}{R}\sum_{l=0}^{\infty}\sum_{m=0}^{l}\left(\frac{R}{r}\right)^{l+1} P_{lm}(\sin\theta)\big(C_{lm}\cos(m\lambda)+S_{lm}\sin(m\lambda)\big),$$

where R is the Earth's mean radius, M the mass of the Earth, G the universal gravitational constant, l and m are the spherical harmonic "degree" and "order," P_{lm} is a "fully normalized" Legendre function, and S_{lm} and C_{lm} are the usual Stokes coefficients. The first few hundred of these can be obtained by numerical evaluation of standard integrals using GRACE data.

The equipotential surface that best approximates the mean ocean surface is known as the "geoid" of the Earth. Gauss introduced the term during the years he spent mapping the Duke of Brunswick's ancestral lands, describing it as "the mathematical figure of the Earth." Being an equipotential surface, it is everywhere perpendicular to the force of gravity, as determined by local plumb lines. Geoids are surprisingly irregular, though significantly less so than the Earth itself. Recent estimates deviate from the standard ellipsoidal approximation by little more than 100 meters (see Figure 1).

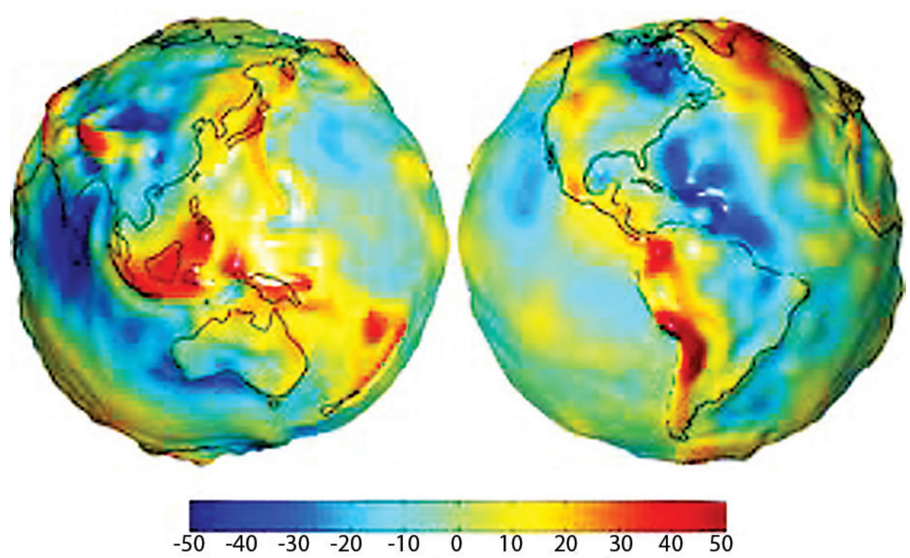

Figure 1. *Three-dimensional visualization of geoid undulations, using units of gravity.*

GRACE data is obtained from a pair of satellites—nicknamed Tom and Jerry—one trailing the other at a distance of about 220 kilometers in polar orbit some 500 kilometers above the Earth's surface. Though that orbit has been deteriorating since March 2002, when the mission was launched, both are expected to remain in service at least until 2015. Circling the Earth 15 times a day, each overflies the equator once every 48 minutes. Hence, the equatorial points over which each passes in a day are only, on average, about 1300 kilometers apart. And because the 450 points over which Tom and Jerry pass during any 15-day period are almost uniformly distributed along the equator, every point on it must lie within about 50 kilometers of at least one crossing point. Sites nearer the poles are, of course, visited more often.

Because the GRACE satellites are in low Earth orbit, the forces of attraction exerted on them by the more massive surface features over which they pass—think mountain ranges and continental ice sheets—must have substantial horizontal components. Moreover, the lead satellite responds sooner

See **GRACE** *on page 6*

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Modeling the Origin of Eusociality

By William Kolata

A 2010 paper* that challenged a decades-old explanation for the evolution of "eusocial organization" in many insects (ants, wasps, bees, termites, thrips, aphids) and certain other animals (snapping shrimp and naked mole rats) caused a stir among evolutionary biologists. The distinguishing feature of a eusocial population is that some individuals reduce their own lifetime reproductive potential to help raise the offspring of others. Eusociality is rare (occurring in only 2% of the 900,000 known species), but successful (social insects account for more than 50% of the known biomass of insects). The controversy engendered by the paper was no doubt enhanced by the identity of one of the authors: Edward O. Wilson, one of the early and strongest proponents of the challenged explanation, which is called "inclusive fitness." Wilson's co-authors, Martin Nowak and Corina Tarnita, are mathematicians with appointments in the Program for Evolutionary Dynamics at Harvard. Nowak, in the keynote address at the Mathematical Biosciences Institute's 10th-anniversary celebration, discussed some of the ideas and the mathematical model presented in the 2010 paper.

Altruistic behavior among bees was recognized by Darwin as a conundrum for his theory of evolution; he suggested that the whole colony was, in some sense, the unit of selection. Slightly more than a century later, the biologist William D. Hamilton, building on work of J.B.S. Haldane, Ronald Fisher, and Sewall Wright, provided an explanation and formalized a foundation for a theory of "inclusive fitness" using kin selection. Hamilton defined inclusive fitness as the personal fitness expressed by an individual in its production of offspring, stripped of all components that could be attributed to its environment. This fitness is augmented by certain quantities of harm and benefit that the individual causes to the fitness of neighbors by his actions. The quantities, expressed in fractions, are coefficients of relatedness—one for clonal individuals, one-half for siblings, one-quarter for half-siblings, one-eighth for cousins, and so forth. Hamilton codified the theory in an inequality: $R > c/b$, where R is relatedness, c the cost, and b the benefit. An especially trenchant case is that of haploid–diploid societies, in which females are produced by fertilization of eggs, males by unfertilized eggs. In these societies, sisters are related more closely to each other (R = three-quarters) than to their mother (R = one-half). The classic example of such societies is found in the *Hymenoptera* (an order of ants, bees, and wasps).

In their paper Nowak et al. show that inclusive fitness holds only in special cases and describe the mathematical model they developed. Based on natural selection, the model is more general than inclusive fitness and agrees with the results for inclusive fitness in the special cases in which it works. They identify weaknesses of inclusive fitness: It holds only in the weak selection limit (all individuals have approximately the same fitness, and the two social strategies (eusocial and solitary) are roughly equally abundant); the interactions between individuals are additive and pairwise; and the theory can deal only with special popula-

See **Eusociality** *on page 5*

*M.A. Nowak, C.E. Tarnita, and E.O. Wilson, *The evolution of eusociality*, Nature, 46 (2010), 1057–1062.

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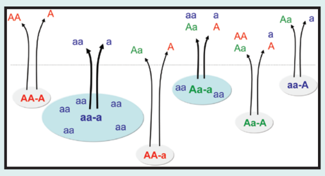
1 **Modeling the Origin of Eusociality**



2 **Gaussian Elimination as an Iterative Algorithm**

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4 **An Unconventional History of the Early IAS Computer**
A "childhood spent roaming the halls of IAS to chat with its staff and . . . playing games with parts of the scrapped computer" gives George Dyson's book on the IAS computer (1946–52) a "surprisingly personal" slant, says reviewer Thomas Haigh. While praising the book's "zesty prose" and welcome emphasis on the computer's applications to various areas of science, Haigh laments the omission of information on related developments elsewhere.

8 **New Momentum for Applied Mathematics in East Asia**
SIAM's East Asia Section held its eighth meeting in Taiwan, where the applied mathematics community is thriving, with new research centers, national academy programs, and funding initiatives. SIAM president Irene Fonseca and EASIAM president Ming-Chih Lai report on developments in the region.

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Obituaries

Chia-Chiao Lin, 1916–2013

Chia-Chiao Lin, who played a pivotal role in the development of applied mathematics both in the United States and in China, died in Beijing on January 13, at the age of 96. The 16th president of SIAM (1972–73), Lin was an Institute Professor Emeritus at MIT, where he was a member of the faculty from 1947 until his retirement in 1987. From 2002, he was a Distinguished Professor at Tsinghua University in Beijing.

The focus of Lin's early research was fluid mechanics, in particular hydrodynamic stability and turbulence, and the aerodynamics of gas turbines, oscillating airfoils, and shock waves. In his doctoral dissertation, under the supervision of Theodore von Kármán, he solved an outstanding problem stemming from work of Werner Heisenberg concerning the stability of parallel flows. He also resolved a longstanding problem concerning the theory of asymptotic solutions of ordinary differential equations of order higher than 2 that are uniformly valid around turning points.

With von Kármán, Lin proposed a spectral theory for homogeneous turbulence, further developing von Kármán's similarity theory and the statistical theory of turbulence. These investigations in hydrodynamic stability and turbulence greatly influenced engineers and scientists working on fluid flow, including geophysical fluid dynamicists. Lin's 1955 monograph, *The Theory of Hydrodynamic Stability*, was the first such publication in this developing field.

Lin then turned to problems in the hydrodynamics of superfluid helium and astrophysics. In 1964, with Frank Shu of the University of California at Berkeley, Lin advanced the density-wave theory of galaxy formation (based on earlier work of Bertil Lindblad) to account for sustained spiral structures. He also contributed to work on related problems in gravitational collapse and star formation. In 1996, Lin and Giuseppe Bertin published the monograph *Spiral Structure in Galaxies: A Density Wave Theory*.

In 1967, at the SIAM Annual Meeting in Toronto, Lin gave the John von Neumann Lecture. His paper based on the lecture, "Dynamics of Self-gravitating Systems: Structure of Galaxies," was published in *SIAM Review* in April 1969. He concluded the paper with two general remarks:

> "First, in statistical mechanics, combinatorial analysis is extremely important: the problem is discrete. At the same time, when one goes into the consideration of the limiting form of the distribution function, one finds it is continuous (in phase space). Thus, it would be unwise to divide applied mathematics artificially in terms of discrete (or finite) and continuous (or infinite) parts. One often has to consider both and to carry out the limiting process in a single theory that deals with one particular subject.
>
> "Second, the current revival in the theoretical study of galactic structure is largely stimulated by the recent improvement in observational technique (especially radio astronomy). In turn, these mathematical studies enable us to understand better the nature of collective modes and to raise again, in sharper focus, some fundamental questions on the relaxation process in a 'collisionless' system. These studies certainly involve quite sophisticated mathematical concepts and theorems. They point toward the interest and the importance of the study of *nonlinear random processes*, and might, by example, contribute to the stimulation and the development of a general mathematical theory, even as the study of the physical process of Brownian motion did. It is in the hope that more general mathematical theories will be stimulated by these studies that I wish to dedicate this survey paper to the late John von Neumann."

It was shortly after the von Neumann lecture and *SIAM Review* paper that Lin was elected SIAM president. Further securing his place in SIAM history was the 1974 publication of *Mathematics Applied to Deterministic Problems in the Natural Sciences*, by Lin and his student Lee Segel (1932–2005). SIAM reprinted the book in 1988 as the first volume in the Classics in Applied Mathematics series. In 2010, reappraising one of the problems from the book, S.G.B. O'Brien [2] commented on what made the book and its modeling approach innovative for its time: Lin and Segel "demonstrate how to deal with a real problem from a qualitative description through the mathematical formulation, simplification, and approximate solution, and, importantly, the interpretation of the mathematical results in terms of the original process." The book has a recent descendant: *A Primer on Mathematical Models in Biology*, by Segel and his student Leah Edelstein-Keshet, which SIAM will publish this month.

In 2002, Lin returned to his alma mater, Tsinghua University in Beijing, as Distinguished Professor. There he founded and served as honorary director of the Zhou Pei-Yuan Center for Applied Mathematics (ZCAM)—now an active hub of research in quantitative biology, applied partial differential equations, scientific computation, and other interdisciplinary subjects linking mathematics, the natural sciences, and engineering.

On his return to China, Lin worked to promote the application of mathematics to the biological sciences. He suggested that new developments in the area should be regarded as part of the natural evolution of applied mathematics with an expanded scope. His own research was on the problem of protein folding—one of the most basic intellectual challenges in computational molecular biology. Instead of concentrating on the prediction of protein structure, Lin tried to understand the mechanism of the process of fast folding toward an equilibrium state. In an analogy with Heisenberg's energy cascade theory, Lin sketched an application of the kinetic theory for dissipative systems to the study of the structure and function of protein molecules. In this way he showed that traditional concepts and methods of statistical physics can be successfully applied to yield predictions for comparison with empirical data [1]. This work provides a completely new idea for the formulation of protein folding as a nonlinear stochastic process, and moves the problem of protein folding closer to resolution.

Though in his 90s, Lin worked tirelessly at Tsinghua to set an example for young researchers. In recent years he oversaw the research of more than 10 PhD students and junior faculty. Until two years ago, he met every week with colleagues and students in his office; when failing health prevented these meetings, he often held them at home, and he continued to participate in academic activities.

C.C. Lin provided guidance and support to ZCAM from its inception. Along with academic advice, Lin contributed substantial personal financial support for the development of the center. In addition to previous gifts to Tsinghua University, in recent years he donated his salary from the Chinese government to help defray the operating expenses of ZCAM. In 2007, he sold some of his property in the U.S. and donated the collected money to the Tsinghua University Education Foundation, which used it to establish the Lin-Liang Research Fund for the long-term development of the center. *—Adapted from "Pioneering Applied Mathematician Chia-Chiao Lin Dies at 96,"* MIT News, *January 14, 2013, with contributions from Jinzhi Lei, Tsinghua University.*

References

[1] C.C. Lin, *On the evolution of applied mathematics*, Acta Mech. Sinica, 19:2 (2003), 97–102.

[2] S.B.G. O'Brien, *Lin & Segel's standing gradient problem revisited: A lesson in mathematical modeling and asymptotics*, SIAM Rev., 53:4 (2011), 775–796.

The 2012 Ig Nobel for Physics

LETTERS TO THE EDITOR

To the Editor:

I read with great pleasure the article on Joseph B. Keller and the 2012 Ig Nobel for physics (*SIAM News*, December 2012). Keller is a man known for his intellect, creativity, and professional integrity (and a personal academic hero of mine). Readers may want to know that the 2012 Ig Nobel prize for physics was shared with Raymond E. Goldstein, Patrick B. Warren, and Robin C. Ball for a delightful paper on the shape of ponytails (*Physical Review Letters*, 2012). The 1999 Ig Nobel for physics was shared with Len Fisher for calculating the optimal way to dunk a biscuit. While it is certainly true that Wilkins won the Nobel prize for the determination of the structure of DNA in 1962, readers will appreciate the fact that it was shared with Watson and Crick.*—Alain Goriely, University of Oxford.*

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Gaussian Elimination as an Iterative Algorithm

By Alex Townsend
and Lloyd N. Trefethen

Gaussian elimination for solving an $n \times n$ linear system of equations $Ax = b$ is the archetypal direct method of numerical linear algebra. In this note we point out that GE has an iterative side too.

We can't resist beginning with a curious piece of history. The *second* most famous algorithm of numerical linear algebra is the conjugate gradient iteration. CG was introduced in 1952, but for years it was not viewed mainly as iterative. Most experts' attention was on its property of exact convergence after n steps. Only in the 1970s was it recognized how powerful CG can be when applied iteratively, converging often to many digits of accuracy in just a few dozen steps (especially with a good preconditioner). It is now one of the mainstays of computational science—the archetypal iterative method.

We are not about to claim that the direct side of GE is going to wither away, as happened with CG. Nevertheless, researchers have begun to use GE as an iterative algorithm, and, as we describe in this article, we apply a continuous analogue of GE as the basis of Chebfun2, an extension of Chebfun for computing with bivariate functions on rectangles.

Usually GE is described in terms of triangularization of a matrix. For the purpose of this article, we offer a less familiar but equivalent description. Given A, GE selects a nonzero "pivot" entry a_{i_1,j_1} and constructs the rank 1 approximation $A_1 = u_1v_1^T/a_{i_1,j_1}$ to A from the corresponding column u_1 (column j_1 of A) and row v_1^T (row i_1 of A). Then it improves this approximation by finding a nonzero entry a_{i_2,j_2} of $A - A_1$, constructing the rank 1 matrix $u_2v_2^T/a_{i_2,j_2}$ from the corresponding column u_2 and row v_2^T, and setting $A_2 = A_1 + u_2v_2^T/a_{i_2,j_2}$. Proceeding in this manner, GE approximates A by matrices A_k of successively higher ranks; the nonzero entry identified at each step is called the *pivot*.

The traditional view of GE is that after n steps, the process terminates. The iterative view is that A_k may be a good approximation to A long before the loop finishes, for $k \ll n$.

Looking around, we have found that a number of researchers are using GE as an iterative algorithm. In this era of "big data" computations, low-rank approximations are everywhere. All sorts of algorithms—from randomized SVDs to matrix completion and the million-dollar Netflix prize-winning algorithm for predicting movie preferences—are employed to construct the approximations; a number of the algorithms can be interpreted as GE with one or another pivoting strategy. Such methods have been developed furthest in the context of hierarchical compression of large matrices, where key figures include Bebendorf ("adaptive cross approximation" [1]), Hackbusch ("$\mathcal{H}$-matrices" [4]), and Tyrtyshnikov ("skeletons" and "pseudo-skeletons" [8]). Mahoney and Drineas have proposed GE-related non-hierarchical algorithms for data analysis ("CUR decompositions" [5]). More classically, iterative GE is related to algorithms developed over many years for computing rank-revealing factorizations of matrices.

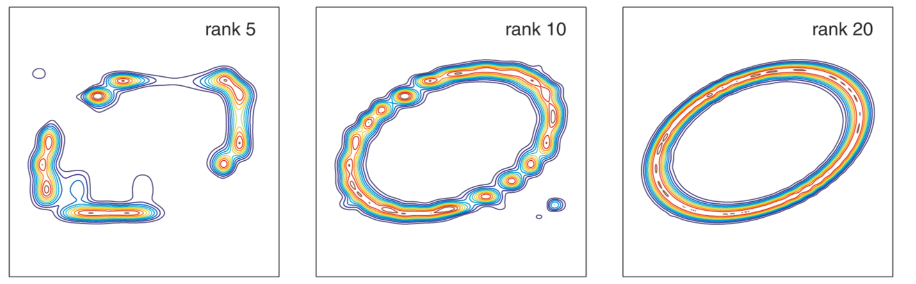

Figure 1. *Iterative Gaussian elimination applied to* $f(x,y) = \exp(-100(x^2 - xy + 2y^2 - 1/2)^2)$ *in the unit square, with contour levels at 0.1, 0.3, . . . , 0.9. At rank 88, f is approximated to 16-digit accuracy. This is an analogue for functions of the rounding of real numbers to floating-point numbers.*

We came to this subject from a different angle. For a decade, the Chebfun software project has been implementing continuous analogues of discrete algorithms for "numerical computing with functions." For example, the Matlab commands `sum(f)` and `diff(f)`, which compute sums and differences of vectors, are overloaded in Chebfun to compute integrals and derivatives of functions.

The challenge we have faced is, how could this kind of computing be extended to bivariate functions $f(x,y)$? After years of discussion, we have addressed this question with the release of Chebfun2 [6], the first extension of Chebfun to multiple dimensions. Chebfun2 approximates functions by a continuous analogue of iterative GE. Given a smooth function $f(x,y)$ defined on a rectangle, it first finds a point (x_1,y_1) where $|f|$ is maximal and constructs the rank 1 approximation $f_1(x,y) = u_1(y)v_1(x)/f(x_1,y_1)$ to f from the slices $u_1(y) = f(x_1,y)$ and $v_1(x) = f(x,y_1)$. Then it finds a point (x_2,y_2) where $|f - f_1|$ is maximal, constructs the rank 1 function $u_2(y)v_2(x)/f_1(x_2,y_2)$, and adds this to f_1 to get a new approximation f_2. After k steps we have a rank k approximation f_k that matches f exactly on at least k horizontal and vertical lines; the process stops when f is approximated to machine precision. The univariate functions $u_j(y)$ and $v_j(x)$ are represented as polynomial interpolants at Chebyshev points, enabling Chebfun2 to leverage the well-established algorithms and software of Chebfun.

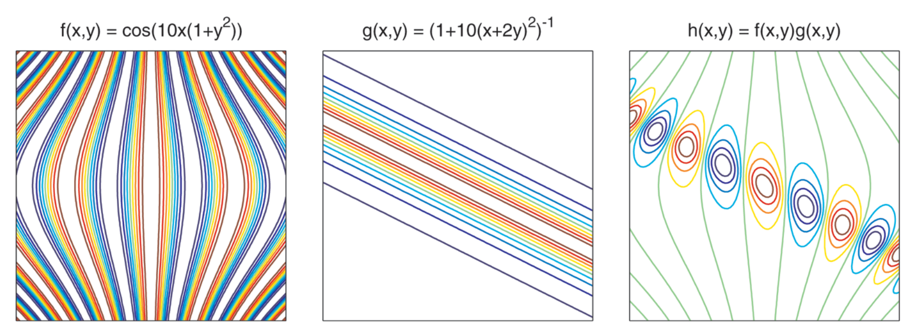

Figure 2. *Iterative GE approximates functions f and g over the unit square to 16-digit accuracy by approximants of ranks 19 and 85, respectively. The product h = fg is approximated to the same accuracy with rank 96, not rank 1615 as one would expect mathematically. This is an analogue for functions of the rounding of a product xy in floating-point arithmetic.*

Notice that this Chebfun2 approximation algorithm, because it finds maxima of functions $|f - f_k|$, corresponds to the variant of GE known as *complete pivoting*. (What we have described is the principle underlying our algorithm. In practice, the computation is accelerated by a more complex interplay between continuous and discrete, as detailed in [7].)

This method for approximating bivariate functions has been used before, by Maple co-inventor Keith Geddes and his students [3]. Their application was mainly quadrature (or rather cubature), whereas we have taken the idea as the basis of a general system for computing with functions.

A few pictures can tell more of the story. Figure 1 illustrates the approximation of a smooth function $f(x,y)$. Mathematically, f is of infinite rank, but GE computes an approximation to machine precision of rank 88. One could compute an *optimal* low-rank approximation by a continuous analogue of the singular value decomposition, but this would improve the rank only to about 80, at the price of much more computing. We find this degree of difference between GE and SVD to be typical when f is smooth.

For numerical computing with functions, the key challenge is not just to represent functions, but to compute with them. Every time an operation like fg or $\sin(f)$ is carried out, Chebfun2 constructs an approximation of the result with rank truncated to achieve about 16 digits of accuracy, just as IEEE arithmetic truncates the result of an operation like xy or $\sin(x)$ to 64-bit precision.

In Chebfun2, rounding operations like the one illustrated in Figure 2 happen all the time, whenever a function is operated on or two functions are combined. On this technology we build function evaluation, integration, differentiation, vector calculus, optimization, and other operations. The power is not yet as great as that of one-dimensional Chebfun, which can deal with singularities and solve differential equations, but it is still remarkable. Chebfun2 solves Problem 4 of the 2002 SIAM 100-Digit Challenge [2], involving the global minimization of a complicated function, to 12-digit accuracy in less than a second! Challenges ahead include the extension of these ideas to differential equations, functions with singularities, more general domains, and higher dimensions, and the development of theory to quantify the convergence of these low-rank approximations.

Gaussian elimination is an iterative algorithm too.

References

[1] M. Bebendorf, *Hierarchical Matrices*, Springer, New York, 2008.

[2] F. Bornemann et al., *The SIAM 100-Digit Challenge: A Study in High-Accuracy Numerical Computing*, SIAM, Philadelphia, 2004.

[3] O.A. Carvajal, F.W. Chapman, and K.O. Geddes, *Hybrid symbolic-numeric integration in multiple dimensions via tensor-product series*, in *Proceedings of ISSAC '05*, M. Kauers, ed., ACM Press, New York, 2005, 84–91.

[4] W. Hackbusch, *Tensor Spaces and Numerical Tensor Calculus*, Springer, New York, 2012.

[5] M.W. Mahoney and P. Drineas, *CUR matrix decompositions for improved data analysis*, Proc. Natl. Acad. Sci. USA, 106 (2009), 697–702.

[6] A. Townsend, Chebfun2 software, http://www.maths.ox.ac.uk/chebfun, 2013.

[7] A. Townsend and L.N. Trefethen, *An extension of Chebfun to two dimensions*, SIAM J. Sci. Comput., submitted.

[8] E.E. Tyrtyshnikov, *Mosaic-skeleton approximations*, Calcolo, 33 (1996), 47–57.

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Back Story: Mathematics Awareness Month 2013

Mathematics Awareness Month is held each April to raise awareness of the important role mathematics plays in our lives. Victor Donnay, a professor of mathematics at Bryn Mawr College, is chair of the advisory committee that organized this year's event. Bryn Mawr sustainability intern Lee McClenon interviewed Donnay for SIAM News*; an edited transcript of the interview follows.*

This year's theme is the Mathematics of Sustainability. What does this mean?

The earth provides us with an astonishing variety of resources. For humanity to flourish, we must balance our human needs, such as those for energy, clean air, fresh water, and adequate food, with the availability of these resources. And we must do so while operating within the complex constraints imposed by the laws of nature and the perhaps equally complex "laws" of human behavior. So sustainability involves environmental, social, and economic aspects, all of which are interconnected. Mathematics contributes in many important ways to understanding and addressing the challenges of sustainability. The poster for Math Awareness Month aims to paint a picture of the balancing act of sustainability. An interactive version on the website (www.mathaware.org) describes some ways in which the images connect to math, sustainability, and each other. We invite visitors to submit their own interpretations via the website blog.

Where did you look to find writers for the essays posted on the Math Awareness Month website?

One of the challenges faced by our committee (Thomas Pfaff, Ithaca College; Catherine Roberts, Holy Cross College; Mary Lou Zeeman, Bowdoin College; and me) is that sustainability is such a broad topic—how does one cover it all? In recruiting authors for the essays, we were aiming to get a wide array of perspectives. Certainly we wanted mathematicians and scientists doing research in areas of sustainability, but we also looked for places where practitioners have used math to solve sustainability problems. One example is the essay from the founding director of sustainability for Philadelphia, who developed a comprehensive green plan for the city. He writes about the role of math in developing an urban planning project. We also have an essay from a LEED architect on how designers use mathematics to create environmentally friendly and economically efficient buildings. Another topic people may not automatically associate with math is international development. We have an essay describing how math is used in the United Nations "Sustainable Energy for All" project, which aims to improve the quality of life in developing countries by providing green energy solutions to meet pressing local needs. Both math and sustainability are such broad, important topics that they can be found in many projects!

Last year Bryn Mawr College was awarded the American Mathematical Society annual award for Exemplary Achievement in a Mathematics Department. Congratulations! What is Bryn Mawr doing for Math Awareness Month this year?

We always do math contests, such as collecting the digits of π or guessing the number of M&Ms in a big jar. We show movies that have math-related themes. We usually do a hands-on workshop for students; last year we did pencil sculptures. Our big event is the Math Awareness Month keynote speaker. This year we are excited to have David Kung from St. Mary's College, the author of one of the Math Awareness Month essays. He will be talking about math and social justice.

Do you have some new components for this year's Math Awareness Month?

When we launched the poster at the Joint Mathematics Meetings in January, people asked us to recommend speakers for their institutions' activities. In response, we are

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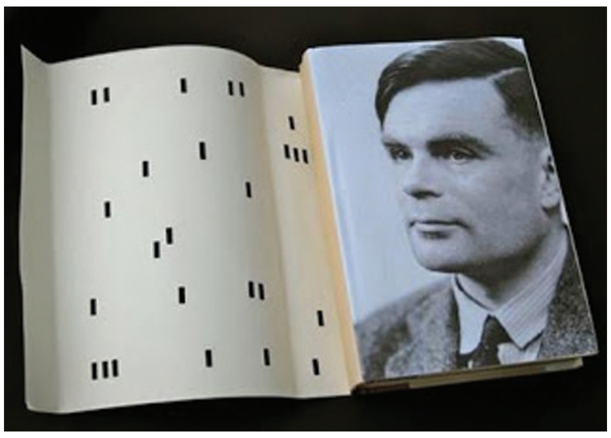
An Unconventional History of the Early IAS Computer

BOOK REVIEW
By Thomas Haigh

Turing's Cathedral: The Origins of the Digital Universe. *By George Dyson, Pantheon Books, New York, 2012, 432 pages, $29.95.*

Turing's Cathedral is an unconventional, surprisingly personal history. It centers on an early electronic computer, constructed at the Institute for Advanced Study in Princeton by a team led by John von Neumann. Planning for the machine began in 1946, and it was fully operational by 1952. It performed pioneering simulations of weather patterns, nuclear explosions, and what would later be called artificial life before being scrapped in 1958. Dyson knits many straggling narrative threads into this core story. He sketches the cast of characters involved with the machine and with IAS, including Klara von Neumann (John's second wife), Vladimir Zworykin of RCA (who tried and failed to provide memory tubes for the machine), legendary mathematician Kurt Gödel, visiting British computer pioneer Andrew Booth, and such Los Alamos scientists as Edward Teller and Stanislaw Ulam. Dyson expands these sketches to explore other work of his characters during the era; some of his story's threads originate in the prehistory of IAS, while others extend forward into a science fiction future of intelligent machines.



Why does Alan Turing (1912–1954) peer out from narrow slits in the dust jacket of a book about John von Neumann's computer?

Why does mathematician, computer pioneer, code breaker, and posthumous gay icon Alan Turing (1912–1954) peer out from narrow slits in the dust jacket of a book about John von Neumann's computer? Dyson never explains his title directly. Perhaps it has something to do with the frenzy surrounding the Turing centennial in 2012. Publishers do like to sell books, and poor old von Neumann has faded almost completely from popular memory, while Turing's cultural prominence only rises. Turing does eventually appear in chapter 13, toward the end of the book, and a little later we unexpectedly discover that the titular cathedral is Google's corporate headquarters.

Dyson (son of the physicist Freeman Dyson) brings these characters to life more effectively than any other writer on the history of early computing. He begins by recalling a childhood spent roaming the halls of IAS to chat with its staff, and later mentions playing games with parts of the scrapped computer. His affection for both is palpable. The human characters are drawn with confidence. Thanks to his perseverance and personal connections, Dyson was able to track down and interview most of the surviving participants, including the reclusive Julian Bigelow, the leading engineer on the project; with well-chosen and often poignant quotations, he has encapsulated their motivations and struggles. He also obtained access to important papers from Klara von Neumann, which are still held in the basement of von Neumann's daughter Marina von Neumann Whitman. Dyson reconstructs Klara's story in compelling detail, rescuing an important contribution to early computing that was merely noted in passing by earlier authors. (Disclaimer: He has been kind enough to pass some of these papers along to me for my own research.)

The computer is similarly humanized. Dyson highlights the huge engineering challenges that faced all computer projects of the 1940s, and makes effective use of the machine's log book to dramatize the constant battle involved in keeping it running with tolerable reliability. One fortunate result of his efforts is that the computer project archives at IAS, where he spent time as a fellow researching the book, have been properly organized and made available to the public.

The tone and structure of *Turing's Cathedral* reminded me less of conventional history and more of the kind of nonfiction that bridges travel and science writing, practiced in different forms by such writers as Bill Bryson and John McPhee. Readers are collected at the beginning of a journey and deposited at the end, but in between their guide ventures down some unexpected byways, throws in long passages on tangentially related topics, and builds up to some personal musings on the meaning of life. If the author has a knack for weaving scraps together, and a voice that entertains rather than grates, the reader will leave the ride happier and wiser. I found Dyson's zesty prose engaging but would have preferred a tighter focus. Readers are tested early, as the world of early computing sketched in the first chapter abruptly vanishes. Von Neumann reappears eventually, but not before Dyson has led us though the entire history of Princeton, from the Lenape clans to the building of a permanent home for IAS.

I particularly welcome Dyson's explorations of the machine's applications to various areas of science, in particular its close relation with Los Alamos and the nuclear weapons program. Discussion of early machines has too often focused on their design and construction, at the expense of the work for which they were constructed. Dyson's book enjoys a far higher profile than any other recent work on the history of computing, publicized with a spate of media appearances and reviewed, seemingly, in every newspaper and magazine that still employs book reviewers. Many of its readers will know nothing of the history of computing, and will be immersed in a fascinating and richly depicted slice of history.

Yet, as a professionally trained historian, I very much hope that Dyson's idiosyncratic work will serve more often as an introduction to scholarly writing on the topic than as a substitute for it. His insistence on the IAS computer and its "fully electronic random access storage matrix" as "as close to a point source" for the origin of the "digital universe" as "any approximation can get" reflects an urge to explain a particular episode as the singular origin of something vast. Pinpointing beginnings is a primal driver of storytelling—consider the Book of Genesis. But historians have spent decades trying to move beyond partisan advocacy for one or another great man as the true inventor of the computer. Looking for a point source leads to history as viewed through a fisheye lens.

When discussing the influence of von Neumann on computing, historians traditionally focus on the 1945 "First Draft Report on the EDVAC" circulated under his name. His personal responsibility for many of the ideas set forth in the document has frequently been disputed, but its huge influence on the computer projects initiated over the next few years has not. Historians who have looked more closely at the era also credit an early description of the planned design for the IAS computer, circulated in 1946, and its early revisions as an important influence on many of these projects. The physical, functional computer was much less influential, in part because engineering delays resulted in its completion only after at least one of the machines modeled on its detailed design was already operational. One of Dyson's idiosyncrasies is to write as if these three achievements could not be separated, commenting relatively little on the 1945 "First Draft." He places the full burden of universe-changing historical importance on the physical IAS computer, which ran its first program in 1951, rather than on ideas that many others had already embraced, and indeed extended, years earlier.

Dyson boosts the historical importance of the IAS computer by omitting or downplaying information on developments elsewhere before or during 1951, with the exception of a tiny 1948 prototype computer at the University of Manchester from which von Neumann's team took the memory technology. Dyson's evidence is truthful, but startlingly incomplete. For example, while he concedes in his introduction that "the IAS machine was not the first computer," he never mentions EDSAC, operational at the University of Cambridge in 1949, which historians have almost universally recognized as the first useful computer built on the model described by von Neumann in 1945. It was also in 1949 that the Manchester team got its memory technology working in a full-scale computer. In 1951 UNIVAC provided the first commercially manufactured computer to the U.S. Census Bureau, while in the U.K. J. Lyons and Company, best known for its chain of teashops, completed its own computer and applied it to business automation. Other computers were already operational in the Soviet Union and Australia. All those milestones pass unmentioned by Dyson.

Dyson asks in conclusion, "How did the von Neumann vector manage to outdistance all the other groups trying to build a practical implementation of Turing's Universal Machine in 1946?" Even an attentive reader might assume that this "outdistancing" involved winning a race rather than losing it by several years. Dyson's implication that the various teams of computer builders inspired by von Neumann's proposed design all saw themselves as trying to implement the computational model described by Turing in his now-celebrated 1936 paper "On Computable Numbers, with an Application to the Entscheidungsproblem" is also likely to raise howls of protest from historians who have looked at early computing.

This disengagement with the historical literature limits the scholarly contribution of the book in other ways. For example, William Aspray's impeccably researched *John von Neumann and the Origins of Modern Computing* is acknowledged in the foreword but never cited in the body of the book; when the two diverge, it is hard to know whether Dyson considered Aspray's interpretation and rejected it on new evidence. Here is one example: In 1972 Nick Metropolis, a collaborator of von Neumann's and a pioneer writer on computer history, gave a well-known paper, "A Trilogy of Errors in the History

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Eusociality

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tion structures. (This paper is not the first to point out the limitations of inclusive fitness based on mathematical arguments. In a 1984 paper in the *Proceedings of the National Academy of Sciences*, for example, biologist Carlos Matessi and mathematician Samuel Karlin concluded that Hamilton's rule has quantitative validity only in the special case of linear fitness functions.)

Nowak et al. begin with a simple example, which they then extend to the haploid–diploid case. The simpler model, for asexual reproduction, is a deterministic model for evolutionary dynamics described by an ordinary differential equation. In their solitary model

$$\frac{dx_0}{dt} = (b_0 - d_0)\,x_0, \qquad (1)$$

x_0 is the number of solitary queens, and b_0 is the reproduction rate and d_0 the death rate of solitary queens.

They compare that model with a eusocial model,

$$\frac{dx_1}{dt} = \sum_{i=1}^{\infty} b_i(1-q)x_i - b_1 q x_1 - d_1 x_1$$
$$\frac{dx_i}{dt} = b_{(i-1)}\, q x_{(i-1)} - b_i q x_i - d_i\, x_i, \qquad (2)$$

in which x_i is the number of colonies of size i; b_i is the reproductive rate and d_i the death rate of a queen in a colony of size i; and q is the probability that a daughter stays in the colony, which can be considered an effect of a mutation.

A eusocial strategy will be selected over a solitary strategy provided that the maximum eigenvalue, λ, of the matrix associated with the right-hand side of the eusocial model satisfies $\lambda > b_0 - d_0$. This depends, in turn, on how the demographic parameters of the queen change as the size of the colony increases. If for a colony of size m, $i < m$, the reproductive rate and death rate of the eusocial queen remain the same as those of the solitary queen, but for $i > m$ the eusocial queen has a reproductive rate of at least $b > b_0$ and a death rate of at most $d < d_0$, then a necessary condition for the selection of eusociality is

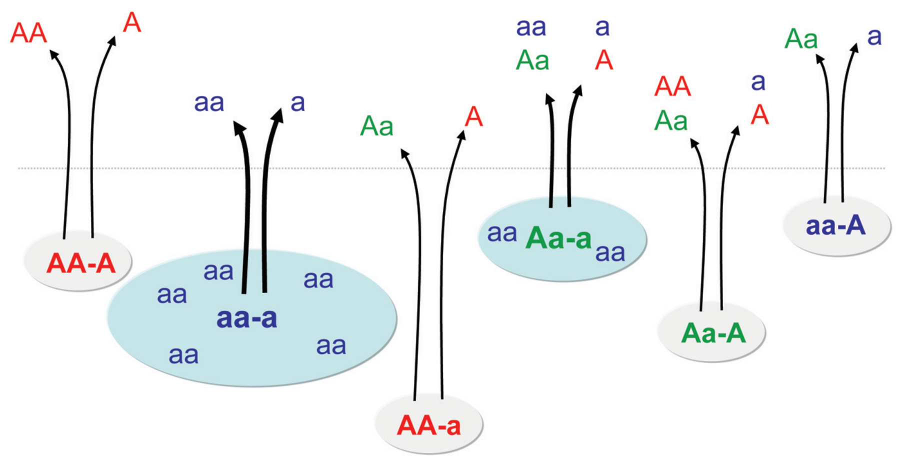
$$b > k_m\,(b_0 + (d - d_0)). \qquad (3)$$

The value k_m grows exponentially with m. For small colonies to evolve eusociality, the reproductive rate of the queen must be increased.

This model can be extended to account for density limitations on reproductive rate and worker mortality—in the former, by multiplying the values of b by a factor $\varphi = 1/(x_0 + \eta X)$, where X is the total population size, and in the latter, by adding the following terms to the equations (2):

$$\alpha x_2 \qquad \text{for } i = 1;$$
$$-\alpha(i-1)x_i + \alpha i x_{(i+1)} \quad \text{for } i > 1,$$

where α is the worker death rate.



Colony structure for the haploid–diploid model of Nowak, Tarnita, and Wilson.

For the parameter values $b_0 = .5$, $d_0 = .1$, $m = 3$, $b = 4$, $d = .01$, $\eta = .01$, and $\alpha = .1$, eusociality is selected for an intermediate range of values ($.36 < q < .9$). For low values of q, there is a small chance that a colony will reach critical size; for large values of q, the colonies produce too few new queens.

The authors build a model for the key case of sexual reproduction with haploid–diploid genetics. They consider a dynamic evolution model to study competition between two alleles, a wildtype allele denoted "A" and a mutant allele denoted "a" that causes daughters to stay in the colony with some probability. There are then three different types of females, AA, Aa, and aa, with probabilities of staying in the colony 0, q_2, and q_3, respectively. If the mutant allele a is dominant, $q = q_2 = q_3 > 0$; if it is recessive, only $q = q_3$ is positive. There are two types of males, A and a, and as a result six types of fertilized queens, AA-A, AA-a, Aa-A, Aa-a, aa-A, and aa-a, where the last letter indicates a wildtype or mutant mate.

The resulting system of equations is similar to the one for the simple case. There are equations for the number of colonies of size i associated with each type of queen, supplemented by three equations, one for the number of each type of virgin female and two for the number of each type of male. These latter equations require three parameters (g, h, β) that specify the death rate of females, the death rate of males, and the rate of successful mating. It is assumed that the males do not die after mating, but have a short lifespan and are thus unlikely to mate more than once.

Assuming that the initial state is dominated by the solitary allele A, Nowak et al. simulate the system for the same parameter values considered in the above example and for values $g = h = .1$ and $\beta = .1$. At equilibrium, they ask, which allele wins the competition as a function of q? If a is dominant, then for $.26 < q < .88$, the eusocial allele wins and for $.88 < q$ there is coexistence of alleles. If a is recessive, the solitary allele A wins the competition as long as $q < .7$; for $.7 < q < .88$, the eusocial allele a wins, and for $.88 < q$, the two alleles coexist.

Based on their model, the authors make the following observations: First, it is difficult to evolve eusociality because of the dependence on favorable parameters—e.g., an increased birth rate. Second, the haploid–diploid model is bistable, and is more easily maintained than evolved. Third, inclusive fitness is not needed to explain eusociality. Finally, once eusociality is evolved, relatedness becomes a consequence of eusociality, rather than a cause of it.

Evolutionary biologists continue to pose objections to the paper, none of which address the model. The future would seem to hold opportunities for refining evolutionary models and gathering the experimental data to support model parameters.

William Kolata is SIAM'S technical director.

IAS Computer

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of Computing." One of these common errors was calling von Neumann's computer "MANIAC." Metropolis insisted that this was not, and never had been, its name and that "MANIAC" should be reserved for the computer he had built at Los Alamos patterned after von Neumann's design. Aspray, and others who subsequently discussed the computer, therefore called it simply the "IAS computer." Alone among its cohort, it is denied a short, unique acronym. To Dyson, however, it is MANIAC throughout. This might be right. He may have learned the truth from new documents or from his oral histories. Perhaps the machine was known within von Neumann's team as MANIAC until someone realized that this glibness would not help their already rocky relationship with the pure scientists of IAS. Dyson does write that the name was "removed" by 1954. Perhaps Metropolis had a selective memory. But because Dyson ignored the existing consensus, rather than acknowledging it and justifying his challenge, he is unlikely to overturn it.

Dyson sometimes makes effective use of technical details to convey the world of early machines, as in his opening claim that in 1953 the world held just 53 KB of operational "high speed random access memory" (by which he means cathode ray tube storage), 5 KB of which were at IAS. At other points his reliance on metaphor rather than detailed explanation can be frustrating. Dyson puts great importance on the transition of computer memory from the one-dimensional tape in the conceptual Turing machine to the "two-dimensional" storage matrix found in a computer memory tube. Yet the physical tube existed in three dimensions, while its storage was treated by the programmer as a single series of numbered locations. The relevant shift was from sequential to random access, not from one- to two-dimensional storage.

The book is generously footnoted, and Dyson has supplemented his oral history interviews and newly discovered sources with visits to several existing archives. Yet his use of these sources is a little erratic. I am currently researching the Monte Carlo calculations performed by von Neumann's group on ENIAC in 1948 and had made copies of several documents cited by Dyson. Within his three pages on this topic and their footnotes I discovered eight distinct errors, mostly transcription problems in quotations, such as "16 cycles" for "160 cycles," omission of words in quoted passages without ellipsis, and the attribution of details from a 1949 letter to an episode in 1948. To Dyson's credit, he has made efforts to correct these in the forthcoming paperback edition. Those minor errors do not undermine the substance of his story, but their density makes me reluctant to rely on details elsewhere in the book without external confirmation.

The best way to decide whether you would enjoy *Turing's Cathedral* may be to check the reader comments at Amazon.com. Scores currently have bimodal distribution, with five- and two-star reviews the most numerous. Try to figure out which score might predict your reaction. The two-star reviews come from people frustrated by the book's insular perspective, insistence on the IAS computer as the singular origin point of modern computing, relaxed sense of chronology, lengthy digressions, and philosophical musings on the "digital universe." His fans praise Dyson's lively and elegant prose, eye for interesting details, and boldness in building what he himself calls a "creation myth" for the modern world. Both judgments are amply supported by the text.

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GRACE

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to those forces than the trailing one, pulling farther ahead of it temporarily. As this happens, the speed at which the intervening gap opens reflects the mass of the gravitating feature. By monitoring that gap, the GRACE scientists are able to measure the masses of significant surface features, with

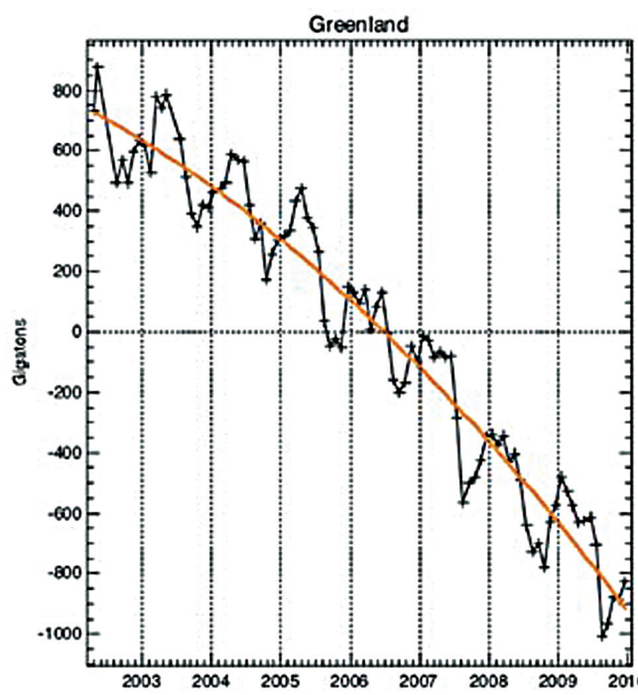

Figure 2. *Mass variability summed over the entire Greenland ice sheet, between April 2002 and December 2009. The black line depicts monthly Gravity Recovery and Climate Experiment (GRACE) results; the orange line is a smoothed version.*

the result expressed in terms of centimeters of water spread over a stated area. Thus, for instance, the Greenland ice sheet is roughly as massive as a puddle 4 cm deep covering an area the size of Colorado. The gap separating Tom and Jerry is measured both by triangulation with GPS satellites in higher Earth orbits, and by high-frequency Doppler ranging equipment installed on both satellites. Lastly, each one carries an accelerometer capable of filtering out the effects of atmospheric drag (unavoidable in low Earth orbit) and other non-gravitational forces.

With GRACE data, the Earth's geoid can be accurately recomputed every 2 to 4 weeks, which permits investigators to estimate the magnitude of seasonal changes in such properties as the amount of water in the soil of various agricultural regions, the depth of the water in each of the seven seas, and the thickness of the Greenland and Antarctic ice sheets. The water in the Atlantic Ocean is deepest, for instance, between January and March, the Indian and Pacific Oceans being then at low ebb. The results concerning the Greenland ice sheet are particularly interesting.

As shown in Figure 2, the sheet is melting fastest along the southeastern shore of the island and in a smaller region on the western shore; Figure 3 displays the total mass of the sheet at monthly intervals since 2002. The seasonal variations, a result of the accumulation of snow and ice in winter and the melting thereof in summer, are plainly visible, as is the downward sloping trend line. The fact that the trend line curves downward from left to right leaves little doubt that the ice sheet is disappearing at a steadily increasing rate. Observers on the ground have long suspected as much, but evidence has been hard to come by. At last, their suspicions are confirmed! GRACE data indicates that the Antarctic ice sheet is disappearing as well, but at a more nearly constant rate.

James Case writes from Baltimore, Maryland.

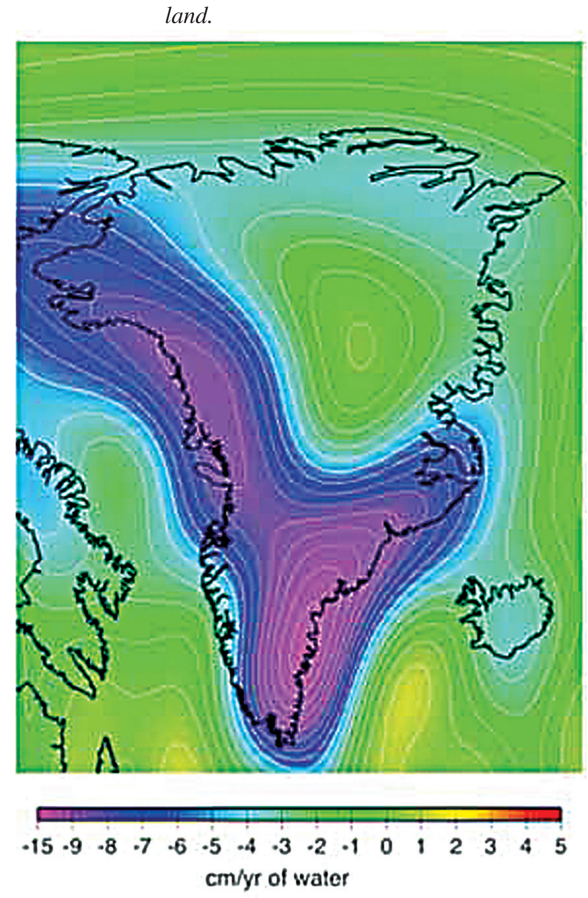

Figure 3. *Distribution of mass loss rate across Greenland, as determined from the GRACE solutions.*

MAM 2013

continued from page 3

creating a speakers bureau so that colleges, universities, and even schools and community groups that would like to organize a talk about math and sustainability can find speakers. Anyone interested in being part of the speakers bureau is encouraged to register on the website. And, of course, in keeping with our theme of sustainability, we encourage groups to invite speakers from their local area rather than flying someone in. Under the motto "Sustainability Counts!" we are collecting teaching materials that connect math and sustainability so that teachers and faculty can engage their students in a sustainability-themed math lesson during Math Awareness Month.

What inspired you to create these new features?

With the world facing such a wide range of sustainability challenges, we wanted to take advantage of this high-profile venue to get the message out that mathematics has an important role to play in sustainability and to encourage all segments of the mathematics community—researchers, teachers, and students—to get involved in seeking solutions. We hope that readers who care about this issue will organize local events—at their institutions, perhaps jointly with schools or community groups, or in partnership with sustainability practitioners. I have found that having a title made it easier for me to take initiative and reach out to people, so I hereby deputize each reader as the chair of a local Math Awareness Month organizing committee. We urge all to share their stories on the Activities section of the website so that others can be inspired by their efforts!

To see the poster, the essays, more information on the speakers bureau, and other features of Math Awareness Month, visit www.mathaware.org.

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 $2.70 per word (minimum $325.00). Display advertising rates are available on request.*

Advertising copy must be received at least four weeks before publication (e.g., the deadline for the May 2013 issue is March 29, 2013).

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

Institute for Mathematics and its Applications University of Minnesota

Call for Nominations: Director

The Board of Governors of the Institute for Mathematics and its Applications (IMA) and the University of Minnesota invite applications for a new director of the IMA, with appointment beginning in July 2015. Distinguished academic credentials, including a PhD or equivalent and a record of scientific leadership, are required. Candidates should have the qualifications to provide scientific and administrative leadership to the IMA. Salary and length of term as director of the IMA are negotiable. The director will be offered a tenured professorship in an academic department at the University of Minnesota. Applicants should have an outstanding track record of research and teaching accomplishments. A candidate's expertise and documented research activities must demonstrate a strong potential toward enhancing both the department's research and the undergraduate and graduate teaching missions; however, teaching responsibilities of the acting IMA director are waived and other departmental duties will be determined at the discretion of the department head.

The IMA was established in 1982 with financial support from the National Science Foundation. The institute connects scientists, engineers, and mathematicians in order to address scientific and technological challenges in a collaborative, engaging environment, developing transformative new mathematics and exploring its applications, while training the next generation of researchers and educators.

Applications, consisting of a cover letter and curriculum vitae, must be submitted through the MathJobs.org website: https://www.mathjobs.org/jobs/jobs/4603. Consideration of applications will begin March 15, 2013. Nominations and questions regarding the position should be addressed via e-mail to: Search Committee Chair, search@ima.umn.edu.

The University of Minnesota is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, color, creed, religion, national origin, sex, age, marital status, disability, public assistance status, veteran status, or sexual orientation.

香港城市大學
City University of Hong Kong

Worldwide Search for Talent

City University of Hong Kong is a dynamic, fast-growing university that is pursuing excellence in research and professional education. As a publicly-funded institution, the University is committed to nurturing and developing students' talent and creating applicable knowledge to support social and economic advancement. Currently, the University has six Colleges/Schools. Within the next two years, the University aims to recruit **100 more scholars** from all over the world in various disciplines, including **science**, **engineering**, **business**, **social sciences**, **humanities**, **law**, **creative media**, **energy**, **environment**, and other strategic growth areas.

Applications and nominations are invited for:

Chair Professor/Professor/Associate Professor/Assistant Professor
Department of Mathematics *[Ref. A/094/49]*

Duties : Conduct research in areas of Applied Mathematics including Analysis and Applications, Mathematical Modelling (including biological/physical/financial problems), Scientific Computation and Numerical Analysis, and Probability and Statistics; teach undergraduate and postgraduate courses; supervise research students; and perform any other duties as assigned.

Requirements : A PhD in Mathematics/Applied Mathematics/Statistics with an excellent research record.

Salary and Conditions of Service
Remuneration package will be driven by market competitiveness and individual performance. Excellent fringe benefits include gratuity, leave, medical and dental schemes, and relocation assistance (where applicable). Initial appointment will be made on a fixed-term contract.

Information and Application
Further information on the posts and the University is available at http://www.cityu.edu.hk, or from the Human Resources Office, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong [Fax : (852) 2788 1154 or (852) 3442 0311/email : hrojob@cityu.edu.hk].

Please send the nomination or application with a current curriculum vitae to Human Resources Office. **Applications and nominations will receive full consideration until the positions are filled.** Please quote the reference of the post in the application and on the envelope. Shortlisted candidates for the post of Assistant Professor will be requested to arrange for at least 3 reference reports sent directly by their referees to the Department, specifying the position applied for. The University reserves the right not to fill the positions. Personal data provided by applicants will be used strictly in accordance with the University's personal data policy, a copy of which will be provided upon request.

The University also offers a number of visiting positions through its "CityU International Transition Team" for current graduate students and for early-stage and established scholars, as described at http://www.cityu.edu.hk/provost/cityu_international_transition.htm.

City University of Hong Kong is an equal opportunity employer and we are committed to the principle of diversity. We encourage applications from all qualified candidates, especially those who will enhance the diversity of our staff.

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

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Old Dominion University

Department of Mathematics and Statistics
Graduate Programs

The Department of Mathematics and Statistics at Old Dominion University invites excellent students to apply for graduate assistantships in its vigorous applied mathematics and statistics MS and PhD programs for the 2013–2014 academic year.

ODU faculty are active in various areas of applied and computational mathematics, scientific computing, analysis, and numerical analysis, and play key roles in the ODU multidisciplinary Modeling and Simulation Graduate Program and the Center for Computational Sciences in the College of Sciences. ODU faculty enjoy an excellent funding record, including funding by NSF, NIH, NASA, AFOSR, Army, and other federal and state funding agencies.

A link to the graduate programs, which includes contact and application information, can be found at http://sci.odu.edu/math/academics/grad.shtml.

RTG Summer School on Microlocal Analysis and Inverse Problems

July 8–26, 2013
University of Washington, Seattle

The Research Training Group in the Department of Mathematics at the University of Washington will host a summer school on solving inverse problems via microlocal analysis, aimed at graduate students and advanced undergraduates who have the required background. Students will attend lectures in the morning and problem sessions in small groups with mentors in the afternoon. On-campus accommodation and meals will be provided, plus a travel allowance of up to $600. The Summer School is supported by an NSF Research Training Grant. Support is restricted to U.S. citizens/permanent residents; international students can be considered but will have to pay all their own expenses.

The course will be taught by Mark Anastasio, Guillaume Bal, Francois Monard, Plamen Stefanov, and Gunther Uhlmann.

Prospective attendees can visit the website for a full course description and prerequisites.

URL: http://www.math.washington.edu/ipde/summer/.

GSMMC 2013: Graduate Student Mathematical Modeling Camp

June 11–14, 2013
Rensselaer Polytechnic Institute

The Department of Mathematical Sciences at RPI is pleased to announce the 10th 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 26, 2013.

Graduate students attending the GSMM Camp are also invited to participate in the Mathematical Problems in Industry (MPI) Workshop, to be held at Worcester Polytechnic Institute during the week following the camp. For further information about MPI 2013, students should visit http://www.math.wpi.edu/MPI2013/.

International Symposium on Fractional PDEs: Theory, Numerics, and Applications

June 3–5, 2013
Newport, Rhode Island

The International Symposium on Fractional PDEs: Theory, Numerics, and Applications will take place on June 3–5, 2013, at Salve Regina University, in Newport, Rhode Island. Fractional partial differential equations are emerging as a powerful tool for modeling some of the most difficult types of complex systems, i.e., systems with overlapping microscopic and macroscopic scales, and systems with long-range time memory or long-range spatial interactions. The purpose of this workshop is to bring together leaders in the theory, numerical methods, and advanced applications of FPDEs, to highlight the current state of this important topic and point forward to new developments.

A tentative list of speakers includes: D. Baleanu (Turkey), K. Burrage (UK), W. Chen (China), Y. Chen (USA), W. Deng (China), K. Diethelm (Germany), R. Gorenflo (Germany), E. Hanert (Belgium), B. Henry (Australia), S. Holm (Norway), C. Li (China), F. Liu (Australia), F. Mainardi (Italy), W. McLean (Australia), M. Meerschaert (USA), S. Momani (Jordan), M. Moradi (Iran), I. Podlubny (Slovakia), A. Sikorskii (USA), Z. Sun (China), S. Umarov (USA), H. Wang (USA), B. West (USA), and S. Yuste (Spain).

More information can be found at: http://www.dam.brown.edu/International%20Symposium/internationalsymposiumonfractionalPDEs.htm.

The symposium is sponsored by ARO, AFOSR, and the new Collaboratory on Mathematics for Mesoscopic Modeling of Materials (CM4), supported by DOE.

Organizers: George Em Karniadakis and Jan Hesthaven, Brown University.

Institute for Mathematics and its Applications

Minneapolis, Minnesota

The Institute for Mathematics and its Applications, located on the University of Minnesota campus, recently announced the following upcoming programs and opportunities:

2013–2014 Thematic Program: The IMA will soon launch its new annual Thematic Program, to run from September 2013 to June 2014. The theme—Scientific and Engineering Applications of Algebraic Topology—will gather researchers from topology, computational geometry, networking, statistics, biology, and other fields to address methods for qualitative analysis and recognition problems in contemporary contexts, including data (finite metric spaces as samples from experiments, surveys, or sensors), networks (Internet traffic, gene regulation, coordinated robotics, communications), and dynamics (systems equipped with only finite resolution or those that are stochastic). The six workshops planned for the year are designed to be truly interdisciplinary. More information about this year's workshops and the thematic program are available online at http://www.ima.umn.edu/2013-2014.

Call for Proposals: Hot Topics Workshops. The IMA's Hot Topics Workshops cover rapidly developing areas of interests, focusing on a specific problem or area of exceptional contemporary significance. These workshops are often cosponsored by a participating institution, corporation, government funding agency, or an NSF-focused research group. More information on submitting a workshop proposal is available online at http://www.ima.umn.edu/solicit/hot-topics-guidelines.html.

New Directions Research Professorships: Applications are invited for New Directions Research Professorships, which provide an extraordinary opportunity for established mathematicians—typically mid-career faculty at U.S. universities—to branch into new directions and increase the impact of their research by spending an academic year immersed in the thematic program at the IMA, where they learn new mathematics and applications, connect their research with important problems, and establish new contacts and collaborations. Applications for professorships during the 2013–2014 (Scientific and Engineering Applications of Algebraic Topology) and 2014–2015 (Discrete Structures: Analysis and Applications) thematic programs are still being accepted. Readers can visit http://www.ima.umn.edu/new-directions for more information as well as an online application.

New Directions Short Course: Applied Statistics and Machine Learning. From June 17 to 28, 2013, the IMA will hold its New Directions Short Course, titled "Applied Statistics and Machine Learning." Applications are now being accepted for the two-week course, organized by Bin Yu (University of California, Berkeley) and David Madigan (Columbia University); the course will introduce participants to a broad array of modern statistical concepts and techniques, with a focus on critical thinking and practical data analysis. The statistical software R will be used extensively and students are expected to have at least rudimentary knowledge of R prior to the course. The course will cover exploratory data analysis (visualization, dimension reduction, clustering), statistical modeling (linear models, generalized linear models, logistic regression, graphical models), and statistical computation (Monte Carlo, Markov chain Monte Carlo, convex optimization). The course will also cover regularized and large-scale modeling techniques.

More information and an online application are available at http://www.ima.umn.edu/2012-2013/ND6.17-28.13. The deadline for applications is April 15, 2013.

New Momentum for Applied Mathematics in East Asia

By Ming-Chih Lai and Irene Fonseca

With more than 120 participants from the region, the 8th conference of the SIAM East Asia Section set a record for attendance. Held at the National Taiwan University, in Taipei, June 25–27, 2012, EASIAM2012 featured SIAM keynote speakers Yalchin Efendiev (Texas A&M University) and Linda Petzold (UC Santa Barbara), who presented work at the frontiers of generalized multiscale finite element methods and spatial stochastic amplification in cell polarization, respectively. Regional invited speakers were Hitoshi Arai (University of Tokyo), Victor Didenko (University of Brunei Darussalam), Leevan Ling (Hong Kong Baptist University), Weiqing Ren (National University of Singapore), and Wei-Cheng Wang (National Tsing Hua University). Student Paper Prizes were awarded to Xuanchung Dong (National University of Singapore), Zhenning Cai, (Peking University), and Seogjeong Lee (Seoul National University); with support from SIAM, each student received a $300 award.

Perhaps the most exciting nontechnical moment (besides the banquet with a performance of traditional Chinese music) came at the closing ceremony, when two new iPads and other prizes were given. What a fun, joyful way to wrap up this exciting conference!

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The opportunity to host EASIAM2012 injected new momentum into applied mathematics in Taiwan. One indication was the kickoff meeting of the Taiwan Society for Industrial and Applied Mathematics (TWSIAM), after two years of preparation, on the second evening of EASIAM2012.

As the host of EASIAM2012, the mathematical community in Taiwan demonstrated the role it has played in advancing applied mathematics in East Asia in the past few decades. About twenty years ago, Taiwanese students started to return home in large numbers after receiving their PhDs abroad (mostly in the U.S.), and mathematical research in Taiwan has progressed significantly ever since. The National Center for Theoretical Sciences (NCTS), established in 1997, has given a boost to core, strategic areas of mathematical research in Taiwan, including number theory, algebraic geometry, and partial differential equations. More recently, several Taiwanese universities have joined the effort to strengthen the mathematical sciences by creating research centers, including the Taida Institute for Mathematical Sciences (TIMS) at the National Taiwan University, and the Center of Mathematical Modeling and Scientific Computing (CMMSC) at the National Chiao Tung University, to name just a few.

In addition to the activities at the universities, the Institute of Mathematics at Academia Sinica has served as a forum for the mathematical community worldwide; it also offers extensive postdoctoral and assistantship programs. The Mathematical Division of the Taiwanese National Science Council has created a subdivision for Interdisciplinary Mathematical Sciences, which, starting in 2013, will support and encourage mathematicians to engage in research that crosses disciplinary boundaries.

The annual meeting of the Mathematical Society of Taiwan, along with exchange participants from Japan and Korea, regularly features internationally recognized invited speakers. (In 2012, Ching-Li Chai of the Academia Sinica and the University of Pennsylvania and Irene Fonseca, of Carnegie Mellon University, then SIAM president-elect, were among the plenary speakers.)

Pictured at the meeting of the Mathematical Society of Taiwan at National Chiao Tung University, Hsinchu, Taiwan, December 2012 (from left): Henry Horng-Shing Lu, Ming-Chih Lai (EASIAM president), Ching-Li Chai, Sze-Bi Hsu, Yan-Hwa Wu (NCTU president, Taiwan), Irene Fonseca (SIAM president), Gerard Jennhwa Chang (TMS president, Taiwan), Jong Hae Keum, Myung Hwan Kim (KMS president, Korea), Hyungju Park, Dongsu Kim (NIMS president, Korea), I-Liang Chern (TWSIAM president, Taiwan), and Chiuyuan Chen.

In many additional ways, 2012 was a fruitful year for mathematics in Taiwan. NCTS organized and generously supported a special year in applied mathematics, which ended on a high note with an international workshop, Theoretical and Computational Challenges in PDEs, and a Distinguished Lecture by Fanghua Lin, "Theory and Applications of Homogenization." In January 2012, ten months before his article appeared in *SIAM News*, Bob Eisenberg made mathematicians aware of the potential benefits of research on ionic solutions at a workshop, Mathematical Models of Electrolytes with Application to Molecular Biology, held at TIMS. A small focused group on biological complex fluids that formed after the workshop continues to work on this front. Finally, in September 2012, prior to the worldwide launch of Mathematics of Planet Earth 2013 (MPE2013), TIMS held a five-day workshop titled International Science Conference on Climate Change: Multidecadal and Beyond, bringing together applied mathematicians and researchers from atmospheric, oceanic, geophysical, meteorological, and environmental sciences to exchange ideas and to address issues arising with climate change.

The future for applied mathematics in Taiwan is exciting! Stay tuned!

Ming-Chih Lai of National Chiao Tung University, Taiwan, is president of the SIAM East Asia Section. Irene Fonseca is president of SIAM.

SIAM Journals Introduce Supplementary Materials

Recently an ad hoc Committee on Supplementary Materials* formulated a number of recommendations for expanding the online options associated with papers published in SIAM journals. Some of these recommendations have now been implemented, and the options are available to authors, starting with the following journals: *SIAM Review, SIAM Journal on Matrix Analysis and Applications, SIAM Journal on Scientific Computing*, *SIAM Journal on Mathematical Analysis,* and *SIAM Journal on Numerical Analysis*. Other journals will soon join this group.

Supplementary Materials, which will be posted online with a link from the webpage for the paper, will consist of un-refereed materials that the author(s), referees, and editor agree are appropriate to accompany the publication. These might include animations of results shown in the paper, additional figures or examples that may be useful to the reader in understanding the paper, or computer code or data sets that were used in generating figures or tables in the paper. Archiving these as Supplementary Materials to accompany the paper will insure that they are available to readers of the journal at a stable URL, and can be cited using the DOI of the article. The refereed portion of the paper should stand on its own as the official publication, while the Supplementary Materials are intended to complement the paper.

All Supplementary Materials must be submitted along with the manuscript, accompanied by an index that lists each attachment and a justification for including it. SIAM submission forms for the journals affected have been redesigned to allow this; details on preparing and submitting this content can be found on the journal-specific Supplementary Materials webpages at http://www.siam.org/journals/.

Referees will be asked to give these materials at least a cursory look to insure that they are appropriate as material associated with the paper. Beyond this, Supplementary Materials are generally not refereed, but the referees or editor may suggest changes, including removing some extraneous Supplementary Materials or moving nonessential items from the main text to the Supplementary Materials.

By identifying a broad range of Supplementary Materials, we hope to encourage authors to submit data or computer code that is a critical component of the scholarship contained in the paper. This will go beyond aiding the reader who wants to understand the details of the work presented. Many funding agencies now require that data and/or computer code associated with published research results be made publicly available. The availability of electronic archives for material associated with SIAM publications may assist our authors in complying with such requirements.

On a related topic, authors are also encouraged to use appendices for traditional printed material that should be refereed and published along with the paper, but that need not be part of the main flow. Appendices will continue to be handled as in the past and will appear as part of the paper. We believe that increased use of appendices, together with the capability of attaching Supplementary Materials, will help authors streamline papers for readability while still including all the necessary components to fully document and illustrate the research presented.

*Pavel Bochev, Sue Brenner (ex officio, former VP for Publications), Pam Cook (ex officio, VP for Publications), Jim Crowley, Tom Grandine, Hans Petter Langtangen, and Randy LeVeque (Chair).