Newsjournal of the Society for Industrial and Applied Mathematics sinews.siam.org

siam news

Volume 50/ Issue 9
November 2017

Multiscale Understanding of Vascular Adaptation: The Vein Graft Model

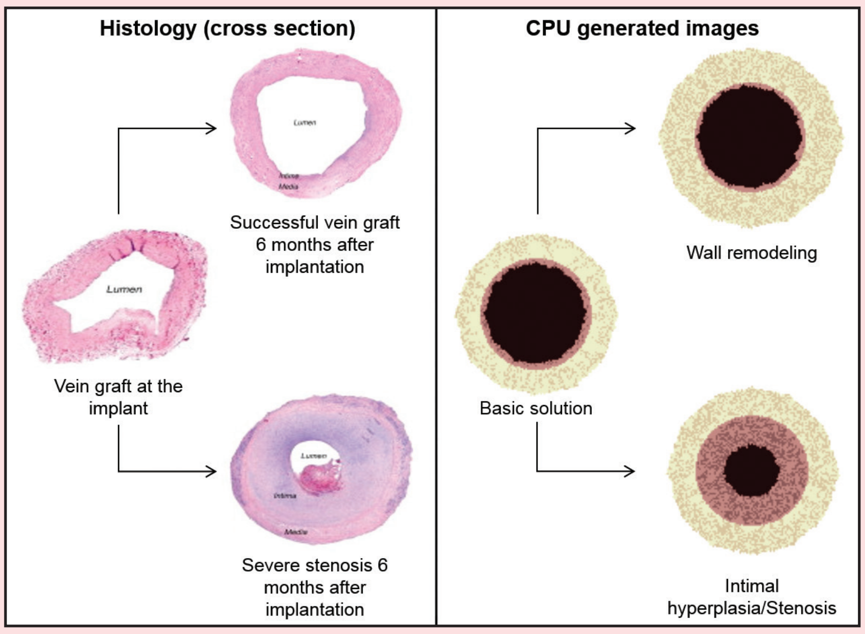


Figure 3. *Clinical observation of a vein graft success and failure six months after surgery (left), replicated with an agent-based model (right). The black portion represents the lumen, the pink portion represents the tunica intima, and the beige portion represents the tunica media. Image courtesy of [5].*

In an article on page 6, Marc Garbey, Stefano Casarin, and Scott Berceli explore ways to improve vein graft durability in patients with cardiovascular disease.

Toward a "Thermodynamics" of Collective Behavior

By Nicholas T. Ouellette

Wheeling flocks of birds, swirling schools of fish, stampeding herds of ungulates: these are some of the most spectacular sights in the natural world. Animal aggregations like these seemingly represent examples of "collective behavior," in which group form and dynamics arise spontaneously without one or more animals in charge or possessing global information. This paradigm's dissimilarity to the way people tend to approach design and control has led to significant interest in the aggregations. How, for example, is the large-scale motion of a flock of birds coordinated, and how does it maintain cohesion? Why do groups often outperform individuals in accomplishing tasks, and how can one predict this solely from information about group makeup and individual interactions? The answers to these and related questions are not only of fundamental interest, but also have potential application to the engineering of distributed systems ranging from swarms of robots to fleets of self-driving cars.

As with any question in physics or applied math, we can both substantiate our understanding and pave the way for applications by building and validating models. In the case of collective behavior, agent-based modeling is the dominant paradigm. Each "animal" is assigned a simple behavior that it performs in isolation (such as moving in a straight line at a constant speed), in addition to a few interaction rules expected to produce the desired group behavior. These rules generally consist of a combination of a long-range attraction (to encourage aggregation), a short-range repulsion (to prevent collapse), and a tendency to align one's direction of motion with that of nearby agents (to promote group order).

Such models can successfully produce spontaneous group order, and different group morphologies—all of which are reminiscent of examples found in nature—are obtained as the relative strength and range of these rules is varied [1]. But do they actually describe real animal groups? That is a difficult question — in part because it is not clear exactly how to validate the models. Traditionally, models are evaluated based on whether the group morphology they produce resembles what is found in nature.

See **Collective Behavior** *on page 4*

New Horizons in the Study of Waves in Space-time Microstructures

By Ornella Mattei and Graeme W. Milton

In the late 1500s, Vincenzo Galilei, father of Galileo, first noticed the relation between the frequency of a vibrating string, its density, and tension on the string (made precise by Marin Mersenne in 1637). In 1747, Jean le Rond d'Alembert found the general solution with which we are all familiar today. The one-dimensional wave equation with spatially periodically-varying moduli—studied by Gaston Floquet in 1883—provides the canonical example of a band-gap, a range of frequencies where no waves propagate. In 1958, Philip Anderson found that localization would occur if the moduli were disordered. Thus, one would think that no more big surprises remain in the study of the linear, one-dimensional wave equation with varying moduli. However, this is not the case if the moduli vary in both space and time, a problem studied by electrical engineers in the 1950s and extensively explored by Konstantin Lurie and his collaborators [3]. Examples of materials with spatially and temporally-varying moduli abound: think of a liquid crystal display, or a small amplitude wave traveling on top of a large amplitude (pump) wave in a nonlinear medium. More recently, time crystals have generated some excitement.

To understand the complexity involved, one need only look at a space-time checkerboard, i.e., the wave equation in a one-dimensional, two-phase medium. Here, the moduli alternate both in space and time, having not only the familiar spatial interfaces, but also temporal interfaces, across which the material properties switch from one phase to the other. At each temporal interface, a wave splits into an outgoing wave and an incoming wave; [1] offers a brilliant experimental demonstration in water waves where one jolts the water tray upwards at a specific time to create a temporal interface. After the jolt, the waves generated by a model of the Eiffel Tower reconverge to the original shape. The Green's function generated by an instantaneous disturbance in the space-time checkerboard is thus concentrated on a complicated cascade of characteristic lines, as shown in Figure 1a. Note that the horizontal axis denotes the spatial variable and the vertical axis denotes the time variable.

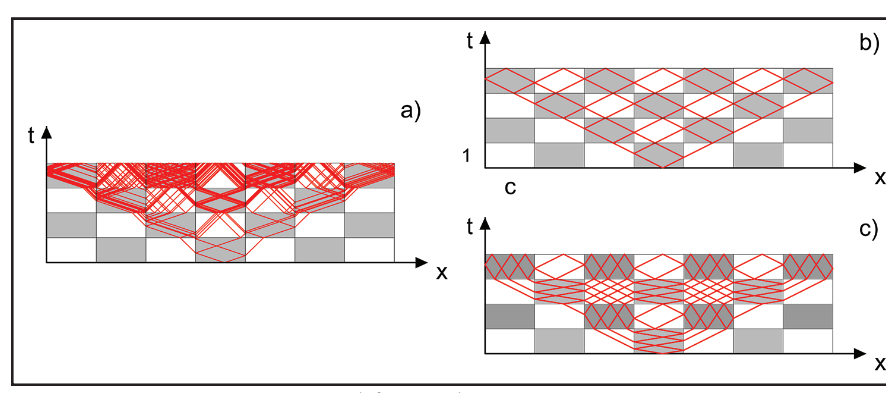


Figure 1. *The characteristic lines of Green's functions in space-time checkerboards.* **1a.** *An example of a generic space-time checkerboard. The initial disturbance propagates giving rise to a cascade of disturbances.* **1b.** *A two-phase space-time checkerboard in which the diagonals of the rectangles have the same slope as the characteristic lines in both phases (the two phases have the same wave speed $c_1 = c_2 = c$).* **1c.** *A three-phase space-time checkerboard (phase 1 is colored in white, phase 2 in light gray, and phase 3 in gray) in which the wave speeds of the phases satisfy the following relation: $c_2/c_1 = c_1/c_3 = 3$. Image credit: Ornella Mattei.*

One way to avoid this complexity is to assume that there is no impedance mismatch, and therefore no reflected wave occurring at spatial boundaries and no incoming wave created at temporal interfaces. Even though the characteristics no longer split, a surprise still exists: neighbouring characteristics can converge, creating the analog of a shock in a linear medium [4]. Our approach to avoiding the complexity is different; if the material properties are suitably chosen—as in Figure 1b and 1c—the disturbance propagates along an orderly pattern of characteristic lines that we call a field pattern. In particular, Figure 1b represents a two-phase space-time checkerboard in which the dimensions of the rectangles are related to the wave speed of the two phases, $c_1 = c_2 = c$. In contrast, Figure 1c shows a three-phase space-time checkerboard in which the wave speeds of the three phases are such that $c_2/c_1 = c_1/c_3 = 3$.

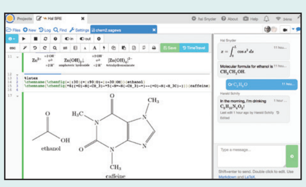
We found other examples—called field pattern materials—of space-time microstructures giving rise to field patterns [6, 7]. To discover field pattern materials, one need only draw the appropriate lines on a candidate space-time geometry. All of the microstructures in [6, 7] have the common property of P- and T-symmetry (see Figure 1b and 1c), where P and T stand for parity and time respectively. Field patterns are PT-symmetric but not separately P- and T-symmetric. Systems with PT-symmetry have been studied extensively—particularly in the context of quantum mechanics—[2], and our field pattern materials share some features with them. In particular, if the PT-symmetry is "broken," then field patterns support both propagating waves and those that can blow up or decay exponentially with time. But if the symmetry is "unbroken," all modes are propagating modes with no blow-up [6, 7].

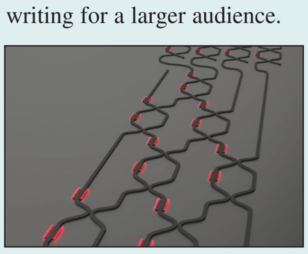
See **Microstructures** *on page 5*

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

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

siam news
Volume 50/ Issue 9/ November 2017





ORCID: A Self-Updating Digital CV

For around 50 years, commercial books have been uniquely identified by international standard book numbers (ISBNs). The more recent digital object identifier (DOI), dating back to 2000, provides a persistent digital identifier for an information source. Many *SIAM News* readers are likely familiar with DOIs for research papers, and know that a DOI can be resolved to a web address by prepending it with https://doi.org/.

What was missing until recently was a way to uniquely identify a researcher. The need for this is obvious to anyone who has tried to explore an individual's publications without access to a complete publication list. A web search is likely to bring up multiple researchers with close names who are hard to distinguish, and even a Google Scholar profile may contain spurious items belonging to similarly-named researchers if the owner does not actively maintain it.[1] MathSciNet goes to some lengths to disambiguate authors, but requires a subscription and does not cover all the literature in which mathematicians publish.

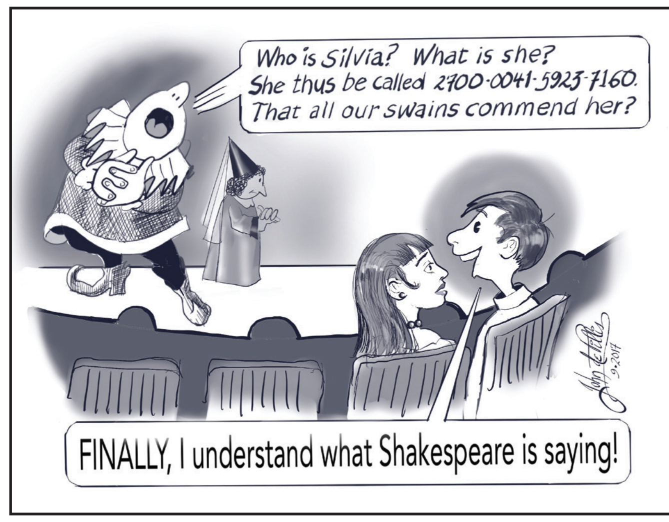
Introduced in 2012, an ORCID (open researcher and contributor identifier) is a unique identifier that allows research publications and research data to be associated with a researcher. It is a 16-digit number, written in the form xxxx-xxxx-xxxx-xxxx or as a URL, such as http://orcid.org/0000-0001-5956-4976 (my ORCID). A nonprofit organization—also called ORCID—maintains the identifiers and obtains its funds from organizational membership (SIAM is a member[2]) and subscription fees.

An ORCID iD[3] is becoming essential for researchers. My university obliges every faculty member to have one, and a growing number of publishers (including INFORMS, the IEEE, and the Royal Society) require that an ORCID iD be entered for each author submitting a paper. This is also true of certain funders in countries including Portugal, Sweden, the U.K., and the U.S.

FROM THE SIAM PRESIDENT
By Nicholas Higham

ORCID iDs are increasingly becoming a quick and unambiguous way to specify a researcher. For example, some journal platforms—such as SIAM's platform and ScholarOne—allow editors to select referees by ORCID iD.

You can register for an ORCID at https://orcid.org. Doing so creates a web page on the ORCID site that you can customize to include your publications and personal information, such as website and other web presences (repositories and social media), education, employer, and any other names by which you might be known (or used to be known). You will need to populate your ORCID record using one of the import tools. Full control over visibility of the record is available at the content heading level ("everyone," "trusted parties," or "only me").



Cartoon created by mathematician John de Pillis.

An ORCID record also includes a funding section. I listed my funding sources while writing this article, and was able to add all of my recent grants with a couple of clicks, thanks to ORCID's links with funding agencies.

SIAM has been collecting ORCID iDs from authors at submission time since June 2017. A benefit of this is that papers' metadata can be automatically posted to authors' ORCID records (provided they have granted permission) via CrossRef (the organization that creates DOIs for SIAM publications). Ultimately, it should therefore be possible for an ORCID record to be kept up-to-date without any action by the owner, who only needs to declare their ORCID ID to SIAM once. An author can do this when submitting an article or by updating their SIAM peer-review system profile.[4] For academics used to repeatedly entering the same information into different systems, ORCID's auto-updating feature should be a welcome change.

How does one get to an author's ORCID page? Typing the name into the search box at https://orcid.org/ is one way. Alternatively, some publishers now include in papers a link from an author name to the corresponding ORCID page.

ORCID is not perfect. It does not validate identification, so there is nothing to stop authors from sharing an ORCID iD, and instances of this have occurred [2]. And while a hallmark of any well-designed information system is the ability to get out whatever data is put in, ORCID currently has limited export capabilities.

At the time of writing, there are over 3.9 million ORCID records, compared with the roughly eight million scientists worldwide.[5] In a recent *Science* article [1], John Bohannon used the 25 percent of ORCID records that are publicly available and contain personal information to study researchers' mobility, identifying some interesting trends. The ORCID data shows a steady growth of foreign scientists immigrating to the U.S. since 1990, with a plateau in 2002, the year after the 9/11 terrorist attacks.

An ORCID iD is becoming an essential part of a researcher's toolkit. It provides a permanent digital CV that acknowledges a researcher's publications and grants and supplies links to them. The integration of ORCID with other information systems promises that much routine form-filling will be reduced to simply entering one's ORCID iD.

References

[1] Bohannon, J. (2017). Restless minds. *Science, 356*, 690-692.

[2] Leopold, S. (2016). Editorial: ORCID is a Wonderful (But Not Required) Tool for Authors. *Clin. Orthop. Relat. Res., 474*, 1083-1085.

Nicholas Higham is the Richardson Professor of Applied Mathematics at The University of Manchester. He is the current president of SIAM.

---

[1] I have had to remove papers from my Google Scholar profile that belong to a retired professor of history at my university with exactly the same name.

[2] https://sinews.siam.org/Details-Page/siam-is-now-a-member-of-orcid

[3] It is standard practice to refer to "ORCID iD," even though the "iD" is superfluous.

[4] https://peerreview.siam.org/

[5] http://en.unesco.org/unesco_science_report

siam news

ISSN 1557–9573. Copyright 2017, all rights reserved, by the Society for Industrial and Applied Mathematics, SIAM, 3600 Market Street, 6th Floor, Philadelphia, PA 19104-2688; (215) 382-9800; siam@siam.org. To be published ten times in 2017: January/February, March, April, May, June, July/August, September, October, November, and December. The material published herein is not endorsed by SIAM, nor is it intended to reflect SIAM's opinion. The editors reserve the right to select and edit all material submitted for publication.

Advertisers: For display advertising rates and information, contact Kristin O'Neill at marketing@siam.org.

One-year subscription (nonmembers): Electronic-only subscription is free. $73.00 subscription rate worldwide for print copies. SIAM members and subscribers should allow 8 weeks for an address change to be effected. Change of address notice should include old and new addresses with zip codes. Please request address change only if it will last 6 months or more.

Printed in the USA.

siam *is a registered trademark.*

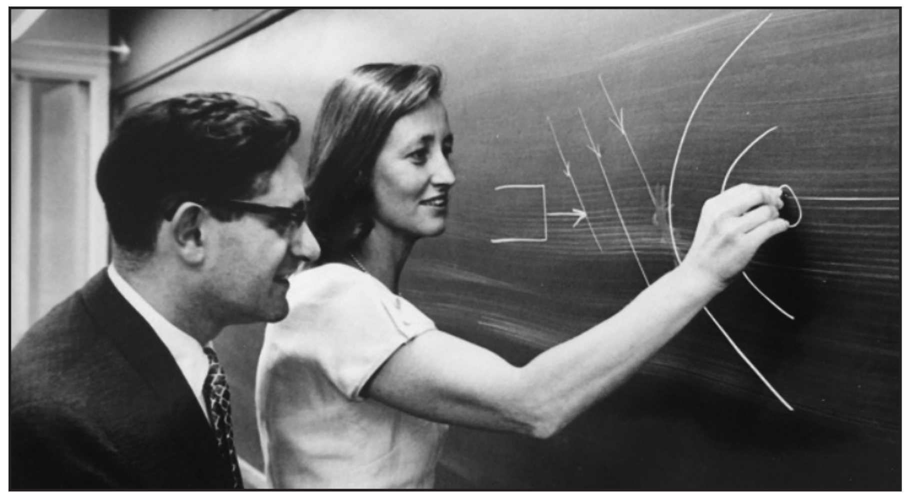
Obituaries

By Walter Strauss

Cathleen Morawetz passed away on August 8, 2017, at the age of 94. A native of Toronto, Canada, she spent most of her career at New York University's Courant Institute. Her honors were many, including the U.S. National Medal of Science, the Steele Prize, and the Birkhoff Prize. She was also a member of the U.S. National Academy of Sciences, president of the American Mathematical Society, fellow of the Royal Society of Canada, an International Congress of Mathematicians Emmy Noether lecturer, and a Josiah Willard Gibbs lecturer.

Cathleen's early work on the theory of transonic fluid flow—referring to partial differential equations that possess both elliptic and hyperbolic regions—remains the most fundamental mathematical work on this subject. The flow is supersonic in the elliptic region, while a shock wave is created at the boundary between the elliptic and hyperbolic regions. In the 1950s, she used functional-analytic methods to study boundary value problems for such transonic problems. One of Cathleen's theorems predicts that if a smooth steady irrotational flow exists around an aerodynamic profile, then a smooth steady transonic flow cannot exist around any slightly perturbed profile. Thus, while shock-free transonic flows occur, she proved that they cannot be stable. Cathleen's predictions were subsequently confirmed through both numerical simulations and actual experiments — shock waves physically appear in the flow past the perturbed profile. This aspect of her work has had an important impact on airfoil design, which attempts to minimize the shocks. She also did fundamental work on magnetohydrodynamic shock structure and other related problems.

Beginning in the 1960s, Cathleen investigated the scattering of linear acoustic and electromagnetic waves off obstacles. This involved studying the asymptotics of the wave equation in an exterior domain with Dirichlet boundary conditions. She developed a series of remarkable energy identities, now collectively known as Morawetz identities, which imply *a priori* that solutions must decay at certain rates. Some of these identities are related to the conformal invariance of the wave equation. In particular, Cathleen proved that the waves decay exponentially if the obstacle is star-shaped. Her estimates were key ingredients in the development of mathematical scattering theory by Peter Lax and Ralph Phillips. In the 1970s, Cathleen's estimates inspired the development of microlocal methods at boundaries to guarantee the local exponential decay of energy. In 1968, she also proved a novel radial estimate, which provides decay for positive-mass equations.



Cathleen Morawetz, 1923-2017. Image courtesy of New York University.

That Cathleen's energy estimates, originally developed for linear problems, have played critical roles in the analysis of nonlinear waves is remarkable. Many mathematicians have used the conformally invariant estimates in the theory of small-amplitude hyperbolic waves, ultimately culminating in the analysis of Einstein's equations of general relativity. The estimates, and especially the radial estimate, have also been instrumental in the study of large-amplitude waves, including the remarkably subtle work Cathleen conducted with me on the nonlinear Klein-Gordon equation. The use of close analogues of her estimates continues to the present day, for nonlinear Schrödinger and other nonlinear dispersive waves, for instance.

Cathleen was an open and charming person. She was admirably able to bring up four lovely children as her mathematical career was simultaneously taking off. She was one of the key personalities to set the tone of openness, generosity, and scientific excellence at the Courant Institute. Cathleen has been a terrific role model for the mathematical community. She will be sorely missed.

Walter Strauss is a professor at Brown University, a SIAM Fellow, and a former editor-in-chief of the SIAM Journal on Mathematical Analysis.

A Rewarding 2016 for SIAM

By James Crowley and Susan Palantino

2016 proved to be a successful year for SIAM programs and publications in many respects. While its financial picture is strong overall, the society did suffer a deficit in its yearly operational budget.

Programs and Publications

SIAM continues to expand its programs and international reach. Revitalization of its student chapter program, which started about 15 years ago, has led to robust growth with a current total of 177 active student chapters across the world; 27 of these are outside North America. SIAM student chapters receive up to $500 a year for operational expenses, and may receive funding for one chapter representative to attend the SIAM Annual Meeting and meet with SIAM leadership.

SIAM also continues to sponsor Student Travel Awards, which provide funding on a competitive basis for travel to SIAM conferences. This program is open to any student in a discipline relevant to SIAM, with preference given to SIAM student members and graduate students participating in the conference in a significant way (such as presenting a talk or poster). The National Science Foundation partly funds the program, which is supplemented by donations from book authors and SIAM members. In addition, the SIAM Board of Trustees has allocated up to $200,000 per year for this purpose. The total $240,000 provided travel grants for approximately 300 students in 2016. Graduate students are an important part of the SIAM conference program, and students typically comprise about 20-30 percent of conference attendees.

At larger conferences, such as the SIAM Annual Meeting and the SIAM Conference on Computational Science and Engineering, SIAM offers special programs targeted towards students. The Annual Meeting includes a student welcome reception, Student Days, the career opportunities meeting, and the career fair. The career fair brings representatives from companies and national laboratories to meet with students interested in learning more about employment opportunities at the respective organizations. 24 companies/laboratories participated in the career fair at the 2016 SIAM Annual Meeting, held in Boston, Mass. Though career fairs tend to be more informational than job fairs, since companies are not necessarily hiring at the time, résumés collected from students (typically between 100-125) are made available to the participating organizations.

SIAM conferences were very successful in 2016 and saw 4,276 total paying attendees, 1,588 of whom were at the SIAM Annual Meeting and the jointly-held SIAM Conference on the Life Sciences. Two SIAM activity group (SIAG) conferences in Europe—the SIAM Conference on Uncertainty Quantification in Lausanne, Switzerland, and the SIAM Conference on Parallel Processing in Paris, France—added more than 1,200 participants to the above totals. SIAGs are beginning to hold more conferences outside of North America, and in such cases, SIAM typically partners with another organization to handle the finances and logistics.

Most of SIAM's 21 SIAGs hold a conference once every two or three years. In 2016, 12 SIAGs held conferences. SIAGs that do not hold a conference in a given year tend to have a presence at the SIAM Annual Meeting.

In addition to activity groups, which are organized around a technical area or topic, SIAM also has regional sections. Sections are subsets of SIAM members in a geographical area — either in part of a country, a specific country, or a group of countries in a given region. SIAM had 12 active regional sections in 2016. Many of these organize conferences periodically, targeted at serving the regional community. SIAM provides some financial assistance to its regional sections to help support their programs.

Publications

SIAM journals are growing in size and scope, and continue to be among the most respected in the field. SIAM now publishes 15 journals, in addition to *SIAM Review* and *Theory of Probability and its Applications* (the Russian translation journal). SIAM has added six journals since 2002, when the *SIAM Journal on Dynamical Systems* was first introduced.

SIAM journals have grown from slightly over 2,000 submissions in 2002 to more than 5,000 submissions in 2016. Though this is due in part to the creation of new journals, submissions to existing journals have increased substantially as well.

SIAM also continues to boast a robust book program, which emphasizes monographs and graduate texts in applied and computational mathematics and related areas. In addition, it publishes peer-reviewed proceedings of several SIAM conferences in computer science and engineering-related fields.

Washington, D.C. Presence

SIAM participates in advocacy for applied mathematics and computational science through the SIAM Committee on Science Policy (CSP), with the support of Lewis-Burke Associates. The CSP meets twice a year in Washington, D.C., where it holds discussions with both leaders from various agencies who fund programs in our discipline and policy makers in the federal government who share an interest in research and education. SIAM also takes an active role in many cross-society organizations, including the Joint Policy Board for Mathematics, the Computing Research Association, and the Conference Board on Mathematical Sciences.

The CSP has initiated a new program—the SIAM Science Policy Fellowship Program—to introduce early-career professionals to advocacy and science policy. Details on this program and instructions on how to apply may be found on the SIAM website.[1]

Membership

SIAM membership remains very strong. Non-student membership has grown substantially over the last decade, and has stayed relatively constant over the past three years. Student membership has grown dramatically since the introduction of free student memberships more than a decade ago. 2016 membership consisted of 8,472 non-student members and 6,144 student members.

Leadership

SIAM is indebted to the service of its elected officers, the appointed vice presidents and members of committees, and leaders of the various subgroups (activity groups, sections, chapters) who are dedicated to serving the society and its membership. It is the commitment and work of all of these people that makes SIAM a successful organization.

See **Rewarding 2016** *on page 4*

[1] https://www.siam.org/about/science/sci-pol-fellowship.php

Collective Behavior

Continued from page 1

Group morphology on its own, however, is almost certainly not sufficient to accurately describe animal aggregations — pattern alone does not imply function [8].

Moving beyond group structure for evaluating models has proved surprisingly challenging. This reflects in part (until recently) the scarcity of quantitative empirical data for animal groups. But deciding what questions to ask of the data is the more fundamental dilemma. One recent line of research attempts to go from observations of animal movement to the rules that generated the motion [4, 5], thus providing support for modeling choices. However, this is a very challenging inverse problem, and not necessarily one that is well-posed, given that animal interactions are almost certainly nonlinear. One can surely try to fit model parameters to the data. But since these agent-based models are not derived from any conservation laws or other first principles, fitting the data to the model neither validates the model per se nor indicates that the chosen framework correctly describes the real biology.

A more tractable approach would be to match the *output* of a model to the observational data. Yet that requires the selection of nontrivial quantities to compute for both the real animals and the model output; as argued above, these quantities should not simply be structural or morphological. In a nutshell, the entire concept of collective behavior is predicated on the idea that the group has an identity distinct from its constituent members. We seek a precise and sufficiently discriminatory way of characterizing the group identity that is unlikely to appear in a model by chance or for the wrong reasons.

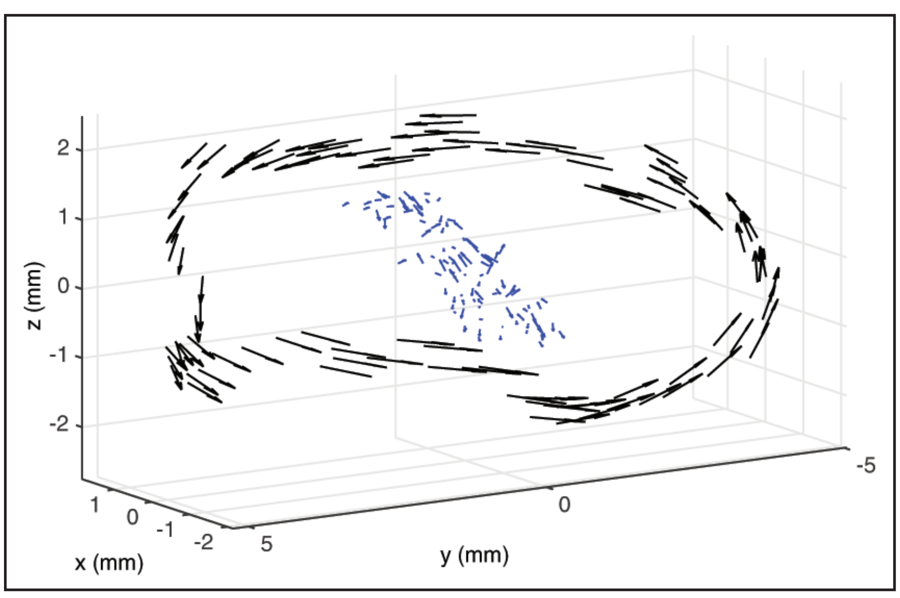


Figure 1. *Positions and velocities of the swarm center of mass for a free, undriven swarm (blue) and an acoustically-driven swarm (black). The motion of the center of mass is normally stochastic, but becomes coherent when driven. Adapted from [6].*

There are many ways to approach this problem. One appealing recent direction involves recognizing that physics has faced a similar question in the realm of thermodynamics and materials characterization. In those cases, one seeks to precisely describe the properties of large groups of molecules (namely, a piece of a material) in a way that does not directly reference the molecular properties. Although we cannot indiscriminately apply the prescriptions of classical thermodynamics to animal groups, given the absence of conservation laws or well-described physical interactions, we can approach the problem with a similar mindset. In particular, we can recognize that one cannot typically determine a material's properties by passive observation alone; one must interact with it, either by applying external perturbations or putting it into contact with another material.

Of course, applying controlled perturbations to animal groups in the wild is very difficult. On the other hand, working in the laboratory places practical restrictions on the types of animals that can be used. Thus, most of the work in determining material-like properties of animal aggregations has used insects as model organisms. For example, Michael Tennenbaum, Zhongyang Liu, David Hu, and Alberto Fernandez-Nieves [10] studied the properties of fire ant aggregations by placing them in an oscillatory rheometer. Fire ants are known to form macroscopic structures by linking their bodies together. The authors used their ant rheometer to show that these aggregations behave similarly to viscoelastic fluids, becoming stiffer and more purely elastic as the density of ants increases.

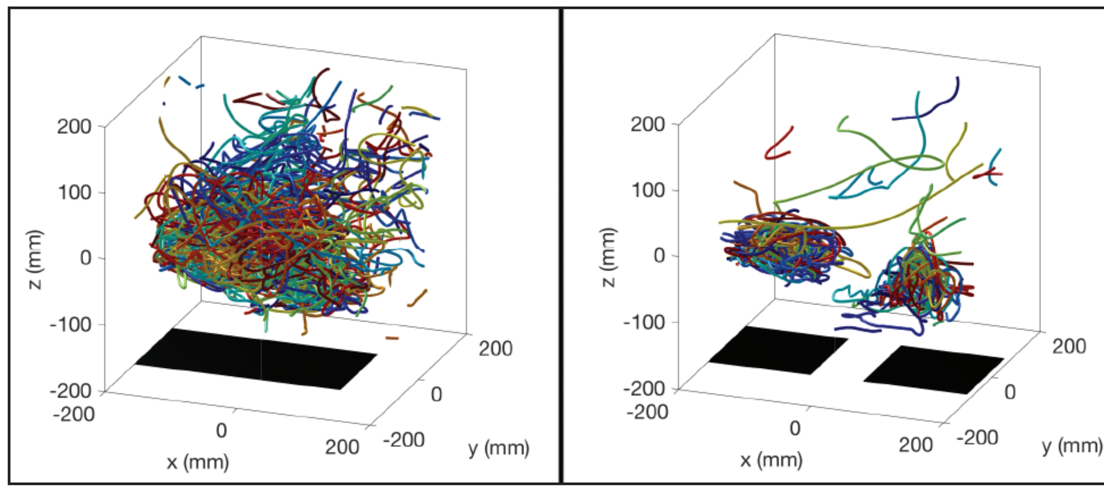


Figure 2. *Observed midge trajectories (with each midge shown in a different color) for one minute of recording time over* **(a)** *one single ground-based target (shown in black) and* **(b)** *two separated ground-based targets. A single swarm can be pulled apart into two as the targets are increasingly separated. Adapted from [7].*

My own lab studies mating swarms of Chironomid midges. Unlike fire ants, these flying insects do not touch each other, and their aggregations are more ephemeral. Nevertheless, we can still interact with the swarms and study their responses. For instance, Chironomids are strongly attuned to acoustic stimuli. We exploited this biological response and played the sound of a flying midge as a stimulus to the swarm, but modulated its amplitude sinusoidally in time. We observed the appearance of a coherent mode in the motion of the swarm's center of mass (see Figure 1) whose amplitude increased linearly with that of the driving sound [6], allowing us to extract a linear susceptibility. In another set of experiments, we used swarming midges' tendency to locate themselves over ground-based visual features to apply the equivalent of a tension test to the swarms, "pulling" one swarm into two (see Figure 2) and showing that the swarms possess an emergent elastic modulus [7].

Most recently, we applied persistent homology [2, 3, 9, 11]—a topological data analysis technique—to study the spatial structure of swarms. Persistent homology treats a pointlike data set as discretization of some underlying unknown object, and seeks to characterize its topology. To do so, one attaches a sphere of radius $\varepsilon/2$ to each point and uses them to build a simplicial complex whose topology can then be analyzed; ε is a free parameter, but topological features invariant for a range of ε (the "persistent" in persistent homology) are assumed to be meaningful. We used this method to study the swarms' simplest topological feature: the number of connected components, as measured by the zeroth Betti number of the simplicial complexes. This analysis revealed that swarms are composed of a dense inner core (containing one large component) and a more diffuse outer region (containing many small components). The boundary between these two regions is reminiscent of a liquid/vapor phase equilibrium, with distinct properties on either side of the interface but free exchange of individuals between the two "phases" [9].

Ultimately, we have been able to characterize properties of animal aggregations that must be reproducible by correct models and are much more stringent than simple morphology or pattern. These experiments can also help us make fundamental progress in understanding what it really means to call an aggregation collective, and why these collectives possess enhanced properties relative to individual animals. Much work remains to be done before we have a unified "thermodynamic" theory of animal aggregations, but we are well on our way.

Acknowledgments: This research was sponsored by the Army Research Laboratory and accomplished under grant numbers W911NF-12-1-0517, W911NF-13-1-0426, and W911NF-16-1-0185. The views and conclusions in this document are those of the author and should not be interpreted as representing the official policies, either expressed or implied, of the Army Research Laboratory or the U.S. government.

References

[1] Couzin, I.D., Krause, J., James, R., Ruxton, G.D., & Franks, N.R. (2002). "Collective memory and spatial sorting in animal groups." *J. Theor. Biol., 218*, 1-11.

[2] Fasy, B.T., & Wang, B. (2016). "Exploring persistent local homology in topological data analysis." *Proceedings of the 2016 IEEE International Conference on Acoustics, Speech and Signal Processing* (6430-6434). Shanghai, China.

[3] Ghrist, R. (2008). "Barcodes: The persistent topology of data." *Bull. Am. Math. Soc., 45*, 61-75.

[4] Herbert-Read, J.E., Perna, A., Mann, R.P., Schaerf, T.M., Sumpter, D.J.T., & Ward, A.J.W. (2011). "Inferring the rules of interaction of shoaling fish." *Proc. Natl. Acad. Sci. USA, 108*, 18726-18731.

[5] Katz, Y., Tunstrøm, K., Ioannou, C.C., Huepe, C., & Couzin, I.D. (2011). "Inferring the structure and dynamics of interactions in schooling fish." *Proc. Natl. Acad. Sci. USA, 108*, 18720-18725.

[6] Ni, R., Puckett, J.G., Dufresne, E.R., & Ouellette, N.T. (2015). "Intrinsic fluctuations and driven response of insect swarms." *Phys. Rev. Lett., 115*, 118104.

[7] Ni, R., & Ouellette, N.T. (2016). "On the tensile strength of insect swarms." *Phys. Biol., 13*, 045002.

[8] Parrish, J.K., & Edelstein-Keshet, L. (1999). "Complexity, pattern, and evolutionary trade-offs in animal aggregation." *Science, 284*, 99-101.

[9] Sinhuber, M., & Ouellette, N.T. (2017). "Phase coexistence in insect swarms." *Phys. Rev. Lett.* (in press).

[10] Tennenbaum, M., Liu, Z., Hu, D., & Fernandez-Nieves, A. (2016). "Mechanics of fire ant aggregations." *Nat. Mater., 15*, 54-59.

[11] Topaz, C.M., Ziegelmeier, L., & Halverson, T. (2015). "Topological data analysis of biological aggregation models." *PLoS ONE, 10*, e0126383.

Nicholas Ouellette is an associate professor in the Department of Civil and Environmental Engineering at Stanford University. His research focuses on the dynamics of nonlinear systems driven out of equilibrium, including turbulent flows, granular materials, and animal aggregations.

Rewarding 2016

Continued from page 3

Looking Ahead

At its July 2017 meeting, the SIAM Board of Trustees decided to embark on a strategic planning exercise beginning in the spring of 2018, under the leadership of SIAM President Nicholas Higham. A group including a subset of the SIAM Board and Council members will meet in what will be called SIAM Advance (a word strategically chosen to avoid calling it a "retreat!"). More information on this will be forthcoming.

Finances

SIAM continued to report a robust and healthy financial picture in 2016. It increased net assets by almost $1.7 million overall, due primarily to gains from investments. In 2016, the society incurred a net operating loss of approximately $400,000, as compared to net income of $177,000 in 2015. At the end of 2016, SIAM had investment reserves totaling over $32 million; this allowed the society to move forward with its programs, enabling it to sustain a loss in lean years. While there are many revenue and expense variances between years, it should be noted that over the last several years SIAM has focused on growth around infrastructure and the use of operating resources to build systems and develop programs to better serve its members and the applied math and computational science community. Several examples of these initiatives and growth areas are mentioned above.

Operating expenses increased by about $230,000, or 1.8 percent, in 2016 as compared to 2015. The largest expenditure for SIAM is salaries and benefits, representing 47 percent of the total. The increase in 2016 compensation costs was approximately 2.4 percent, mostly the result of modest salary increases. Many expenditures—associated with conferences, *SIAM News*, and membership—decreased or remained unchanged.

Operating revenue declined slightly between 2015 and 2016, a decrease of roughly $360,000, or 2.9 percent. Revenue was lower in some program areas such as conferences (meetings are usually slightly smaller in even years).

SIAM has established strong internal controls over financial operations. Policies are in place to ensure adequate constraint over expenditures, thereby keeping costs at reasonable and justifiable amounts. In addition, the society strives to earn revenue through its programs and operations, allowing it to sustain long-term growth and excellence in its services to members and the community as a whole.

Read the complete 2017 annual[2] and financial[3] reports from SIAM.

James Crowley is the executive director of SIAM. Susan Palantino is SIAM's chief operating officer.

[2] http://www.siam.org/about/pdf/2016annualreport.pdf.

[3] http://www.siam.org/about/pdf/2016financialreport.pdf

Microstructures

Continued from page 1

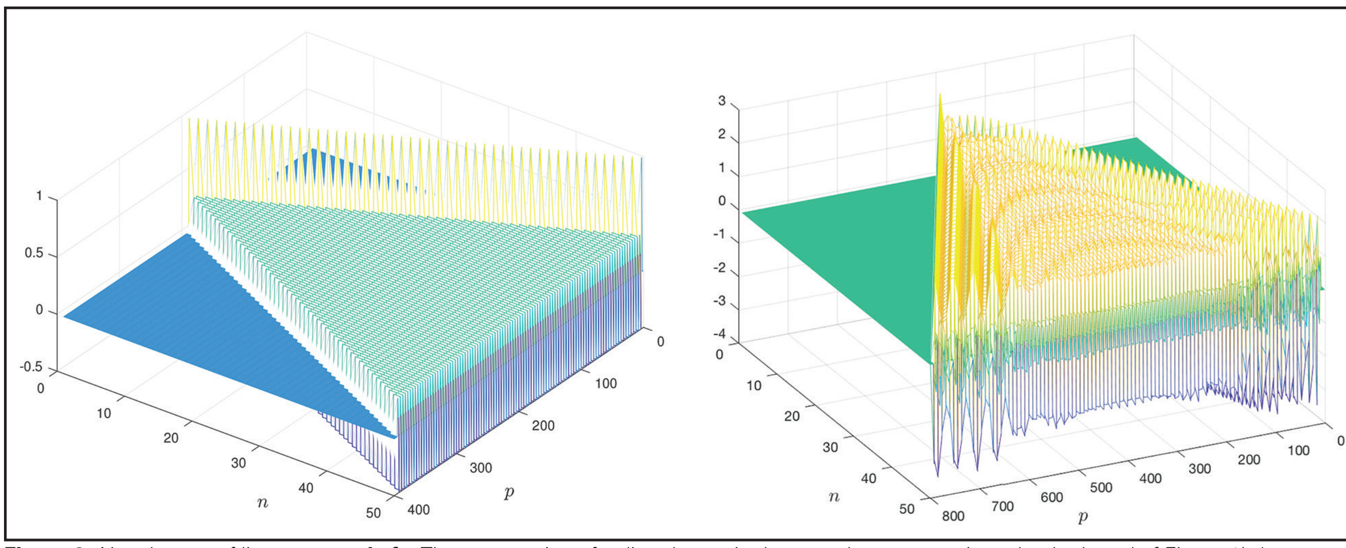


Figure 2. *Novel types of linear waves.* **Left.** *The propagation of a disturbance in the two-phase space-time checkerboard of Figure 1b (on page 1).* **Right.** *The propagation of a disturbance in the three-phase space-time checkerboard of Figure 1c. Here n represents time in discrete snapshots and p represents space, indexing the characteristic lines at those times. Image credit: Ornella Mattei.*

Whether the condition of PT-symmetry is broken or unbroken depends on the type of space-time microstructure and the material parameters. For instance, the condition of PT-symmetry is always unbroken for any range of properties of the two phases for the two-phase checkerboard (see Figure 1b, on page 1), whereas both propagating modes and growing modes (coupled with decaying modes) could exist for the three-phase checkerboard (see Figure 1c), depending on the choice of the material parameters.

Interestingly, when there is no blow-up, the waves generated by an instantaneous disturbance at a point look like shocks with a wake of oscillatory waves whose amplitude remarkably does not zero away from the wave front [6]. Figure 2 depicts this new type of linear wave, representing the amplitude of a wave propagating through the space-time checkerboards of Figure 1a and 1b (on page 1); Figure 2a corresponds to 1b, and 2b corresponds to 1c (the latter clearly corresponds to a choice of material parameters such that the condition of PT-symmetry is unbroken, thus avoiding a blow-up). As each field pattern lives on its own discrete network of characteristic lines, we determine the solution only on such a network—at specific points—denoted by the parameter p at specific times n, both chosen in accordance to the field pattern's periodicity. In Figure 2a, the wave propagates with the same intensity at the edge of a triangular shape with its vertex at the point of injection of the disturbance, and the solution is periodic inside the triangular shape. In Figure 2b, on the other hand, the solution inside the triangular shape is no longer periodic.

Another very interesting feature of field pattern materials is the infinite degeneracy of their dispersion diagrams, determined by applying Bloch-Floquet theory [5]. To understand this concept, it is important to realize the existence of a family of field patterns rather than a single field pattern. A single field pattern can be excited in many different ways; choosing a different point for the initial disturbance generally (but not always) yields a field pattern with a different geometry. The families of field patterns (notice that the number of families is infinite) all have the same dispersion law, relating the Bloch wavenumber k to the crystal frequency ω. An infinite space of Bloch functions—a basis for which are generalized functions, each concentrated on a field pattern—is therefore associated with every point on the dispersion diagram. The dynamics separate into independent dynamics on the different field patterns, each with the same dispersion relation.

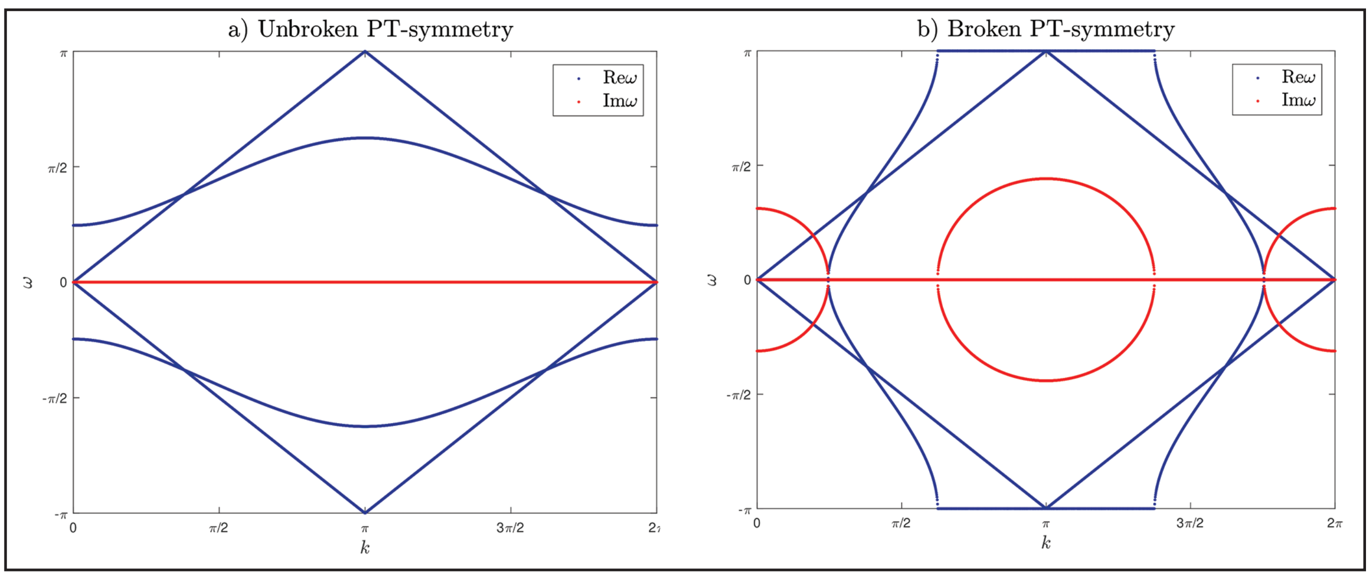


Figure 3. *Dispersion diagrams for the three-phase space-time checkerboard shown in Figure 1c (on page 1) for different values of the material parameters.* **3a** *corresponds to a condition of unbroken PT-symmetry, whereas* **3b** *corresponds to a condition of broken PT-symmetry, in which* $\mathrm{Im}\omega$ *takes nonzero values indicative of exponentially growing and decaying modes. Image credit: Ornella Mattei.*

For the two-phase checkerboard geometry of Figure 1b (on page 1), the dispersion relation is simply $\omega = \pm k$, independent of the choice of material parameters. In particular, the dispersion relation is exactly the same as the trivial case of a homogeneous material. However, the wave propagation in the homogeneous case is significantly different: an instantaneous disturbance would have fronts that travel at the group velocity $\partial\omega/\partial k = \pm 1$, in contrast to the inhomogeneous case where the fronts are trailed by an oscillating wave with an amplitude that depends on the material parameters (see Figure 2a). Besides proving that field patterns are a new type of wave, this example also shows that the band structure alone is insufficient in determining the longtime response to a localized disturbance.

Figure 3 depicts the dispersion diagrams of Figure 1c's (on page 1) three-phase checkerboard for different choices of the material parameters. For some combinations of parameters, the condition of PT-symmetry is unbroken and ω is real. Yet for other combinations, the PT-symmetry is broken so that growing modes (coupled with decaying modes) exist in addition to propagating modes, and ω is complex.

There is a wealth of problems still to be studied. What happens when one perturbs the field pattern material geometry? Is a chaotic description using the concepts of statistical physics then appropriate? How does this generalize to higher dimensions and other wave equations? What happens when there is a small amount of dispersion, loss, or nonlinearity? Like the discoveries of anomalous resonance, cloaking, nonreciprocity, and topological insulators, this research shows that the study of linear systems is far from a dead subject. On the contrary, many exciting discoveries lie ahead.

Acknowledgments: Our work was supported by the National Science Foundation through grant DMS-1211359, and largely completed at the Institute for Mathematics and its Applications at the University of Minnesota during the special program on mathematics and optics.

References

[1] Bacot, V., Labousse, M., Eddi, A., Fink, M., & Fort, E. (2016). Time reversal and holography with spacetime transformations. *Nat. Phys., 12*, 972-977.

[2] Bender, C.M. (2007). Making sense of non-Hermitian Hamiltonians. *Rep. Prog. Phys., 70*, 947-1018.

[3] Lurie, K.A. (2007). *An Introduction to the Mathematical Theory of Dynamic Materials*. (Vol. 15). *Advances in Mechanics and Mathematics* (1st ed.). Berlin, Germany: Springer-Verlag.

[4] Lurie, K.A, Onofrei, D., & Weekes, S.L. (2009). Mathematical analysis of the waves propagation through a rectangular material structure in space-time. *J. Math. Anal. Appl., 355*(1), 180-194.

[5] Mattei, O., & Milton, G.W. (2017). Field patterns: a new type of wave with infinitely degenerate band structure. Preprint, *arXiv:1707.05756*.

[6] Mattei, O., & Milton, G.W. (2017). Field patterns without blow up. *New J Phys., 19*, 093022.

[7] Milton, G.W, & Mattei, O. (2017). Field patterns: a new mathematical object. *Proc R Soc A., 473*, 20160819.

Ornella Mattei is a postdoctoral research fellow in the Department of Mathematics at the University of Utah. Graeme Milton is a distinguished professor of mathematics at the University of Utah. He is a SIAM Fellow and a recipient of the SIAM Ralph E. Kleinman prize, among other distinctions.

Multiscale Understanding of Vascular Adaptation: The Vein Graft Model

By Marc Garbey, Stefano Casarin, and Scott Berceli

Cardiovascular diseases continue to dominate humanity's morbidity and mortality [1]. Contemporary therapies for occlusive arterial diseases include angioplasties, stent deployment, endarterectomies, and bypasses. However, these procedures suffer from unacceptably high failure rates due to re-occlusive events, resulting mainly from unfavorable vascular adaptation.

Vascular adaptation following local injury occurs due to a combination of intimal hyperplasia (thickening of the innermost layer of a blood vessel) and inward remodeling (shrinking of the blood vessel wall). Over the past three decades, researchers have used a wide variety of approaches to investigate intimal hyperplasia and wall remodeling in an effort to identify novel therapeutic strategies. Despite incremental progress, no durable treatments have evolved to become clinical realities.

Due to its potential impact on improving post-surgical outcomes, vascular adaptation has been the target of several mathematical modeling-based studies. Employing standard approaches used by biologists to condense a problem to its core components, prior strategies have focused largely on reductionist approaches and used deterministic, continuous models to describe the physical and biological components of vascular disease progression. However, advancing the understanding of such a complex phenomenon requires the integration of divergent types of data into quantitative models that can be used to predict vascular dynamics and remodeling outcomes [3].

Although early attempts to manipulate the remodeling response proposed a variety of single-bullet approaches, failure of these efforts suggests that intersection of targeted strategies would help overcome the redundant biology in this complex system. Using the integration of multiscale modeling and experimental techniques, one can identify and manipulate critical gene targets in vivo to improve vein graft durability. Specifically, we hypothesize that a gene regulatory network—modulated by defined blood shearing forces—determines the global adaptive response of the vein graft wall following acute injury.

Unlike many other disease processes within the vascular system, which occur in the time scale of decades, vein bypass graft failure occurs in the timeframe of weeks to months. With a well-defined initial condition (i.e., normal vein at the time of implantation [3]) and well-characterized environmental exposure (i.e., pressure and flows of the arterial circulation), the pathophysiology of vein graft disease is suitable for mathematical modeling.

To abate the incidence of this failed adaptation, we suggest an efficient post-surgical therapy at the genetic level. We thus propose a multiscale model that can replicate the graft's healing and detail the level of impact of targeted genes on the healing process. A key feature of our model is its capability to link the genetic, cellular, and tissue levels with feedback bridges in such a way that every single variation from an equilibrium point is reflected on all other elements; this creates a highly-organized, multiscale loop (see Figure 1).

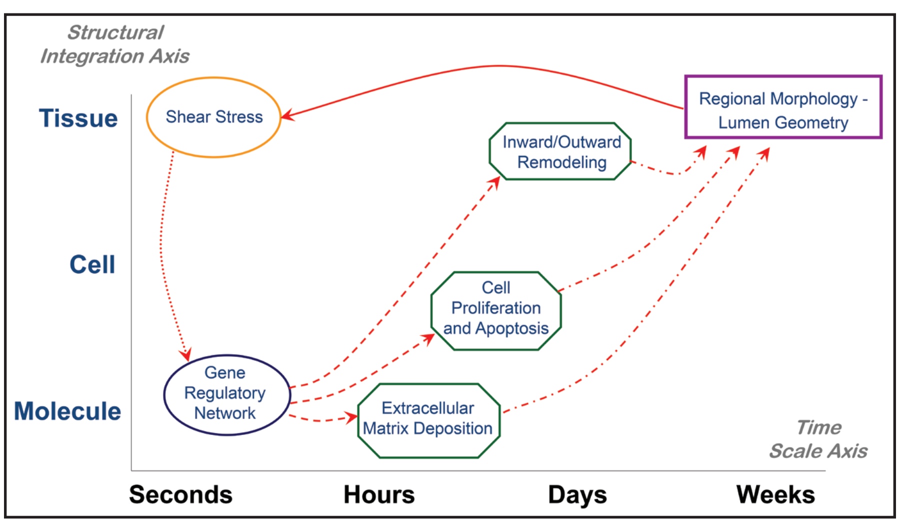


Figure 1. *A loop of interdependent events, where the dynamic interplay between physical forces and gene networks regulates the early graft remodeling and describes the graft arterialization process. Image courtesy of [2].*

A mechano-biological description is able to develop a variety of frameworks reflecting our initial understanding of the graft's healing process. For example, one may use the set of incompressible Navier-Stokes (NS) equations to describe flow in the lumen and provide shear stress values along the wall. A hyperelastic model of tissue deformation coupled with NS supplies the transmural pressure and strain energy distribution inside the wall. A reaction-diffusion equation estimates the delivery and distribution of a growth factor inside the wall, offering a simplified link between the lumen wall thickening—triggered by shear stress value—and cellular functions.

A gene regulatory network modulates the response to these mechanical conditions within this integrated system. The level of gene expression dictates specific cellular functions, such as cell proliferation, death, mobility, and matrix deposition. An agent-based model (ABM), which replicates the basic cellular functions triggered by gene expression, describes the resulting tissue adaptation at the cellular level. Finally, the resulting variations in tissue morphology influence the local mechanical environment, with these closed-loop events continuing across time scales ranging from seconds to months. This complex model is implemented in a modular way and can take advantage of heterogeneous high-performance computing architecture. Most importantly, the model's agility expresses the ongoing discussion between experimentalists, computational scientists, and practicing clinicians who provide critical insight into the ultimate utility of this approach. There is indeed no point in reproducing the exact biology or flow conditions — even if this was possible, analyzing the model would eventually become as complicated as studying the animal model itself! Instead, the art is the development of a portfolio of models available on demand to address the specific needs of patients [7].

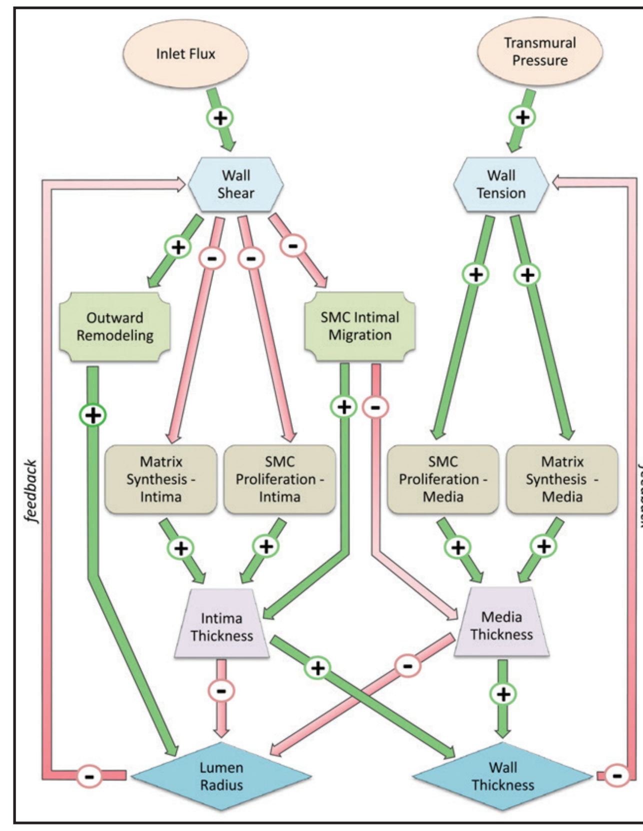


Figure 2. *Dynamical system (DS) flow chart illustrating the primary interacting elements in vein graft adaptation. Image courtesy of [4].*

Figure 1 provides a good sense of how various feedback loops regulate the adaptation phenomenon. In view of the first model implementation, a dynamical system (DS) calibrated on experimental observations was developed to classify the dominant mechanisms that modulate both intima hyperplasia formation and wall remodeling. A top-down approach—nicely described in Figure 2—regulates the DS. Surprisingly enough, the DS allows us to give a sense of positive or negative adaptation, interpreted as convergence to critical points in the phase space. Even though simple in nature, this conceptual system has shown that adaptation may come at the price of numerous oscillations in lumen geometry, a phenomenon commonly observed by clinicians but previously unexplained [4].

An important goal of this model is to provide insights into the significance of spatial dependency among cellular and matrix elements, individuating a match against histologic data with the ability to contribute much more information on the fundamental cellular events that lead to unique pattern formations (see Figure 3, on page 1) [6]. Such level of detail is aimed at delivering a deeper understanding of the fundamental mechanisms without getting lost in the specifics. An important advancement has been cross-validating the upscale DS and multiscale ABM, offering different tools and contrasting approaches to investigate various aspects of the biology that lead to the same biologic conclusion [5]. Our focus has been to develop an ABM that is nimble yet fundamentally sound, and able to present the necessary level of complexity without slavishly reproducing an exact replica of the multitude of biologic networks within the system. While it is unlikely that such an ambitious goal could even be achieved, this would far outstrip the experimental capabilities that are critical to fueling the accuracy and reproducibility of such a model.

See **Vascular Adaptation** *on page 8*

Anticipating Next Year's Annual Meeting

The SIAM Annual Meeting is the largest and most important applied mathematics conference of the year. Unlike the many topical meetings, which are generally focused on a single SIAM activity group (SIAG) or field, the Annual Meeting acts as a forum that bridges subdisciplinary boundaries and promotes interaction across SIAM's diverse international membership in academia, industry, and government.

The 2018 SIAM Annual Meeting[1] (AN18) will take place from July 9-13, 2018, in Portland, Ore. As always, the schedule is a surfeit of riches. The scientific program is built around 14 invited talks, a handful of prize lectures, minitutorials, minisymposia, poster sessions, and contributed talks. Other highlights include the I.E. Block Community Lecture (followed by the Community Reception), Past President's Address, Prizes and Awards Luncheon, Workshop Celebrating Diversity, Student Days, the industry panel, funding agencies panel, career fair, Professional Development Evening, and much more. The 2018 meeting will occur simultaneously with the SIAM Conference on Mathematical Aspects of Materials Science,[2] the SIAM Conference on Applied Mathematics Education,[3] and the SIAM Workshop on Network Science.[4] Special tracks will also be organized by the SIAGs in algebraic geometry, dynamical systems, and geosciences. But the meeting themes go well beyond these topics, covering the gamut of applied and computational mathematics.

At this time, we invite SIAM community members to help guide the scientific content of AN18 by submitting a proposal for a minisymposium (thematic group of lectures), a minisymposterium (thematic group of posters), or an individual presentation in lecture or poster format. We especially encourage submissions that include an accessible introduction to a topic; emphasize communication across disciplinary boundaries; and explain the topic's motivation, key issues, and impact to non-specialists. Minisymposium proposals are due by January 10, 2018, while contributed lecture, poster, minisymposium, and presentation abstracts are due by January 31, 2018.

The AN18 Organizing Committee has selected a stellar group of invited speakers[5] covering a broad range of applied mathematics, listed here with tentative presentation titles:

• *Understanding Network Structure and Function in the Human Brain*. Danielle S. Bassett, University of Pennsylvania, USA

• *Structure and Randomness in Encrypted Computation*. Craig B. Gentry, IBM Research, USA

• *On Coin Tosses, Atoms and Forest Fires*. Martin Hairer, University of Warwick, UK

• *The Future of Scientific Computation*. Bruce Hendrickson, Lawrence Livermore National Laboratory, USA

• *Applied and Computational Mathematics: A New Curriculum for 21st Century Discovery and Innovation*. Jeffrey Humpherys, Brigham Young University, USA

• *The Mathematics of Wrinkles and Folds*. Robert V. Kohn, New York University, USA

• *Recent Advances in Dimensionality Reduction with Provable Guarantees*. Jelani Nelson, Harvard University, USA

• *Nonlinear Patterns and Waves: From Spectra to Stability and Dynamics*. Björn Sandstede, Brown University, USA

• *Automatic Behavioral Analysis for Computational Psychiatry at Home*. Guillermo Sapiro, Duke University, USA

• *Seeing Through Rock: Mathematics of Inverse Wave Propagation*. William W. Symes, Rice University, USA

• *Snow Business: Computational Elastoplasticity in the Movies and Beyond*. Joseph M. Teran, University of California, Los Angeles, USA (American Mathematical Society Invited Address)

• *Algebraic Vision*. Rekha R. Thomas, University of Washington, USA

• *Connections and Reconnections: A Link Between Mathematics, Physics and DNA*. Mariel Vazquez, University of California, Davis, USA

• *Challenges for Numerical Analysis in Large-Scale Simulation*. Barbara Wohlmuth, Technische Universität München, Germany.

In addition, Thomas Hales of the University of Pittsburgh will deliver the I.E. Block Community Lecture, entitled *How Paradoxes Shape Mathematics and Give Us Self-Verifying Computer Programs*.

The following minitutorials[6] will also take place:

• *Geometric Deep Learning on Graphs and Manifolds Going Beyond Euclidean Data*. Organized by Michael Bronstein, Università della Svizzera Italiana, Switzerland

• *Simulation-Based Statistics*. Organized by Tim Hesterberg, Google, USA.

This and future issues of *SIAM News* will feature short articles by the speakers introducing the topics of their talks. The current issue features introductions by Bruce Hendrickson and Guillermo Sapiro (see below).

The 2018 SIAM Annual Meeting will be a conference you will not want to miss — an exceptional opportunity to broaden your horizons, exchange ideas, and interact with the SIAM community. Mark your calendar for July 9-13, 2018, and plan to join us in Portland.

— AN18 Organizing Committee Co-chairs Douglas N. Arnold and Lois Curfman McInnes.

[1] http://www.siam.org/meetings/an18/
[2] http://www.siam.org/meetings/ms18/
[3] http://www.siam.org/meetings/ed18/
[4] http://www.siam.org/meetings/ns18/
[5] http://www.siam.org/meetings/an18/invited.php
[6] http://www.siam.org/meetings/an18/mini.php

Automatic Behavioral Analysis for Computational Psychiatry at Home

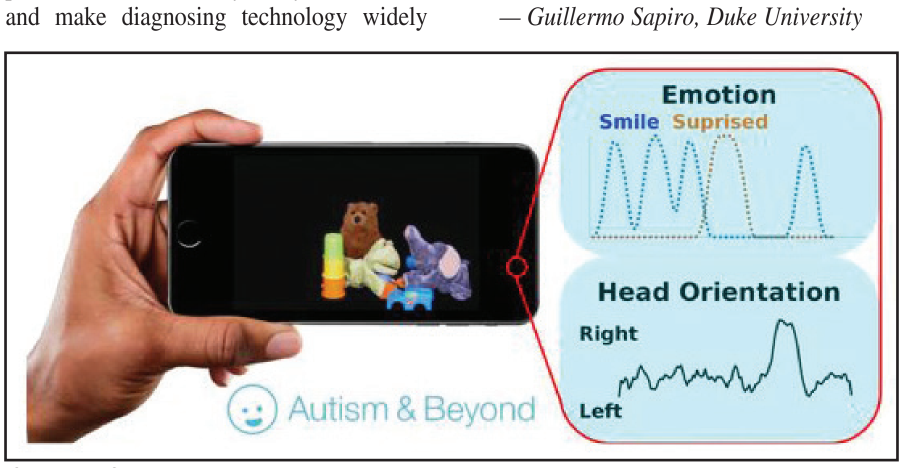
According to the Centers for Disease Control and Prevention, autism affects one in 68 children, with higher incidences among males and siblings of children on the Autism spectrum. Autism can be diagnosed in children as young as 18 months, but the current average diagnosis age in the United States is about five years old. Waiting time to see an autism specialist in leading U.S. hospitals can be up to 18 months, and about 70 percent of counties in the state of North Carolina lack a specialist. South Saharan Africa has an estimated half billion children, served by only about 50 specialists. These are just a few examples illustrating the challenges of developmental and mental health screening, diagnosis, and monitoring, where the introduction of algorithms and technology is lagging far behind other medical disciplines.


Guillermo Sapiro, Duke University

Despite major advances in magnetic resonance imaging and genetics, behavioral observation is still the gold standard for monitoring developmental disorders and mental health. There is thus a need to develop mathematical and computational tools, which can operate on standard hardware such as smartphones, to automatically analyze behaviors and make diagnosing technology widely available to the general population. This calls for a unique teaming of psychiatrists, mathematicians, engineers, and developers to create the right stimuli to evoke appropriate behaviors that can be properly understood by mathematics and algorithms, all integrated into mobile devices for stimuli presentation, sensing, and analysis. The necessary tools range from emotion analysis, understanding, and gaze tracking to audio interpretation, pressure sensitivity, and more standard bio-signals, such as heart rate. The integration of all sensing modalities available in today's ubiquitous mobile devices can thus enable personalized and at-home screening, diagnosis, and tracking of developmental and mental health disorders, opening the door to new developments with great societal impacts.

During the 2018 SIAM Annual Meeting, I will present our interdisciplinary team's demonstrated advances in the development of apps—currently being used in pediatric clinics and downloadable from iTunes—for mental health monitoring. Our work has produced the largest existing dataset of child behavior recorded in natural environments.

— Guillermo Sapiro, Duke University

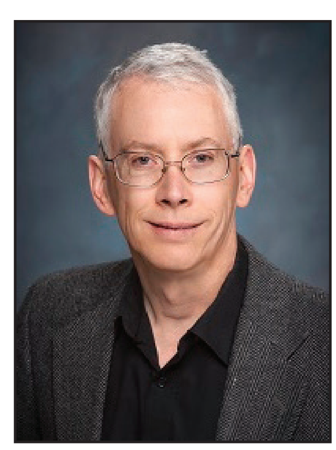


Guillermo Sapiro's research team is developing apps to improve mental health monitoring in pediatric clinics. Sapiro will present his team's advances at the 2018 SIAM Annual Meeting.

The Future of Scientific Computation

Attempts to predict the future have a long and inglorious history. Cultures from time immemorial have devoted their very best technologies to the task, utilizing apparatuses such as tea leaves, crystal balls, and animal entrails. But as Niels Bohr famously observed, "prediction is very difficult, especially if it's about the future."

Certainly, many aspects of the world are inherently unpredictable. But humans have made enormous progress in recent decades regarding certain kinds of predictions. We can forecast weather many days in advance, predict the ecological impact of different policy options, anticipate the effect of interest rate changes on the economy, and foresee the implications of greenhouse gas emissions on the climate in 2100.


Bruce Hendrickson, Lawrence Livermore National Laboratory

This predictive power comes not from new insights in supernatural divination, but rather through advances in applied mathematics and computational science. In fact, mathematicians make predictions all the time; we usually call it "time integration." Are there lessons to be learned from applied mathematics that might provide fresh insight into thinking about the future — particularly the future of scientific computing itself? In an invited talk at the 2018 SIAM Annual Meeting, I will argue that there are.

Applied mathematicians typically develop or utilize sets of equations that describe the system being modeled. These equations are commonly the result of conservation laws: temporal invariants that greatly constrain the system's possible future evolution. Although less rigorous than conservation of mass, might there be invariants that constrain the evolution of scientific fields?

One constant in scientific computing is the continual progress of mathematical models, numerical formulations, and efficient and robust algorithms, which underpin every computation and ensure the field's enduring progress. But unlike most scientific disciplines, scientific computing benefits from another "invariant" known as Moore's Law — Gordon Moore's empirical observation in 1965 that the density of integrated circuits grows exponentially. The natural corollary of this observation for the scientific computing community is that computers of the next decade will be dramatically superior to those of today, even if the precise technology path is unclear. This "invariant" looks likely to hold for at least another decade. As Isaac Newton observed, scientific communities advance by standing on the shoulders of the giants that preceded them. But Moore's Law has offered scientific computing an additional turbo boost; it is as if our giants were riding up an escalator!

Ever-faster computers have enabled the consistent progress of scientific computing in a manner that is quite clear with hindsight. Research focus areas in one decade have often become the building blocks for more ambitious goals in the subsequent decade. For example, intense research on scalable linear solvers in the 1980s and early 1990s enabled very large-scale implicit simulations by the turn of the century. The increased speed of these highly-resolved forward simulations then allowed the community to focus on *outer-loop* questions, such as uncertainty quantification, design optimization, and inverse problems. This consistent, rapid progress has enabled researchers to continually shift focus to more expansive questions that require new advances in mathematical formulations and algorithms.

Armed with this perspective, I believe it is possible to integrate forward in time from today and gain insight into likely trends for the next decade of scientific computing. I will share the conclusions of this projection at the 2018 SIAM Annual Meeting.

— Bruce Hendrickson, Lawrence Livermore National Laboratory

The CoCalc Computing Environment

By Hal Snyder

CoCalc is a cloud-based service that makes a large collection of state-of-the-art open-source mathematical software available to any user with a web browser and an internet connection. Its intent is to make the working scientist's time as productive and fulfilling as possible. The CoCalc platform supports dozens of programming languages—such as Python, Sage, R, Julia, C, C++, Haskell, Scala, and Fortran—and thousands of libraries and packages, including statistical and machine learning software for data science, computer algebra systems for symbolic mathematics, and scientific packages for physical sciences and bioinformatics.

Users can achieve mathematical computation without the need to install and maintain operating systems, compilers and interpreters, libraries, and packages. There are often ways to install a package that is not already available within a user's project, and requests to install packages globally are typically processed in less than a day.

Work that extends across several programming languages and toolsets can be performed within a consistent setting and with minimal friction.

Built for Mathematics

William Stein, the lead developer of SageMath, introduced CoCalc as "SageMathCloud" in April 2013 as a hosted platform for the SageMath software system. Since its earliest versions, CoCalc has included support for computer algebra and numerical computation systems, including Sage, R language, SymPy, NumPy, SciPy, GNU Octave, PARI/GP, GAP, Singular, and Maxima.

The three most common file formats—Jupyter notebooks (.ipynb), Sage worksheets (.sagews), and Markdown files (.md)—all support LaTeX (see Figure 1). A full-featured text editor for LaTeX documents and a customizable build system make it possible to create complicated LaTeX documents using several LaTeX engines—pdflatex, latexmk, and xelatex—with most packages preinstalled. One could achieve dynamic typeset content with SageTeX for Sage and Rnw/knitr (see Figure 2) for R.

CoCalc chat supports Markdown with embedded LaTeX, both in standalone "chat room" files and side chat panes viewable in terminal sessions, notebooks, and files open for editing.

Open Source

Most of the CoCalc code base, including over 240,000 lines of user interface and server-side code, is open source, and users can very easily run it on their own computers with Docker. The CoCalc website[1] uses Kubernetes, which relies on some code that is not open source, to provide a high level of scalability and security. All of the software tools, packages, and libraries provided to users through CoCalc, however, are open source. This has the usual benefits for users in that they don't have to deal with "black box" secret computations or be locked into the CoCalc platform.

SOFTWARE AND PROGRAMMING

The underlying environment for CoCalc projects is Ubuntu Linux. Users comfortable with shell programming may open multiple terminal sessions in the browser to their projects. Workflows can extend beyond the CoCalc platform to users' remote systems using SSH integration techniques. It is also possible to install almost any package locally in a project.

Software packages are frequently updated. The CoCalc team tracks major releases and offers rolling updates of package sets.

[1] https://cocalc.com

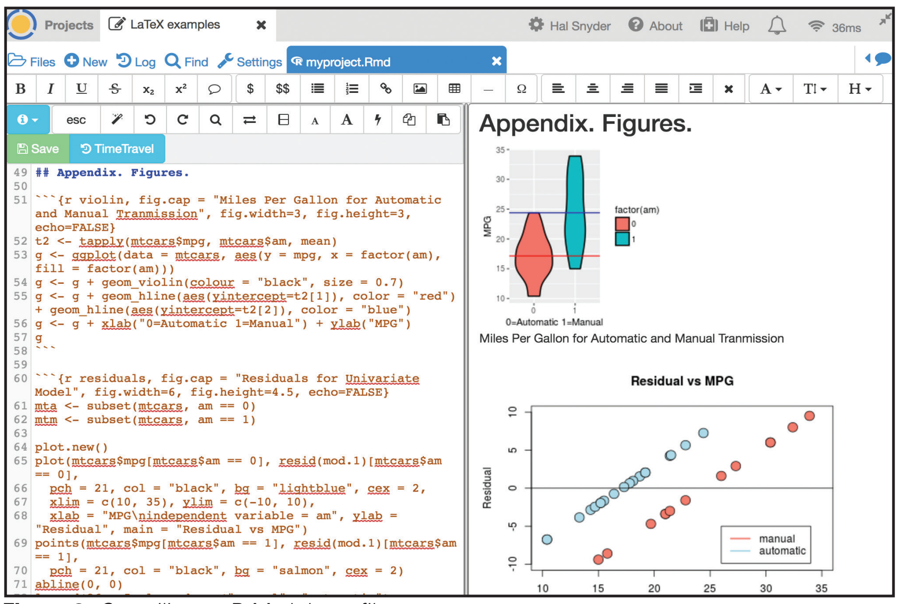


Figure 2. *Compiling an R Markdown file.*

Robust Data Storage

Should a user want to revert to previous versions or accidentally delete his or her files, CoCalc provides data-recovery methods and automatic backups. The system stores several hundred read-only snapshots of all the user's files that are easy to browse, allowing one to recover older versions of files that might not have been edited via the web-editor (and instead by Vim or Emacs via a terminal), or obtain past versions of data files output from computations.

For those using the web editor, every change to a file is recorded and stored indefinitely on CoCalc's servers at roughly a two-second resolution. This high definition file history can be viewed using TimeTravel, which contains a mode showing precisely the changes between two points in time, including information on the authors of the changes (see Figure 3, on page 10). Since internet connections can be unreliable, CoCalc enables a user to continue editing offline; changes are merged into the live document upon reconnecting.

Collaboration and Teaching

The owner of a CoCalc project may invite any number of collaborators. Users can collaborate in real time while editing virtually any file type. Each collaborator has a separate cursor that is visible to all users who have the file open at any given time. There is no explicit limit on the number of simultaneous users, which greatly enhances team effort. For example, both the client and server sides of the Jupyter notebook were completely rewritten in CoCalc for improved collaboration. Furthermore, video chat is available through the side chat panel.

CoCalc has been used for teaching courses at the university level for several years. Subjects include pure and applied mathematics, data science, physics, and bioinformatics. An integrated course management system is available for working with students in courses and workshops: an instructor can push an assignment file to all students and let them work on it, then collect it, grade it, and return the graded files. For finished results, any file or folder in a project may be shared (published). It is then viewable without a CoCalc login on a read-only basis.

Additional Resources

In summary, CoCalc offers an extensive open-source mathematical computing and authoring environment that supports several forms of collaboration and eliminates the work of installing software.

To learn more about CoCalc, visit the website[2] and create a free account. Free accounts offer a platform for unlimited projects and collaborators, with 3GB of disk space per project. Upgrades, including more disk space, CPU power, and outside network access, incur charges. More informa-

See **CoCalc** *on page 10*

[2] https://cocalc.com

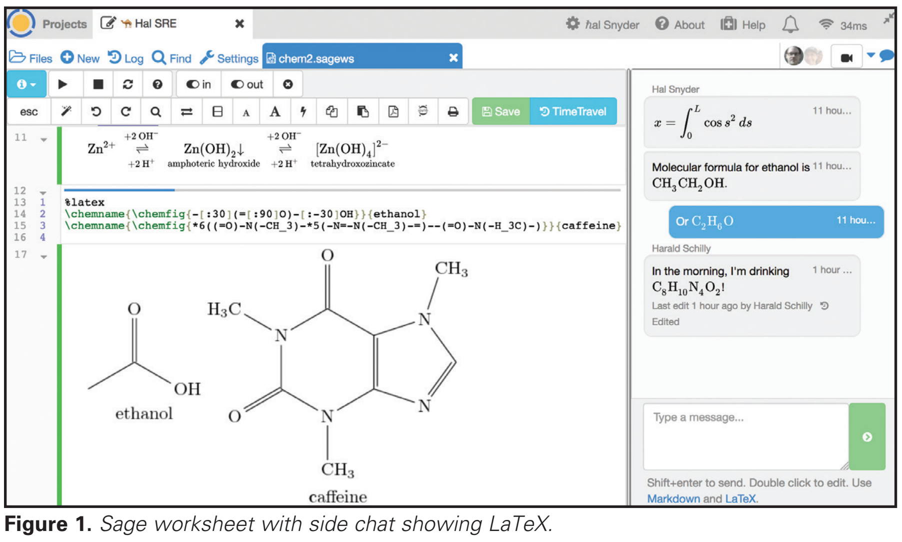


Figure 1. *Sage worksheet with side chat showing LaTeX.*

Vascular Adaptation

Continued from page 6

However, our main goal remains not only to reproduce known experiences but also to identify opportunities for therapeutic intervention. With this in mind, the model must evolve towards an approach that integrates gene activity in a manner facilitating virtual gene therapy trials that predict the clinical impact of the proposed intervention. In a sense, the multiscale model is a systematic way to integrate disparate experimental data—corresponding to measurement of the biomechanical environment, gene expression, cell replication, and tissue remodeling—into a coherent representation of a complex, dynamic system.

As the experimental data keeps adding up, one must calibrate and partially validate the model at various scale levels. The modular approach of the construction grants important flexibility in achieving this crucial task. Once validated at various levels, the integrated model allows one to test the outcome of intersecting gene therapies, and can offer the potential to prolong lumen patency, improve long-term effects, and provide targets for clinical investigation [2].

Given the inherent uncertainty of experimental biologic data, it is unrealistic to expect such a high degree of model precision so as to arrive at a single optimum solution. Instead, the anticipation is that the development and systematic application of this model can narrow the range of potential gene therapies from millions of possibilities to a handful that are able to be tested and eventually made patient specific. It may also help to prevent trapping the research with the "magic bullet" approach, which relies on some new protein discovery that works in a Petri dish but eventually fails due to the system's feedback mechanisms.

Although multiscale modeling has taken a foothold in many disciplines across the biomedical research landscape, its application to clinical disease has been sparse. While our focus has been on the vascular system and its response to surgical manipulation, on a more fundamental level this work sets the template for integrating experimental data with a computational framework to explore the potential of genomic modification to improve patient outcomes or eradicate a disease process. On a broader scale, such an approach is readily adaptable to a range of human pathologies that present a discrete initiating event and interact with the environment during disease progression. Cancer biology—where a genetic trigger leads to cell activation and uncontrolled growth—and life-threatening sepsis—where an acute infection leads to hemodynamic instability and collapse—present promising areas for further expansion of this novel architecture.

References

[1] American Heart Association. (2016). *Heart Disease, Stroke and Research Statistics At-a-Glance*. Retrieved from https://www.heart.org/idc/groups/ahamah-public/@wcm/@sop/@smd/documents/downloadable/ucm_480086.pdf.

[2] Casarin, S., Berceli, S.A., & Garbey, M. (2017). Linking Gene Dynamics to Intimal Hyperplasia – A Predictive Model of Vein Graft Adaptation. *Proc. Comp. Sci., 108*, 1842-51.

[3] De Vries, M.R., Simons, K.H., Jukema, J.W., Braun, J., & Quax, P.H.A. (2016). Vein graft failure: from pathophysiology to clinical outcomes. *Nat. Rev.: Cardiol., 13*, 451-470.

[4] Garbey, M., & Berceli, S.A. (2013). A dynamical system that describes vein graft adaptation and failure. *J. Theor. Biol., 336*, 209-220.

[5] Garbey, M., Casarin, S., & Berceli, S.A. (2017). Vascular Adaptation: Pattern Formation and Cross Validation between an Agent Based Model and a Dynamical System. *J. Theor. Biol., 429*, 149-163.

[6] Garbey, M., Rahman, M., & Berceli, S.A. (2015). A multiscale computational framework to understand vascular adaptation. *J. Comput. Sci., 8*, 32-47.

[7] Zhang, Y., Barocas, V.H., Berceli, S.A., Clancy, C.E., Eckman, D.M., Garbey, M.…Trayanova, N.A. (2016). Multi-scale Modeling of the Cardiovascular System: Disease Development, Progression, and Clinical Intervention. *Ann. Biomed. Eng., 44*(9), 2642-60.

Marc Garbey co-founded (with Barbara Bass) the concept of computational surgery. He is the scientific director of the Center of Computational Surgery at the Houston Methodist Hospital, professor of applied mathematics at the University of La Rochelle, and adjunct professor in the Department of Bioengineering at Texas A&M University. Stefano Casarin is a postdoctoral research fellow at the Center for Computational Surgery at Houston Methodist Research Institute and Vice President of International Affairs at the Methodist Association of Professional and Trainee Affairs. Scott Berceli, M.D., Ph.D., is a professor of surgery and bioengineering at the University of Florida and Chief of Vascular Surgery at the North Florida/South Georgia Veterans Health System.

Celebrating Claude Shannon's Legacy

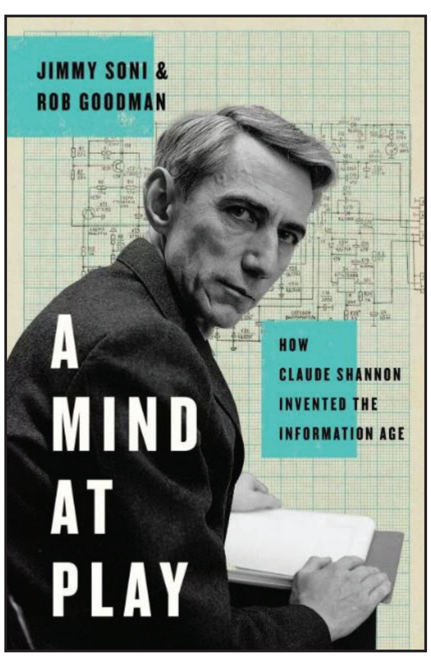
A Mind at Play: How Claude Shannon Invented the Information Age. *By Jimmy Soni and Rob Goodman. Simon & Schuster, New York, NY, July 2017. 384 pages. $27.00.*

BOOK REVIEW
By Ernest Davis

Jimmy Soni and Rob Goodman's claim that mathematician Claude Shannon (1916-2001) "invented the information age" seems like an overstatement, but only a slight one.

Shannon's 1948 treatise, "A Mathematical Theory of Communication," was an extraordinary work of genius that laid the foundations of information theory. It set up the basic conceptual framework for analyzing information and communication across a noisy channel; defined central concepts, particularly entropy; and proved the fundamental bounds on efficiently coding information and communicating it across a noisy channel. The paper was spectacularly clear and extremely readable, with an entertaining extended digression on the use of k-gram Markov models to generate language-like text. While Shannon did not arrive entirely at the theory out of the blue—he cited earlier work by Harry Nyquist and Ralph Hartley, and concurrent work by Norbert Wiener, among others—the credit for most of the content and the elegant conceptual package belongs purely to him.

Shannon's other great accomplishment was his 1937 master's thesis, "A Symbolic Analysis of Relay and Switching Circuits," which largely invented the analysis of digital circuits in terms of Boolean algebra; Shannon proved that any Boolean function can be computed using switching circuits. He also contributed to foundational work in computational linguistics, cryptography, and artificial intelligence.



A Mind at Play: How Claude Shannon Invented the Information Age. By Jimmy Soni and Rob Goodman. Image courtesy of Simon & Schuster.

Shannon's scientific genius was combined with an extraordinarily easy temperament. He was uninterested in fame and had little interest in fortune, though in fact he was quite well off due to successful early investments in technology companies. His passions were for his scientific work, for tinkering with ingenious physical devices, for chess, for jazz, for juggling, and for unicycling — for whatever caught his interest, either serious or playful. He was altogether unpretentious, with a quiet, understated, self-deprecating wit and no taste at all for pompous pontification.

Shannon had a remarkably realistic view of his own work. After the publication of "A Mathematical Theory of Communication"—when information theory became all the rage and was hyped by both scientists and the popular press, often with more excitement than understanding—he felt obliged to write a short essay, "The Bandwagon," to caution against unrealistic expectations:

> While we feel that information theory is indeed a valuable tool in providing fundamental insights into the nature of communication problems and will continue to grow in importance, it is certainly no panacea for the communication engineer or, *a fortiori*, for anyone else. Seldom do more than a few of nature's secrets give way at one time. It will be all too easy for our somewhat artificial prosperity to collapse overnight when it is realized that the use of a few exciting words like *information*, *entropy*, *redundancy*, do not solve all our problems.

On the whole, Shannon enjoyed a pleasant, quiet, and satisfying life, though a few clouds do appear in his biography. His father died when he was young and he quarreled with his mother. He did not much enjoy the year he spent at the Institute for Advanced Study, and seems to have disliked his cryptanalysis work during World War II, though he never talked much about it. Although Shannon's first marriage ended after a year, a thoroughly happy second marriage lasted until the end of his life. Joseph Doob wrote a harsh, unfair review of "A Mathematical Theory of Communication." Norbert Wiener created a small fuss about the comparative merits of his own theory of cybernetics vis-à-vis Shannon's information theory — a fuss that upset the neurotic Wiener much more than the placid Shannon. Tragically, Shannon succumbed to Alzheimer's in his last years.

But for most of his life he lived at peace with the world, happy in his marriage, enormously admired by his colleagues and the world at large, and employed at jobs—first at Bell Labs and then at the Massachusetts Institute of Technology—that almost entirely allowed him to live as he liked and do precisely what he wanted. Shannon epitomized the stereotype of the genius as eccentric; no one could have been further from the stereotype of the genius as a tortured soul.

Shannon was universally lauded and admired; he was showered with prizes, honors, and so many honorary degrees that he built a device resembling a rotating tie rack to hold all of the hoods. Even Doob eventually came around. In 1963, Andrey Kolmogorov wrote, "[Shannon] can be considered equally well as one of the greatest mathematicians and as one of the greatest engineers of the last few decades."

A Mind at Play: How Claude Shannon Invented the Information Age is the first full-length biography of this great scientist, and it is excellent. It is superbly written, easily readable, and thoroughly researched. Though the authors do not come from a scientific background—their previous collaboration was a biography[1] of Cato the Younger, the opponent of Julius Caesar—as far as I can tell, they get everything right. The exposition of the science is crystal clear and correct,[2] though not at all deep, even by popular science standards. The character portraits and evocations of the historical atmosphere possess the ring of truth, and historical judgments are sound and fair. Soni and Goodman explain the impact and significance of Shannon's work very clearly and in depth, but—like Shannon himself and unlike many biographers—they do not overhype it.

See **Claude Shannon** *on page 12*

[1] *Rome's Last Citizen: The Life and Legacy of Cato, Mortal Enemy of Caesar* (2012).

[2] I spotted one tiny error, too minor to be worth describing.

Reflecting on Reflections

MATHEMATICAL CURIOSITIES

By Mark Levi

I. When looking at a shiny ball bearing in my outstretched hand, I see the reflection of my head. This tiny image seems to lie somewhere inside the sphere. Where exactly? More precisely, what is the limiting position of the point I (*Image*) in Figure 1, as $MA \parallel NB$ approaches NB? The answer turns out to be *the midpoint of the radius OB*.

Figure 1 explains why. We have

$$\angle 1 \overset{A}{=} \angle 2 \overset{B}{=} \angle 3 \overset{C}{=} \angle 4,$$

where A holds because the incoming rays are parallel, B is the law of reflection, and C holds because the two angles are vertical. Summarizing, $\angle 1 = \angle 4 \overset{def}{=} \theta$, making the triangle OAI equilateral and implying that

$$OI = \frac{r}{2\cos\theta} \to \frac{r}{2} \quad \text{for} \quad \theta \to 0,$$

as claimed. V.I. Arnold's engaging book [1] contains a derivation of this fact, although it takes slightly more than a page of calculation.

II. An even shorter derivation of the image location results from the mirror formula, which states that the source-to-mirror distance d_1 and the image-to-mirror distance d_2 satisfy

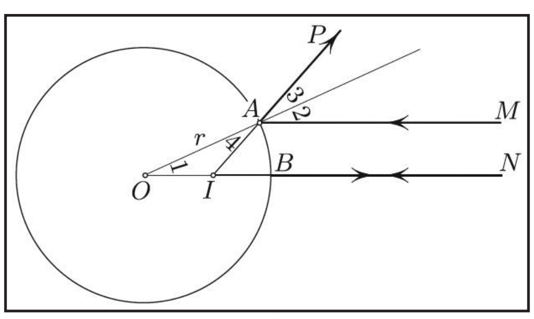


Figure 1. *The reflected ray AP seems to emanate from the point I. And I approaches the midpoint of the radius OB as the ray MA approaches the ray NB.*

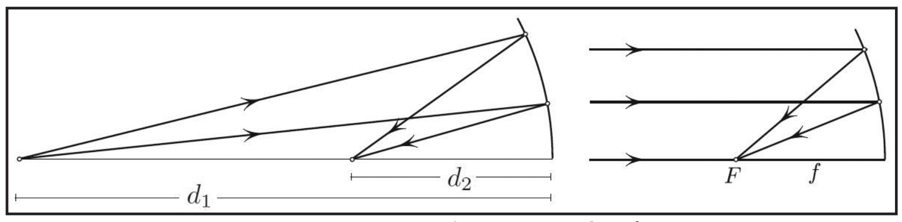


Figure 2. *Illustration of the mirror formula. If* $d_1 = \infty$, *then* $d_2 = f$.

$$\frac{1}{d_1} + \frac{1}{d_2} = \frac{1}{f}, \qquad (1)$$

where f is the focal length of the mirror (see Figure 2). But setting $d_1 = r$ (the radius of curvature of the mirror at B) yields $d_2 = r$ (see Figure 3), since the rays emanating from the center of curvature collect

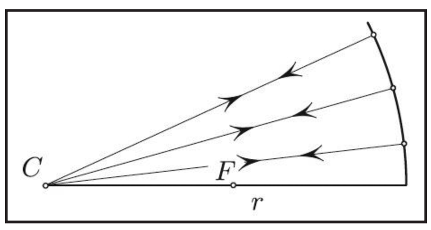


Figure 3. *If* $d_1 = r$ *(the radius of curvature), then* $d_2 = r$.

back at the center (infinitesimally speaking, i.e., replacing the reflector by its osculating circle). In short, (1) yields

$$\frac{1}{r} + \frac{1}{r} = \frac{1}{f},$$

of $f = r/2$, as claimed.

III. Figure 4 shows how the mirror formula comes out of the reflection law $\theta_1 = \theta_2$. We have $\theta_1 = \angle 3 - \angle 1$, where $\angle 3 = ks + o(s)$ (k being the curvature at B), and $\angle 1 = s/d_1 + o(s)$. With the similar expression for θ_2, the reflection law amounts to

$$ks - \frac{s}{d_1} = \frac{s}{d_2} - ks + o(s).$$

Dividing by s and taking the limit for $s \to 0$ gives[1]

$$\frac{1}{d_1} + \frac{1}{d_2} = 2k.$$

Substituting $d_1 = \infty$ and $d_2 = f$, we conclude that $2k = 1/f$. This proves the mirror formula (1) and reproduces the fact that the focal distance is half the radius of curvature, $f = 1/2k = r/2$. Incidentally, we proved this for any smooth curve, not necessarily a circle.

[1] Retaining the names d_1, d_2 for the limiting values of the distances, in a mild abuse of notation.

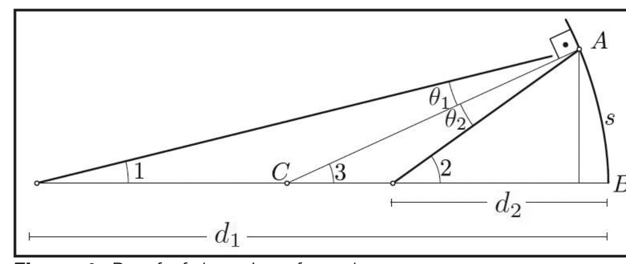


Figure 4. *Proof of the mirror formula.*

The figures in this article were provided by the author.

References

[1] Arnold, V.I. (2014). *Mathematical Understanding of Nature: Essays on Amazing Physical Phenomena and Their Understanding by Mathematicians*. Providence, RI: American Mathematical Society.

Mark Levi (levi@math.psu.edu) is a professor of mathematics at the Pennsylvania State University.

CoCalc

Continued from page 8

tion on pricing is available on the website, while the CoCalc wiki[3] offers a wealth of tutorial and reference information. Articles about new features and system internals can be found on the CoCalc blog.[4] The source code is on GitHub.[5]

[3] https://github.com/sagemathinc/cocalc/wiki

[4] http://blog.sagemath.com

[5] https://github.com/sagemathinc/cocalc

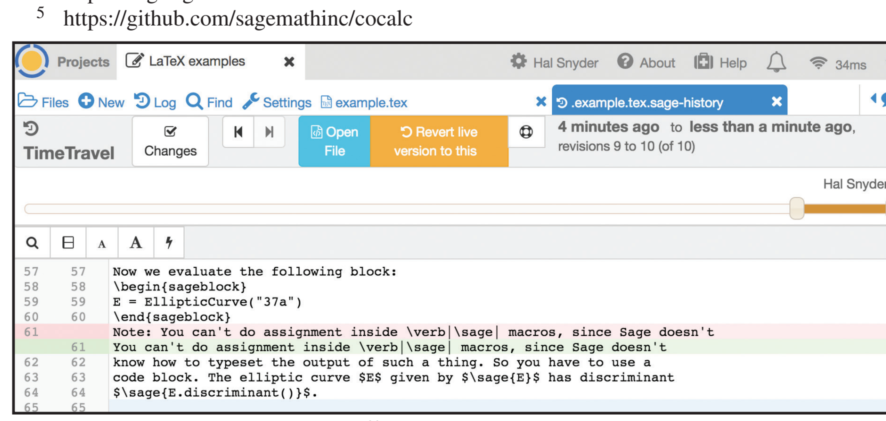


Figure 3. *Edit history showing the difference between two versions.*

Historical note: CoCalc was previously known as SageMathCloud. It was renamed in May 2017.

Hal Snyder earned his M.S. in mathematics from the University of Chicago and his M.D. from Northwestern University. He has worked in operating systems internals and distributed systems for over 30 years, and is currently a senior software developer for CoCalc at Sagemath, Inc.

Professional Opportunities and Announcements

Send copy for classified advertisements and announcements to ***marketing@siam.org****; For rates, deadlines, and ad specifications visit* ***www.siam.org/advertising****.*

*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****.*

Dartmouth College

Department of Mathematics

The Department of Mathematics announces a tenure-track opening for the 2018-2019 academic year. There is a preference for a junior appointment, but we welcome applicants suitable for a high initial rank. The successful applicant will have a research profile with a concentration in applied or computational mathematics, and have demonstrated an ability to work across disciplines such as biology, physics, or computer science, as well as those at the Geisel School of Medicine at Dartmouth, the Norris Cotton Cancer Center, or the Thayer School of Engineering. Applicants should apply online at **www.mathjobs.org**, **Position ID: APACM #10567**. Applications received by **December 15, 2017** will receive first consideration. For more information about this position, please visit our website at **https://www.math.dartmouth.edu/activities/recruiting/**.

Dartmouth College is an equal opportunity/affirmative action employer with a strong commitment to diversity and inclusion. We prohibit discrimination on the basis of race, color, religion, sex, age, national origin, sexual orientation, gender identity or expression, disability, veteran status, marital status, or any other legally protected status. Applications by members of all underrepresented groups are encouraged.

California Institute of Technology

Computing and Mathematical Sciences Department

The Computing and Mathematical Sciences (CMS) Department at the California Institute of Technology (Caltech) invites applications for a tenure-track faculty position. CMS is a unique environment where innovative, interdisciplinary, and foundational research is conducted in a collegial atmosphere. Candidates in all areas of applied and computational mathematics, computer science, and statistics are invited to apply. Areas of interest include (but are not limited to) scientific computing, optimization, statistics, probability, networked systems, control and dynamical systems, robotics, theory of computation, security, privacy, machine learning, and algorithmic economics. In addition, we welcome applications from candidates who have demonstrated strong connections between computer science, engineering, and applied mathematics, and to other fields such as the physical, biological, and social sciences.

A commitment to world-class research, as well as high-quality teaching and mentoring, is expected. The initial appointment at the assistant professor level is for four years, and is contingent upon the completion of a Ph.D. degree in applied mathematics, computer science, engineering, or a related field.

Applications will be reviewed beginning **November 15, 2017**, and applicants are encouraged to have all their application materials on file by this date. For a list of documents required and full instructions on how to apply online, please visit **http://www.cms.caltech.edu/search**. Questions about the application process may be directed to **search@cms.caltech.edu**.

We are an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color,

See **Professional Opportunities** *on page 11*

Professional Opportunities

Continued from page 10

religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law.

Boston University

Department of Mathematics and Statistics

The Department of Mathematics and Statistics at Boston University invites applications for a tenure-track assistant professor in dynamical systems. Ph.D. required, salary commensurate with experience. The position will begin in July 2018, pending budgetary approval. Strong commitment to research and teaching at the undergraduate and graduate levels is essential. Please submit all materials to **mathjobs.org**. Alternatively, send a cover letter, curriculum vitae, research statement, teaching statement, and at least four letters of recommendation, one of which addresses teaching, to Dynamical Systems Search, Department of Mathematics and Statistics, Boston University, 111 Cummington Mall, Boston, MA 02215. Application deadline is **December 1, 2017**. We are an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law. We are a VEVRAA Federal Contractor.

Boston University

Department of Mathematics and Statistics

The Department of Mathematics and Statistics at Boston University invites applications for a tenure-track assistant professor in geometry. Ph.D. required, salary commensurate with experience. The position will begin in July 2018, pending budgetary approval. Strong commitment to research and teaching at the undergraduate and graduate levels is essential. Please submit all materials to **mathjobs.org**. Alternatively, send a cover letter, curriculum vitae, research statement, teaching statement, and at least four letters of recommendation, one of which addresses teaching, to Geometry and Mathematical Physics Search, Department of Mathematics and Statistics, Boston University, 111 Cummington Mall, Boston, MA 02215. Application deadline is **December 1, 2017**. We are an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law. We are a VEVRAA Federal Contractor.

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

Williams College

The Williams College Department of Mathematics and Statistics invites applications for a **tenure-track position in Statistics**, beginning fall 2018, at the rank of assistant professor (a more senior appointment is possible under special circumstances). The candidate should have a Ph.D. in Statistics or a closely related field by the time of appointment. We are seeking candidates who show evidence and/or promise of excellence in teaching students from diverse backgrounds and a strong research program that can engage undergraduate students. The candidate will become the sixth tenure-track statistician in the department, joining a vibrant and innovative group of statisticians with an established statistics major. For more information on the Department of Mathematics and Statistics, visit *http://math.williams.edu/*.

At Williams, we are committed to building a diverse and inclusive community where members from all backgrounds can live, learn, and thrive. In your application materials, we ask you to address how your teaching, scholarship, mentorship and/or community service might support our commitment to diversity and inclusion. Candidates may apply via http://apply.interfolio.com/43065 by uploading a cover letter addressed to Professor Klingenberg, a curriculum vitae, a teaching statement, a description of your research plans, and three letters of recommendation on teaching and research.

Expectations: The teaching load is two courses per 12-week semester and a winter term course every other January. The candidate will be expected to teach introductory statistics, core courses for the statistics major, and electives in their area of expertise. The successful candidate will establish an independent research program that results in scholarly publications. Williams College provides broad support for start-up funds, funding for student research assistants, faculty professional development funds, and a shared computer cluster for parallel computation.

Review of applications will begin on or after **November 1st** and will continue until the position is filled. All offers of employment are contingent upon completion of a background check. Further information is available at *https://faculty.williams.edu/prospective-faculty/background-check-policy/*.

Williams College is a coeducational liberal arts institution located in the Berkshire Hills of western Massachusetts with easy access to the culturally rich cities of Albany, Boston, and New York City. The College is committed to building and supporting a diverse population of approximately 2,000 students, and to fostering an inclusive faculty, staff and curriculum. Williams has built its reputation on outstanding teaching and scholarship and on the academic excellence of its students. Please visit the Williams College website, ***http://www.williams.edu/***.

Boston University

Department of Mathematics and Statistics

The Department of Mathematics and Statistics at Boston University invites applications for a three-year postdoctoral position in dynamical systems, starting July 2018. Strong commitment to research and teaching is essential. Please submit all materials to **mathjobs.org**. Alternatively, send a cover letter, curriculum vitae, research statement, teaching statement, and at least four letters of recommendation, one of which addresses teaching, to Dynamical Systems Postdoctoral Search Committee, Department of Mathematics and Statistics, Boston University, 111 Cummington Mall, Boston, MA 02215. Application deadline is **December 15, 2017**. We are an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law. We are a VEVRAA Federal Contractor.

Institute for Pure and Applied Mathematics/University of California, Los Angeles

Associate Director

The Institute for Pure and Applied Mathematics (IPAM) at UCLA is seeking an Associate Director (AD), to begin a two-year appointment on August 1, 2018.

The AD is expected to be an active and established research mathematician or scientist in a related field, with experience in conference organization. The primary responsibility of the AD is running short and long programs in coordination with the organizing committees. The selected candidate will be encouraged to continue his or her personal research while fulfilling these duties.

For a detailed job description and application instructions, go to **http://www.ipam.ucla.edu/5nhZK**. Applications will receive fullest consideration if received by **February 15, 2018**, but we will accept applications as long as the position remains open. UCLA is an equal opportunity/affirmative action employer.

New York University/Courant Institute of Mathematical Sciences

Department of Computer Science

The Department of Computer Science expects to have several regular faculty positions and invites candidates at all levels to apply. We will consider outstanding candidates in any area of computer science, in particular in scientific computing, verification, programming languages, machine learning, and data science.

Faculty members are expected to be outstanding scholars and participate in teaching at all levels, from undergraduate to doctoral. New appointees will be offered competitive salaries and startup packages. In addition, we fully expect to secure affordable housing for the appointees within a short walking distance of the department. New York University is located in Greenwich Village, one of the most attractive residential areas of Manhattan.

The department has 36 regular faculty members and several clinical, research, adjunct, and visiting faculty members. The department's current research interests include algorithms, cryptography, and theory; computational biology; distributed computing and networking; graphics, vision, and multimedia; machine learning and data science; natural language processing; scientific computing; and verification and programming languages.

Collaborative research with industry is facilitated by geographic proximity to computer science activities at AT&T, Facebook, Google, IBM, Bell Labs, NEC, and Siemens.

Please apply at **https://cs.nyu.edu/webapps/facapp/register**.

To guarantee full consideration, applications should be submitted no later than **December 1, 2017**; however, this is not a hard deadline, as all candidates will be considered to the full extent feasible, until all positions are filled. Visiting positions may also be available.

EOE/AA/Minorities/Females/Veterans/Disabled/Sexual Orientation/Gender Identity.

Georgia Institute of Technology

School of Mathematics

The School of Mathematics at Georgia Tech is accepting applications for **tenure-track faculty in statistics**. Applications by highly-qualified candidates, and especially those from groups underrepresented in the mathematical sciences, are particularly encouraged. See **www.math.gatech.edu/resources/employment** for more details and application instructions.

Georgia Institute of Technology

School of Mathematics

The School of Mathematics at Georgia Tech is accepting applications for **non-tenure track post-doc faculty in pure and applied mathematics and statistics**. Applications by highly qualified candidates, and especially those from groups underrepresented in the mathematical sciences, are particularly encouraged. See **http://math.gatech.edu/employment-opportunities** for more details and application instructions.

Faculty Position in Operations Research and Information Engineering (ORIE)

Operations Research and Information Engineering (ORIE) is available at the Cornell Tech campus in New York City

A faculty position in Operations Research and Information Engineering (ORIE) is available at the Cornell Tech campus in New York City. The position is part of the Jacobs Technion-Cornell Institute, and we particularly encourage candidates whose work fits into Jacobs Institute application-domain emphases in the areas of digital-physical systems (especially in urban environments) and digital health technology.

The position is within Cornell University's School of ORIE, and applicants with research interests represented within Cornell ORIE are welcome at all levels, including tenured and tenure-track. The School consists of a diverse group of high-quality researchers and educators interested in probability, optimization, statistics, simulation, and a wide array of applications such as e-commerce, supply chains, scheduling, manufacturing, transportation systems, health care, financial engineering, service systems and network science. Cornell ORIE spans both the Ithaca and New York City campuses, but the successful candidate's teaching and research will be based in New York City. (Interested candidates can apply for a Cornell Tech in NYC position, a Cornell Ithaca ORIE position, or both, but the two campuses have different application sites; please see the Cornell Ithaca ad for the Ithaca application URL.)

Candidates must hold a Ph.D. in operations research, mathematics, statistics, or a related field by the start of the appointment, and have demonstrated an ability to conduct outstanding research at the level of tenure-track or tenured faculty in Cornell ORIE. They must also have a strong commitment to engagement outside of academia in ways that foster significant commercial or societal impact, as aligned with the mission of the Cornell Tech campus. The successful candidate will be expected to pursue an active research program, to teach Master's and Ph.D.-level graduate courses, and to supervise graduate students.

To ensure full consideration, applications should be received by December 1, 2017, but will be accepted until all positions are filled. Applicants should submit a curriculum vitae, brief statements of research and teaching interests, and the names and contact information of at least three references. They should also identify one or two top publications to which they have made significant contributions. A distinguishing characteristic of research at Cornell Tech, in addition to world-class academic work, is that it engages deeply with external communities, organizations, K-12 education, and industry to address real-world problems and contexts that amplify the direct commercial and societal impact of our research. Accordingly, within a clearly identified subsection of the research statement, the candidate should address prior accomplishments and future plans related to this kind of direct commercial and/or societal impact of their research.

Applications are on-line at
https://academicjobsonline.org/ajo/jobs/9778
Inquiries about your application may be directed to
slm339@cornell.edu.

Diversity and Inclusion are a part of Cornell University's heritage. We are a recognized employer and educator valuing AA/EEO, Protected Veterans, and Individuals with Disabilities.

Writing for Mass Media: You're Better Positioned than You Think

By Jesse Dunietz

Every researcher is also part writer. It's a label that may be unfamiliar or even unwelcome to many graduate students, professors, and industry scientists. But between grants, papers, and reports to higher-ups, writing is undeniably a huge part of research.

Yet somehow, even with all that practice, the thought of writing for a mass-market magazine or news site can seem like a leap into a world so foreign that it's unapproachable. The apparent chasm between us and a broader audience is further widened by the mathematical intensiveness of our work.

After all, what layperson wants to read about math? Thousands, it turns out, with appropriate translation, and the barriers to reaching them are lower than you might think. Over the course of my Ph.D. in computer science at Carnegie Mellon University (CMU), I've been increasingly drawn to science writing, culminating in an American Association for the Advancement of Science (AAAS) Mass Media Fellowship[1] this past summer at *Scientific American*. I've found the most daunting obstacles to be largely illusory, vanishing as soon as I was nudged into confronting them. And not only was my background not an impediment, it proved to be an unexpected boon; my mathematical training opened up otherwise impenetrable stories to me — and to thousands of readers by extension.

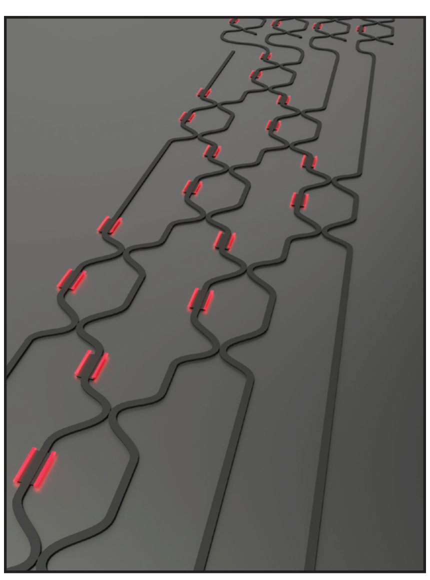


Figure 1. *A visualization of the optical channels in a nanophotonic chip that performs matrix multiplications, which are critical to deep learning techniques in artificial intelligence. Image credit: Nicholas Harris.*

I didn't start out being particularly comfortable with the prospect of mass media publishing. In fact, it took me the better part of a year to go from pondering the possibility of writing something to actually submitting a piece. I knew I enjoyed writing, and I felt a longstanding urge to share my love of all things science and computation. Even so, the notion of publishing anything public-facing felt alien, and I didn't have a clue about the logistics of approaching an outlet.

What finally moved me was as simple as having to put pen to paper. I attended ComSciCon,[2] a student-organized science communication workshop for graduate students where all attendees were expected to draft a piece. Once I ended up with even a partial draft, letting my work molder rather than polishing and submitting it somewhere felt like a shame. A few months after the workshop, my first piece[3] was finally published online — all it had taken was that initial prod and a pointer to an editor. I was hooked.

[1] https://www.aaas.org/page/about-1
[2] https://comscicon.com/
[3] https://blogs.scientificamerican.com/guest-blog/quantum-computing-disentangled-a-look-behind-the-d-wave-buzz/

Emboldened, I started writing for a student blog[4] at CMU, even working my way up to submitting articles to online publications (turns out, the logistics pretty much consist of an email[5] saying, "Hey, want me to write this piece for you?"). But I always hewed closely to my own expertise, writing about topics on which I could speak with personal authority. Finding sources, conducting interviews, and ramping up quickly on unfamiliar topics—in other words, actual reporting—still felt out of reach.

This time, the crucial nudge came from the AAAS Mass Media Fellowship program. Each summer, the fellowship embeds about two dozen STEM Ph.D. students and postdoctoral researchers in major newsrooms like the *Los Angeles Times*, the *Washington Post*, and *Wired*. Thanks to the generous sponsorship of SIAM, I was placed at *Scientific American* for 10 weeks this past summer. And while I was thrilled to be attempting science writing more seriously, I started the summer still cowering at the prospect of reporting.

Once again, sitting down and just getting started showed me how manageable the task really was. As soon as I jumped into the cycle of scanning upcoming abstracts and pounding out pieces, I had to begin contacting scientists all over the world. Within a few days, interviewing sources went from a major, anxiety-laden production to a casual routine repeated as often as five times a day. The world of the science writer again proved less foreign than I'd feared.

Even as I branched out to stories outside my expertise, my familiarity with computer science and physics continued to be valuable. Math-heavy topics like algorithms and particle physics tend to get less coverage than biology or environmental science, in part because they can be difficult for writers to take on; it's not always easy to tell at a glance when such a story is important or novel, and the corresponding papers are often impenetrable without some familiarity with, say, linear algebra or quantum mechanics. Given my background, these mathematically intensive stories became my niche, expanding my notion of how—and to whom—my expertise could be useful.

For example, one of my first stories described a new light-based computer chip[6] that holds great promise for artificial intelligence (AI) (see Figure 1). Had I not already been familiar with the centrality of deep learning techniques to modern AI and of matrix multiplications to deep learning, I doubt I would have recognized the study's potential impact. My mathematical knowledge also proved essential to explaining the technology itself, the crux of which is an optical component that performs an operation isomorphic to a 2×2 matrix multiplication. To describe the mechanics in detail, though, I would have had to explain how matrix multiplications implement weighted sums, how wave interference corresponds to matrix multiplications, and how changes in a light beam's timing can alter interference patterns. After wrestling through several drafts with my editors, I ultimately managed to craft a high-level analogy involving sluices and pumps. Built on intuitions—developed over years of research—for what matrices really do, the analogy conveyed the key processes without getting bogged down in detail at each step.

The optical computing story wasn't an exception, either. I had similar experiences covering a cryptographic protocol[7] for genomic data privacy, techniques for tracing cryptocurrency crimes,[8] and a new method for detecting neutrinos.[9] Time and again, my mathematical knowledge enabled me to wade deep into the science and emerge with a clear, concrete explanation.

[4] https://sciencenonfiction.org/
[5] https://www.xojane.com/diy/how-to-pitch-an-editor
[6] https://www.scientificamerican.com/article/light-powered-computers-brighten-ai-rsquo-s-future/

Jesse Dunietz served as a SIAM-sponsored AAAS Mass Media Fellow at Scientific American this past summer. Image credit: Rebekah Corlew.

If you value writing and are hankering to contribute your knowledge to the wider world, I'd urge you not to let the unfamiliarity of science writing give you pause. Just take the plunge — the pragmatic hurdles are smaller than they seem, and your mathematical grounding makes you an especially valuable translator of complex topics. If you need help getting started, the science writing community is incredibly friendly and supportive. Of course, it helps to have direct supervision and feedback from editors, as I did this summer, but most people (including me!) will happily field questions about the publishing process from new writers. There are also fantastic public forums, like The Open Notebook,[10] where established writers share advice, experiences, and thoughts.

Practically speaking, if you are a student or postdoctoral researcher, I can't recommend the Mass Media Fellowship strongly enough (applications[11] are now open; the deadline is January 15th). If you are past the postdoctoral stage, I'd still encourage you to look for other opportunities to write for audiences beyond academia, be it recurring freelance pieces, the occasional op-ed, or just a personal blog. There's a real appetite for high-quality information about STEM, and that's one thing to which we researchers can certainly cater. So embrace your inner writer and make your voice heard!

Jesse Dunietz is a Ph.D. candidate in computer science at Carnegie Mellon University (CMU) specializing in language technologies. He was also the founding president of CMU's Public Communication for Researchers program, which helps graduate students learn and practice science communication with people of all backgrounds.

[7] https://www.scientificamerican.com/article/cryptographers-and-geneticists-unite-to-analyze-genomes-they-can-rsquo-t-see/
[8] https://www.scientificamerican.com/article/the-imperfect-crime-how-the-wannacry-hackers-could-get-nabbed/
[9] https://www.scientificamerican.com/article/ever-elusive-neutrinos-spotted-bouncing-off-nuclei-for-the-first-time/
[10] https://www.theopennotebook.com/
[11] https://www.aaas.org/page/apply

Claude Shannon

Continued from page 9

The authors recount all well-known anecdotes of Shannon, including the whimsical devices he built: his mechanical mouse "Theseus," which learned a maze; his THROBAC machine, which computed in Roman numerals; the "Ultimate Machine," which turned itself off when turned on; flame-throwing trumpets; and juggling machines. They have also unearthed some lesser-known projects: Shannon's collaboration with Edward Thorp, wisely abandoned, to build a wearable computer that would beat the odds on roulette wheels; a chess-playing computer he built in 1949, which played the end game with six pieces; an unpublished 70-line poem entitled "A Rubric on Rubik's Cube," to be sung to the tune of "Ta-Ra-Ra Boom-De-Ay!"

Soni and Goodman also tell the curious story of Shannon's doctoral thesis, which—for good reasons—is comparatively obscure. In 1910, during the flush of the eugenics movement, the Eugenics Record Office (ERO) was established in Cold Spring Harbor, NY, with funding from the Carnegie Institution and other sources. 25 years later, the eugenics movement had been discredited. Vannevar Bush, who was then president of the Carnegie Institution, decided to withdraw its funding, and the office closed in 1939. Meanwhile, the ERO had accumulated an enormous quantity of genealogical and personal information, some of it meaningful. Bush sent Shannon there to work with geneticist Barbara Stoddard Burks and sift through the material for any valuable information. Shannon's thesis developed an algebra for theoretical genetics. It was mathematically creative, but reflected major gaps in his command of the literature; he reproved a theorem that had been known for two decades. The work was not published and Shannon did not pursue the subject any further. However, according to a current expert in population genetics whom Soni and Goodman consulted, there would have been some value in its publication, in hindsight.

Since Shannon's life was not enormously eventful, the book has plenty of room for background and supplementary material—including short biographical sketches of Nyquist, Hartley, Doob, Wiener, Bush, Burks, and Warren Weaver—and historical accounts of various analog computers, such as Lord Kelvin's tide-predicting machine.

All in all, *A Mind at Play* is a very entertaining and important account of the life and works of an extraordinary scientist.

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