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Numerical Models for Urban Seismic Risk Analysis

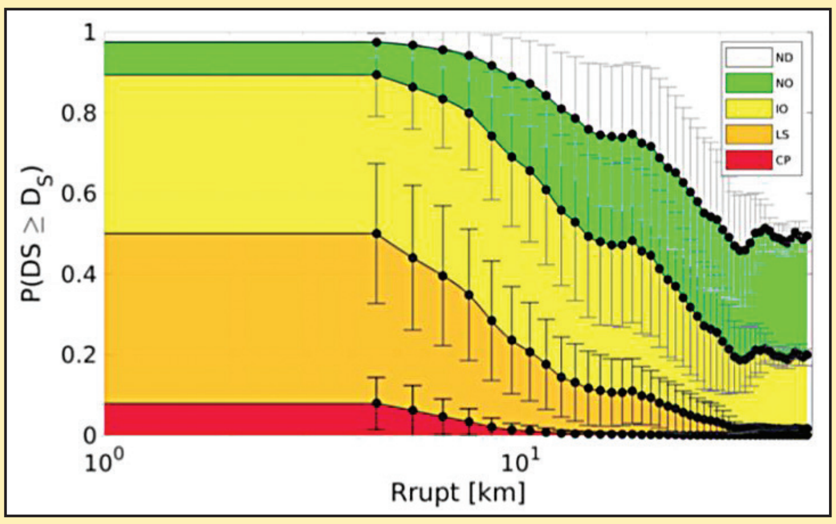

Figure 4. *Probability of exceeding all damage states (DS) as a function of closest distance to the fault rupture (Rrupt) for a given scenario of 6.5 Mw. The shaded white region indicates no damage (ND), green depicts normal operation (NO), yellow represents immediate occupancy (IO), orange denotes life safe (LS), and red depicts collapse prevention (CP). Mean and standard deviation estimates are illustrated by filled dots and bars respectively. Figure courtesy of Laura Melas.*

Seismic risk characterizes a built environment's susceptibility to earthquake damage, and urban seismic risk specifically focuses on particular vulnerabilities that impact cities. In an article on page 2, Alfio Quarteroni describes mathematical methods for seismic risk quantification in densely-populated areas.

Linking Extreme Weather to Climate Change

By Matthew R. Francis

As the world's climate changes, the warming atmosphere and oceans produce heavier rainfalls and more hurricanes, snowstorms, and other instances of extreme weather. Climate models predict the change in frequency of these events as a result of human-driven global warming. However, scientists and non-scientists alike are interested in whether climate change is responsible for *specific* weather events — such as Hurricane Maria, which devastated Puerto Rico in 2017.

"The kosher answer to this used to be that we can never say that climate change causes a specific event," statistician Claudia Tebaldi of the University of Maryland's Joint Global Change Research Institute said. "This has actually changed over time, because a few recent events were so extreme that the probability of observing them without climate change would have been practically zero."

In other words, scientists and science communicators are growing increasingly confident about linking specific weather to global changes, a subfield of climate science and meteorology known as "event attribution." Researchers calculate the probability of a particular event's occurrence with or without climate change by considering a combination of factors, including human activity and variations that are independent of human contribution. Event attribution is a relatively recent discipline; scientists first used it to link climate change to the 2003 European heat wave [4], which killed thousands of people.

Communication to both the public and policymakers is a major part of event attribution. "The idea is to make this type of analysis—and the communication that ensues—a part of water-cooler conversation, the same sort of thing as weather forecasts," Tebaldi, who formerly worked at the National Center for Atmospheric Research, said.

After all, people already informally attribute weather events to climate change, or disingenuously use specific weather events as ammunition for climate change denial. Since these conversations happen anyway, event attribution can steer them in more productive directions. For instance, hurricanes occurred long before human records existed, but *some* hurricanes only result from increased greenhouse gases produced by human activity. In short, cer-

See **Extreme Weather** *on page 4*

How Bees Use Physics to Keep Hives Cool

By Lakshmi Chandrasekaran

Have you ever wondered how an organism tries to solve a physiological problem on scales much larger than itself? For instance, humans construct architectures that are tens to hundreds of times bigger than themselves via a combination of systematic design, global planning, and effective communication between individuals.

How does this work for insects such as bees, wasps, termites, or ants, which tend to cohabitate in large colonies? To survive as a colony, social insects must solve some key problems, including maintaining mechanical stability, thermal regulation, and ventilation within the colony. "Here we see a fundamentally different approach to the solution, without a plan or a planner," said L. Mahadevan, Lola England de Valpine Professor of Applied Mathematics, of Organismic and Evolutionary Biology, and of Physics at Harvard University. "Organisms respond to local rules and harness the environment to communicate information on scales much larger than themselves." Building on earlier work pertaining to the thermoregulation of bee clusters [3] and active mechanical adaptation of bee swarms [4], Mahadevan's group recently addressed the way in which a swarm of bees in a congested hive stays cool on hot summer days [5].[1]

European honeybees (*Apis mellifera*) live in large, crowded enclosures with a single opening that limits passive ventilation. The colonies comprise more than 10,000 bees living together within tree hollows or other pre-existing cavities. These narrow, confined spaces present continuous survival challenges, including the need to maintain a stable temperature. This is especially true during extreme heat, when nest temperatures can reach a high of over 40° Celsius.

To understand how bees regulate colony temperatures, Jake Peters, now a postdoctoral fellow at Cornell University, monitored a group of artificial beehives housed at Harvard's Concord Field Station. Figure 1a depicts the experiment, wherein a dense group of honeybees ventilates the hot box. The swarm creates an active fanning flow by moving to one side of the entrance and pulling hot air out of the hive. The other side of the entrance has few to no bees. Figure 1b shows that as the air temperature (red curve) increases along the nest entrance of a hive, the density of the fanning bees increases (black curve), as does the outward velocity of air (blue curve). The spatial patterning of the fanner bees yields a global convective flow that then cools the hive. But how do the bees spontaneously arrange themselves this way without a plan, especially since they start out by being uniformly distributed at the entrance?

To explain this phenomenon, Mahadevan's group hypothesized that the fanning bees use fluid flow to both measure the hive temperature and self-organize at the entrance. To understand the implications of this idea, the researchers created a mathematical model inspired by observations of the temperature, fluid flow, and fanner bee density along the colony's entrance.

The model starts by characterizing the local fanning response of individual bees to the local air temperature, which is a proxy for the temperature inside the hive. "Indeed, by pulling the air out by fanning, the bees at the entrance can determine whether the nest needs to be cooled," Mahadevan said. If it does, they recruit additional fanner bees that then work together to pull the hot air out. Mahadevan's team links bee behavior, air temperature, and airflow by measuring how the distribution of fanning bees $\rho(x,t)$, local air temperature $T(x,t)$, and local flow velocity $v(x,t)$ vary with time t along the nest entrance x. Their model assumes that the local temperature determines the probability of a bee fanning at the entrance. The local density of fanning bees is given by

See **How Bees Use Physics** *on page 3*

[1] Mahadevan co-authored this paper with Orit Peleg, a former postdoctoral fellow at Harvard who is now a faculty member at the University of Colorado, and Jake Peters, a former graduate student at Harvard who is now a postdoctoral fellow at Cornell University. Their work was supported by the National Science Foundation.

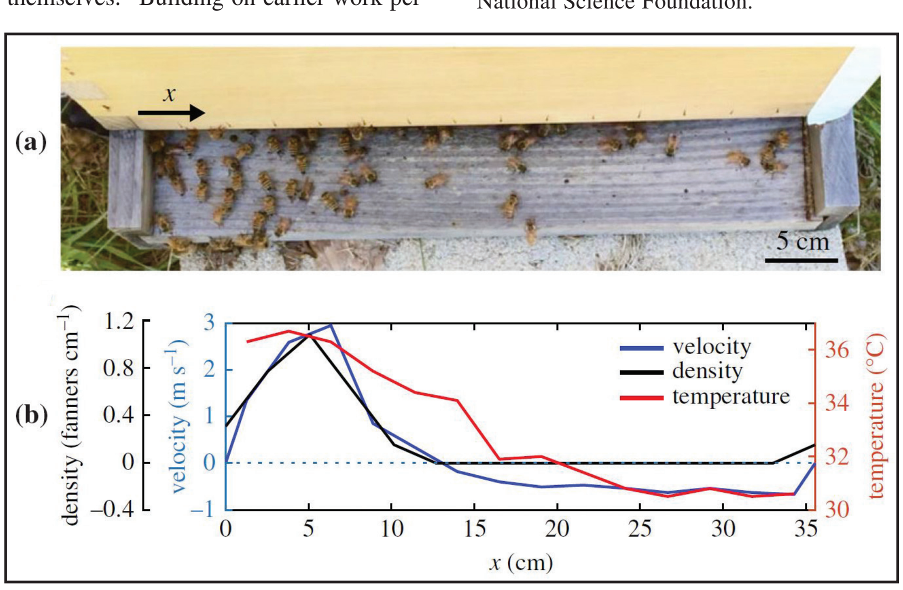

Figure 1. *Honeybee activity at a hive's entrance.* **1a.** *Honeybees ventilating at the entrance. There is a dense group of fanning bees at the left of the entrance and a dearth of fanning bees at the right.* **1b.** *The air velocity (blue line), density (black line), and temperature (red line) along a hive's nest entrance. Negative values indicate inflow while positive values indicate outflow. Figure courtesy of [5].*

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Numerical Models for Urban Seismic Risk Analysis

By Alfio Quarteroni

Researchers estimate that more than 500,000 detectable earthquakes occur each year; approximately one-fifth of these are felt, and 100 cause damages.[1] An earthquake's amplitude and duration of induced ground motion, as well as building vulnerability, dictate the number of fatalities and severity of economic loss.

Determining seismic risk—the liability to a built environment from earthquake damage—forms the basis of mitigation strategies. Urban seismic risk, as the name suggests, focuses on specific issues that impact cities. Seismic risk assessment generally involves the quantification of seismic hazard, which is then combined with suitable vulnerability models of structures and facilities for estimating damage probability. Ultimately, a predefined metric measures expected loss.

Mathematical models for seismic hazard quantify the expected earthquake shaking in a given area in terms of various ground motion intensity measures (IMs), such as *peak ground acceleration* (PGA) or *spectral acceleration* (SA) *response ordinates*. PGA is the largest absolute value of ground acceleration that occurs during earthquake shaking at a certain location, whereas SA describes the maximum acceleration of an object (a damped linear oscillator) that is subject to an earthquake and moving along one physical dimension.

For a prescribed building typology (e.g., given structural material, height, and quality), suitable fragility/vulnerability models—which are conditioned on the level of IM and provide the probability of damage/loss—can determine direct physical damage. Our numerical model for risk determination utilizes synthetic earthquake ground motion scenarios and vulnerability models that predict seismic ground motion's effect on buildings [4]. Here I describe our mathematical approach for seismic risk quantification in densely-populated areas (see Figure 1).

[1] https://earthquake.usgs.gov/

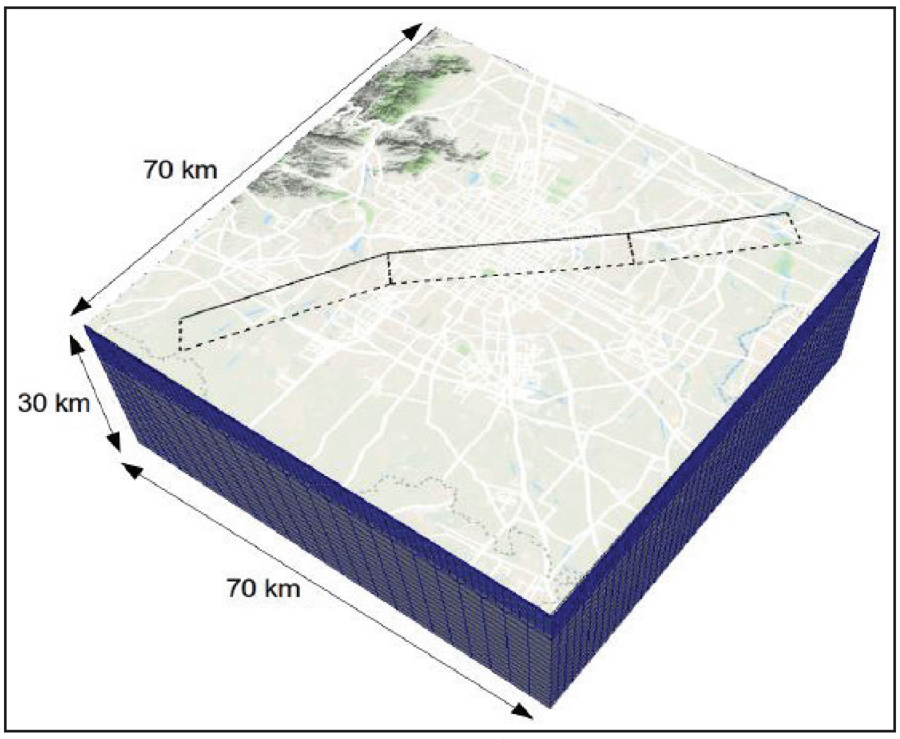

Figure 2. *Three-dimensional computational model for the Beijing area. Black segments represent the location of the Shunyi-Qianmen-Liangxiang fault. Figure courtesy of Ilario Mazzieri.*

A key element of seismic risk analysis is the characterization of seismic ground shaking and its spatial variability using three-dimensional, physics-based numerical simulations of potential earthquakes with prescribed moment magnitude Mw (measure of the earthquake's strength), hypocenter location, and source characteristics in the target region.

From a mathematical standpoint, three-dimensional, physics-based models are comprised of partial differential equations that yield the displacement of a (visco) elastic medium—the ground—subjected to an external excitation (seismic) source. The main challenges in the design and analysis of numerical models meant to capture all of the problem's important physical features while simultaneously retaining affordable costs are as follows: (i) *geometric flexibility* to correctly describe the complex, three-dimensional features of the domain (the portion of the ground through which seismic waves propagate); (ii) *accuracy* to capture the media's heterogeneity and the different spatial and temporal scales; and (iii) *scalability* to exploit high-performance computing architectures for large-scale computations.

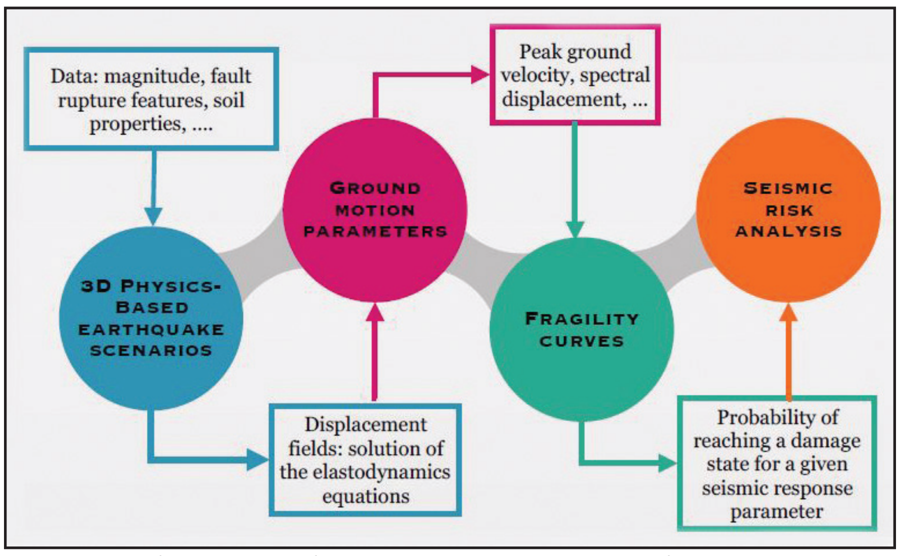

Figure 1. *Workflow overview of the proposed mathematical model for seismic risk analysis. Figure courtesy of Paola Antonietti.*

Spectral element (SE) methods are among the most powerful tools in the field of computational seismology. These methods solve problems in a finite-dimensional space made of high-order, piecewise continuous polynomials that are sampled at Gaussian integration points. Further improvement of SE methods for the viscoelasto-dynamics wave propagation equations yield the discontinuous Galerkin spectral element (DGSE) method [1-2]. The main idea of this method relies on a domain decomposition paradigm: the computational domain is partitioned into a number of nonoverlapping substructures, and spectral elements are employed within each subdomain. The discrete solution can remain discontinuous across interfaces, and (weak) continuity is recovered according to the discontinuous Galerkin (DG) paradigm, i.e., by penalizing the jump of the discrete displacement.

This is a very efficient approach for large-scale applications because it keeps the proliferation of numerical unknowns under control, which typically swamps elementwise DG schemes whose finite-dimensional space contains elementwise piecewise discontinuous polynomials. Moreover, the DGSE method in [2] preserves the same accuracy of SE methods and features low numerical dissipation and dispersion errors [3]. This guarantees a precise approximation of both the amplitude and wave-field phase, which provide important information about the interior structure and consistency of soil layers. Additionally, the DGSE method is much more flexible than the SE method, as it allows an adaptive choice of the local (elementwise) discretization parameters, the element size, and the local polynomial degree. The DGSE method also enjoys a high level of intrinsic parallelism, making it well suited for massively parallel computations.

We simulated a number of synthetic earthquake scenarios by varying magnitude, location, and fault-rupture geometry, albeit in a physically consistent way. Each simulated earthquake behaves like a real tremor and provides the full waveform of ground motion at any (sampled) point of the modeled region. One can compute any ground motion IM (e.g., the response spectral displacement) from the synthetic

See **Urban Seismic Risk** *on page 5*

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How Bees Use Physics

Continued from page 1

$$\frac{\partial \rho}{\partial t} = k_{\text{on}}(T) - k_{\text{off}}(T), \quad \rho(x,t) \in [0, \rho_{\max}], \tag{1}$$

where k_{on} and k_{off} describe the rate at which bees begin or stop fanning behavior respectively. The maximum achievable density is represented by $\rho_{\max}$, which depends on space availability at the nest's entrance.

The group modeled the fanning rates to describe the probability that a bee will fan at a given temperature via the following simple, switch-like sigmoidal function:

$$k_{\text{on}} = k_0 \frac{\tanh\big(m(T - 36^{\circ}C)\big) + 1}{2} \tag{2}$$

and

$$k_{\text{off}} = k_0 - k_{\text{on}}. \tag{3}$$

The parameter m determines the slope of the sigmoidal function that controls the temperature range over which bees ventilate. Since m is the model's only behavioral parameter, Mahadevan and his colleagues hypothesize that natural selection has likely acted on the inter-individual variation in fanning thresholds. Such variation ensures efficient ventilation over the range of temperatures that the bees experience. Mahadevan compares the variable fanning threshold to slightly imperfect artificial temperature sensors in a building. "Having many sensors, each of which operates over a slightly different range of temperatures, collectively smooths out fluctuations in the environment and controls building temperature well," he said. Similarly, subtle genetic variations—akin to the different sensors—confer different temperature thresholds in individual bees, above which they begin to fan. This mechanism enables bees to better react to temperature variations by responding to their individual local environments. Previous studies have shown that such diversity is essential to maintaining stable fanning behavior for efficient ventilation.

Mahadevan's model then couples this fanning behavior to a minimal equation for fluid mass conservation across the hive entrance. To characterize the airflow, it assumes that each bee generates an outward airflow with velocity v_b. Since the nest has only one opening, air that is actively drawn from the entrance must be balanced by air that flows into it to ensure conservation of mass. The following equation characterizes airflow in and out of the nest:

$$v(x,t) = l_b v_b \left[\rho(x,t) - \frac{1}{L}\int_0^L \rho(x,t)\,dx\right] + D_v \frac{\partial^2 v(x,t)}{\partial x^2}, \tag{4}$$

where v_b is the outward air flow generated by each bee. D_v indicates the scaled momentum diffusivity, L denotes the size of the nest length, and l_b represents the characteristic length scale derived from the fanning pressure gradient and fluid friction. The first term in (4) captures the outward airflow due to the actively fanning bees. However, this outflow must be balanced by inflow elsewhere, thus demanding the presence of a global inhibitor (second term) as it reverses flow direction and conserves the hive air volume. The last term represents local fluid friction and penalizes large velocity gradients (e.g., reversals in flow directions).

Finally, the researchers use a simple heat transfer equation that models temperature variation along the entrance, given by

$$\frac{\partial T(x,t)}{\partial t} = -cv(x,t)\Delta T + D_T \frac{\partial^2 T(x,t)}{\partial x^2}. \tag{5}$$

Here, $\Delta T = \begin{cases} T - T_h, & \text{if } v \geq 0 \\ T_a - T, & \text{if } v < 0 \end{cases}$, and T_h and T_a are the hive and ambient temperatures respectively. Dimensionless forms of the equations reduce the number of parameters to just four: a scaled entrance size, a scaled thermal diffusivity, a scaled fluid friction parameter, and a scaled fanning bee size.

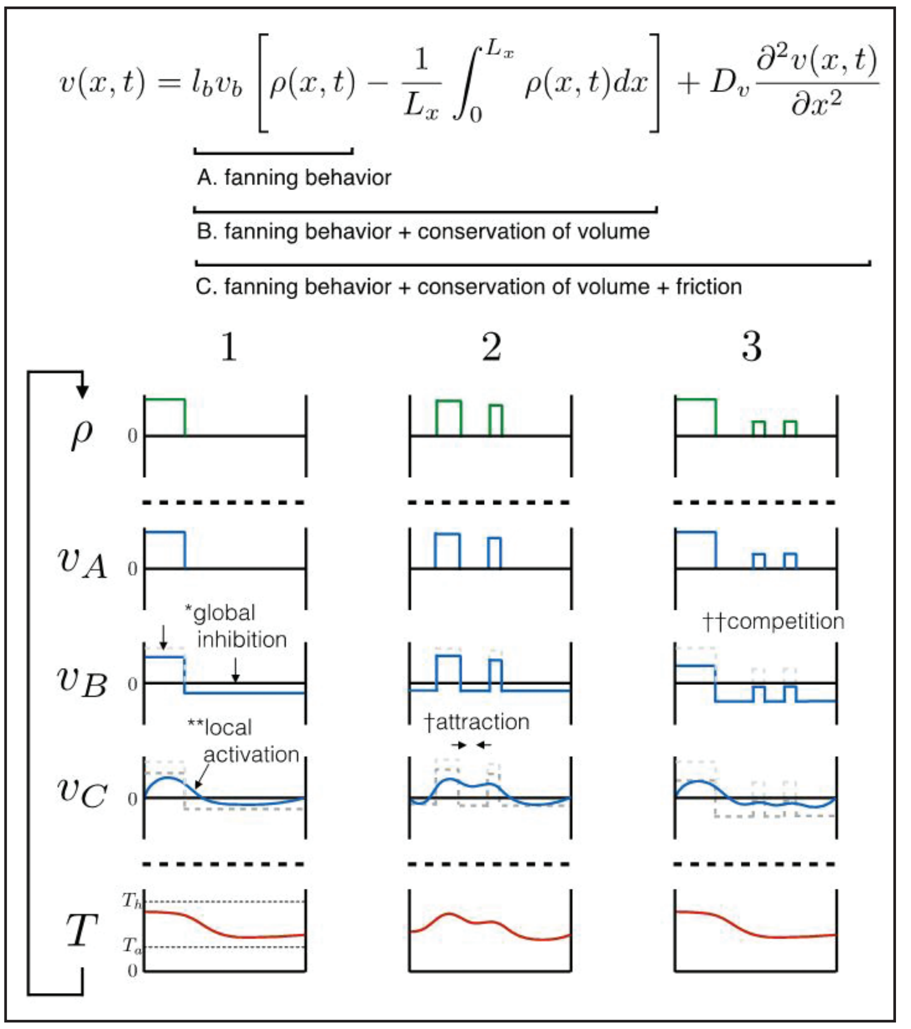

Figure 2. *A schematic demonstrating the mechanisms of self-organization that emerge from the model. The fluid conservation equation is broken down into components: A is the direct result of fanning behavior, B is conservation of volume, and C is friction (or effective diffusion of velocity). The following variables are plotted: the distribution of fanners (ρ); velocity, calculated based only on fanning behavior (v_A); velocity, calculated based on fanning and conservation (v_B); velocity, calculated based on fanning, conservation, and friction (v_C); and temperature profile (T). Scenario 1 is a simple example that illustrates how volume conservation contributes to global inhibition of fanning behavior, and how fanning contributes to local activation. In other words, bees are more likely to fan adjacent to other fanning bees due to friction/diffusion. Scenario 2 illustrates a case in which friction/diffusion drives attraction between adjacent fanning groups. As a result, fanners are more likely to fan between fanning groups. Finally, Scenario 3 illustrates the potential for conservation of volume to act as a global inhibitor. Large fanning groups are more likely to grow and smaller groups are more likely to shrink and disappear due to this competition. Figure courtesy of [5].*

Interestingly, the form of equations (1) through (5) shows that fluid flow driven by bee recruitment follows a local excitation and global inhibition pattern. Fanning bees tend to excite other local fanners, while fluid conservation leads to long-range inhibition (see Figure 2). This collectively yields the emergent behavior observed in the field.

Mahadevan and his collaborators numerically solved equations (1) through (5) to show that fanning behavior results in a clustering of the bees along one half of the nest's entrance. This causes active outward flow of hot air where bees are present, and passive inward flow of cooler air everywhere else. Such behavior gives rise to a global convective flow that cools the hive. "Because of bees' ability to measure local temperatures and fan to generate air flow—which then feeds back on their recruitment—this solution arises spontaneously," Mahadevan said. The model's predictions are qualitatively consistent with observations and show how fanning bees harness the dynamics of the physical environment and bring about self-organized behavior.

Studies like this one demonstrate how complex behavior in social insects can arise on large scales from simple local rules and long-range physical channels for communication, such as those induced by flow or elasticity. This type of work is quite distinct from the better-studied stigmergic mechanisms that rely on strongly localized communication channels, and has the potential for far-reaching implications [1]. For example, one could apply the insect ventilation problem to devise new strategies for passive and active sustainable human architecture [2].

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References

[1] Heylighen, F. (2016) Stigmergy as a universal coordination mechanism. *Cog. Syst. Res., 38*, 4-13.

[2] Holbrook, C., Clark, R.M., Moore, D., Overson, R.P., Penick, C.A., & Smith, A.A. (2010). Social insects inspire human design. *Bio. Lett., 6*(4), 431-433.

[3] Ocko, S.A., & Mahadevan, L. (2014). Collective thermoregulation in bee clusters. *J. Roy. Soc. Inter., 11*(91), 20131033.

[4] Peleg, O., Peters, J., Salcedo, K., & Mahadevan, L. (2018). Collective mechanical adaptation of honeybee swarms. *Nat. Phys., 14*, 1193-98.

[5] Peters, J., Peleg, O., & Mahadevan, L. (2019). Collective ventilation in honeybee nests. *J. Roy. Soc. Inter., 16*(150), 20180561.

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Extreme Weather

Continued from page 1

tain weather events simply could not have transpired in human history before the rise of industrialization in Europe.

Going to Extremes

Because climate affects weather, changes in climate impact the type and severity of local weather. Higher temperatures drive evaporation, which can increase or suppress precipitation depending on specific conditions (for example, higher humidity prevents overnight cooling). Droughts therefore occur more frequently, and relatively more rain or snow falls during severe storms.

While these statements are well understood and uncontroversial, the challenge lies in linking individual weather events to climate and demonstrating that they could only occur—and/or be as severe—because of human-induced changes to the atmosphere. Researchers examine both human-driven and human-independent factors to assign a probability indicating that a particular weather event can be credited to climate, drawing on multiple climate models and local weather data.

Since this method is not fruitful for every thunderstorm or dry August, event attribution research focuses on extreme weather, which requires that one define "extremity" in a consistent way. Transparency when selecting which events to study is therefore essential, both to avoid any appearance of bias and make the process as automatic and replicable as possible.

The major criteria that define such extreme events include duration—storms localized in time simply have less available data—and potential or actual damage to people. As a result, not all extreme weather measured by rainfall or windspeed will trigger event attribution analysis. For instance, a hurricane that never makes landfall is not a good candidate for event attribution, though it can help improve statistics for determining storm frequency.

An additional complication arises when researchers are confident about linking increases in certain types of weather to climate change, but models for describing specific storms are less robust. This is especially true for events characterized by significant air circulation, such as hurricanes and typhoons. Researchers can link general surges in the frequency of these storms to climate, thanks to measurements of ocean surface temperatures and other factors; however, blaming a *particular* hurricane on global warming is difficult. Scientists still do not fully understand nontropical cyclones such as nor'easters (essentially winter hurricanes at high latitudes), so event attribution can neither link them to climate change nor dismiss such a link (see Figure 1). Similarly, a connection between global warming and extreme tornado activity might exist, but models are not yet good enough to demonstrate that relationship.

However, instances of extreme weather that are primarily temperature-driven are good candidates for event attribution, since the link between extreme temperatures and climate change essentially provides the basis for many models. For this reason, event attribution is most successful for heat waves, heat-associated droughts, and decreased cold spell durations.

Researchers have only recently begun to identify events with excessive rain or snowfall that can be credited to climate change. For instance, while current winter temperatures are generally higher than in the past, this is not true for heavy snowstorms, including snowfalls at very low temperatures, which are more common now than in the historical record. "In the case of precipitation, the system's variability is so high that it was really hard to detect a new trend," Tebaldi said. "But more and more, scientists are detecting precipitation changes that are consistent with an increase in warming climate."

Event attribution is necessarily model-dependent because researchers have to estimate the probabilities of events occurring with and without the influence of climate change. The field suffers from many of the same difficulties that plague all climate research, namely that humanity is collectively running an uncontrolled and unreplicable experiment on Earth's climate. Though we only have one time series of data (that is, history) to go on, this history guides the model-building process. For instance, researchers have used past data to successfully model hypothetical temperatures for various places without greenhouse gas emissions, and then compared these models to actual observations (see Figure 2) [3]. Also, while Earth represents only one "experiment" at the present time, researchers often employ multiple models and simulations to produce many different outcomes for comparison with reality.

Scientists use these models—with appropriate uncertainties—to estimate the probability of a weather event with (P_1) and without (P_0) climate change. Event attribution then utilizes two related quantities to decide if an incident is attributable. The fraction of attributable risk (FAR) and risk ratio (RR) are defined as follows:

$$FAR = \frac{P_1 - P_0}{P_1} \qquad RR = \frac{P_1}{P_0}.$$

These values are easily interpretable for the purpose of public discussion. For FAR values close to 1 and large RR values, we can confidently state that a given event could only occur because of climate change. Smaller values require more nuanced language.

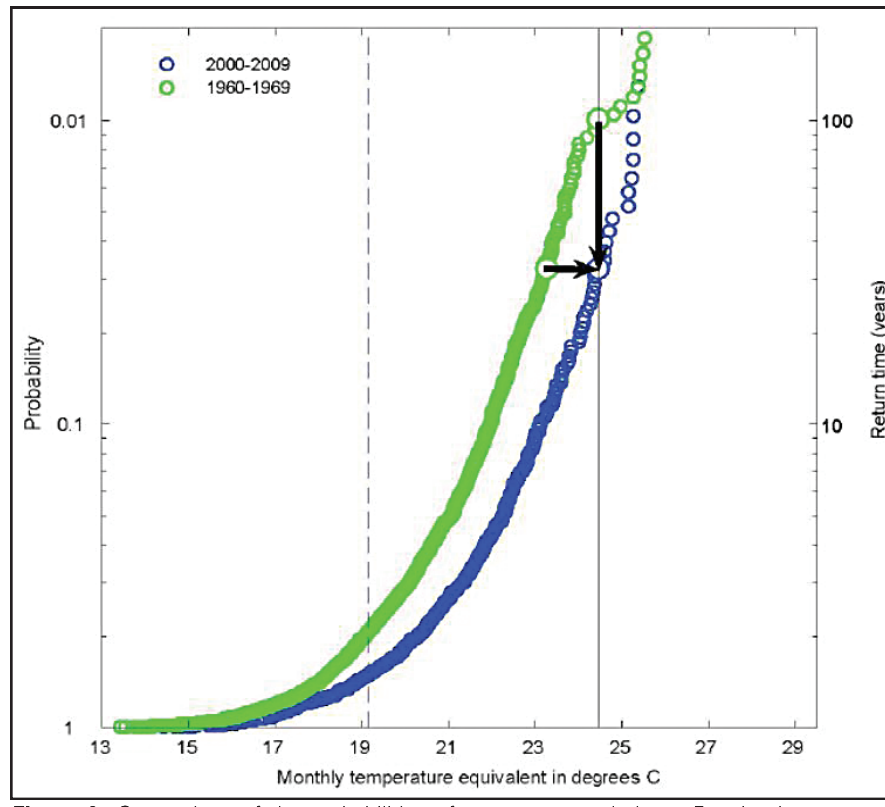

Figure 2. *Comparison of the probabilities of temperatures during a Russian heat wave in the 1960s versus the 2010s. This plot shows that climate change is clearly responsible for hotter summers; dangerous heat waves are some of the clearest cases for event attribution research. Figure courtesy of [3].*

The common approach obtains probabilities by solving the linear equation

$$y = Xa + u$$

for $\boldsymbol{a}$, where $\boldsymbol{y}$ is the vector containing observed quantities, $\boldsymbol{u}$ is the effect of climate without human influence (typically represented by a Gaussian random vector), and $\boldsymbol{X}$ is the matrix that represents all of the weather system's estimated responses to climate change [2]. The vector $\boldsymbol{a}$ contains the linear regression amplitudes that map each response onto the observed quantity in $\boldsymbol{y}$. One can calculate the probability that a particular response f—represented by the column X_f—has an influence on the weather by using the probability that the corresponding amplitude a_f is positive [1-2].

Language and Accuracy Matter

Apart from the scientific problem, people often have trouble grasping the meaning of probabilities, which makes it challenging to communicate event attribution to policymakers and the general public. To mitigate this issue, World Weather Attribution—an international collaboration between universities and other organizations—rapidly analyzes weather events. Affiliated researchers use peer-reviewed methods to produce comprehensible reports on weather, in addition to more detailed analyses to inform policy.

Event attribution also helps clarify unclear terminology in common usage. For example, reports stating that a storm occurs "once every 100 years" (or those that make similar assertions) are often predicated on pre-climate-change assumptions. By comparing the real world to an imaginary world without global warming, event attribution provides alternative language for public communication.

While this approach is effective for Europe and North America, weather models and data are less robust for large parts of the world. Much of Asia, Africa, and the Pacific islands are both poorly modeled and extremely vulnerable to the effects of climate change. Event attribution research must take this into account before it can claim true global success.

However, the urgency of climate change demands global and non-parochial responses. Just as researchers developed event attribution to fill the need for clear analysis and communication, the next phase must encompass the whole planet. After all, we're all in this together.

References

[1] Hannart, A., & Naveau, P. (2018). Probabilities of causation of climate changes. *J. Clim., 31*, 5507-5524.

[2] Hegerl, G., & Zwiers, F. (2011). Use of models in detection and attribution of climate change. *Wiley Interdiscip. Rev.: Clim. Change, 2*, 570-591.

[3] National Academies of Sciences, Engineering, and Medicine. (2006). *Attribution of Extreme Weather Events in the Context of Climate Change*. Washington, D.C.: National Academies Press.

[4] Stott, P., Stone, D., & Allen, M. (2004). Human contribution to the European heatwave of 2003. *Nature, 432*, 610-614.

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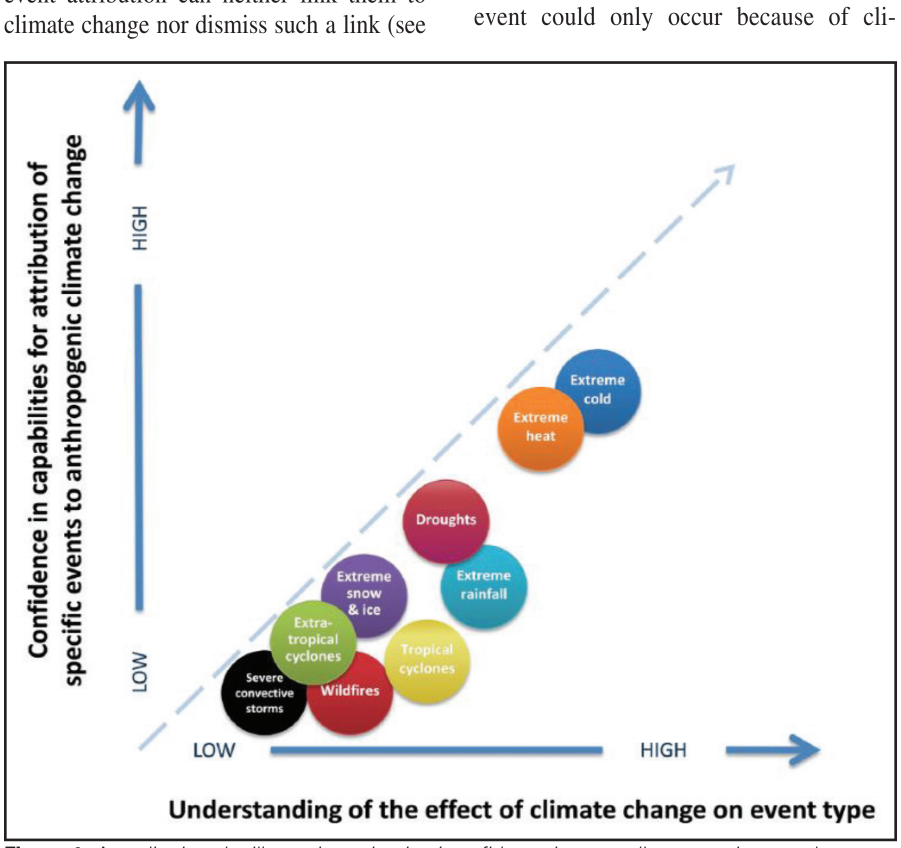

Figure 1. *A qualitative plot illustrating scientists' confidence in generally connecting weather types with climate change (x-axis), and their confidence in specific event attribution (y-axis). Temperature-driven weather, such as warmer winters and hotter summers, carry the most confidence, while atmospheric circulation weathers have the lowest confidence levels. Figure courtesy of [3].*

Computational Research Software: Challenges and Community Organizations Working for Culture Change

By Lois Curfman McInnes, Daniel S. Katz, and Scott Lathrop

SOFTWARE AND PROGRAMMING

Do you *use* software in your research? Do you *develop* software, either for your own work or to share with others? Are you a leader, stakeholder, or supporter of a project that uses or develops research software?

Computational science and engineering (CSE) depends on software that integrates advances in mathematics, statistics, computer science, and core disciplines from science and engineering. Modeling, simulation, and data analytics are driving new discoveries and technological innovations that benefit all areas of study and all sectors of society — from the physical, life, and social sciences to business, finance, and government policy.

High-quality software typically emerges from sustained community involvement, requirements gathering, sharing, and collaboration. Improvements in software development and utilization are ensuring that software is reusable and research results are reproducible, thereby reducing time to novel scientific discoveries.

However, we currently face a dramatic increase in software complexity due to a confluence of trends in emerging heterogeneous computer architectures and new frontiers of predictive science. Here we discuss technical and social challenges in research software, and introduce efforts in this area by grassroots organizations as well as projects to improve software quality, productivity, and sustainability. These endeavors ensure the integrity of research results and enable more effective collaboration. We emphasize numerical software while also considering the broader scope of research software.

Computational Software Successes and Strategies

The SIAM community has a long tradition of advancing theory, algorithms, and software for computational mathematics and scientific computing, including the development of popular mathematical libraries that underpin countless CSE advances. For example, high-performance packages like deal.II, DUNE, FeniCS, hypre, p4est, PETSc, Sundials, SuperLU, Trilinos, and waLBerla provide discretizations, solvers, integrators, and related capabilities for large-scale numerical simulations. Software libraries—high-quality, encapsulated, documented, optimized, tested,[1] and multiuse software collections—provide the functionality desired by application developers who do not want to spend time "reinventing the wheel." A library user only needs to know the library interface, and when and how to appropriately utilize library functionality.

Well-designed software libraries encapsulate cutting-edge algorithms and domain-specific expertise, thereby enabling users to reduce coding efforts while also customizing and extending capabilities as needed to exploit application-centric knowledge. A key design principle for high-performance packages is the use of interfaces that are independent of physical processes and separate from algorithm choices and data structures. Employment of abstractions for mathematical objects (such as vectors and matrices) to enable a clean user interface supporting a variety of underlying implementations is also important. For example, a high-level matrix platform can uphold sparse and dense representations, including variants for parallel architectures and heterogeneous central processing unit/graphics processing unit configurations, as well as composite and matrix-free operators. Such approaches help developers manage complexity and change.

[1] In an ideal world, open-source software has fewer bugs than closed source software since more people view it. See "Linus's Law" at https://en.wikipedia.org/wiki/Linus%27s_Law.

Technical and Social Challenges in Research Software

As we work toward predictive science, the use of good design for individual software efforts is not enough; we must be able to combine and leverage diverse codes for the various phases of modeling, simulation, and analysis. Collaboration is essential because the full scope of required functionality is too broad for any single person or team to deeply understand (see Figure 1). At a practical level, collaborative software efforts require high-quality, trusted code that is sustainable, extensible, and portable. Simulations built from external software must be compatible and interoperable. Regular tests for interoperability help to ensure sustainability. To assure confidence in computational science discoveries, teams need to improve transparency and reproducibility of computational results.

We must therefore embrace software ecosystem perspectives that explicitly consider relationships among distinct codes and their development communities. Research software is almost never entirely developed by a single project; each project instead depends on, uses, and builds upon software from other projects and developers. Much like research itself, research software is developed and maintained by a community ecosystem of competing and collaborating efforts. The open-source movement and its

See **Research Software** *on page 6*

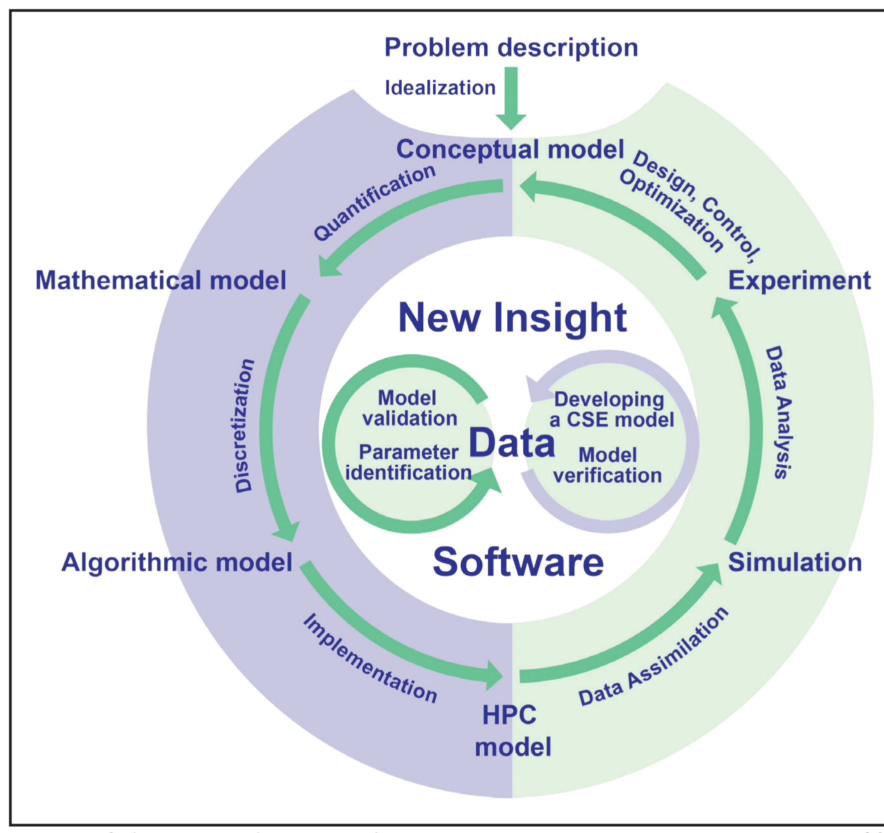

Figure 1. *Software is the foundation of sustained computational science and engineering (CSE) collaboration and scientific progress. Figure courtesy of [2].*

Urban Seismic Risk

Continued from page 2

waveform, depending on the class of structures/infrastructures at risk. After computation, we used the selected IM as input to the fragility functions for the target class of structures to determine the probability of exceeding a given damage state. The fragility curve (FC) measures the probability of surpassing certain performance or design criteria as a function of the level of seismic input intensity. It is defined as the conditional probability of a given damage state (DS) that exceeds a threshold ds, based on a value of the ground motion IM, i.e., $FC(IM, ds) = P(DS \geq ds \,|\, IM)$.

To illustrate the aforementioned workflow, we calculated the seismic hazard/risk analysis of the Beijing metropolitan area. Situated on a sedimentary basin with over 20 million inhabitants, Beijing is one of many megacities that are highly susceptible to seismic threats. The characterization of strong ground motion is hence critical to risk assessment studies in this region. We constructed a three-dimensional numerical model for Beijing by exploiting the following features: (i) the topography model, (ii) the sedimentary base's depth, (iii) a kinematic representation of potential ruptures breaking the Shunyi-Qianmen-Liangxiang (SQL) fault, and (iv) the three-dimensional velocity profiles. The SQL fault, which lies near downtown Beijing, is 90 kilometers long and has the potential to generate seismic events up to 7.3 Mw.

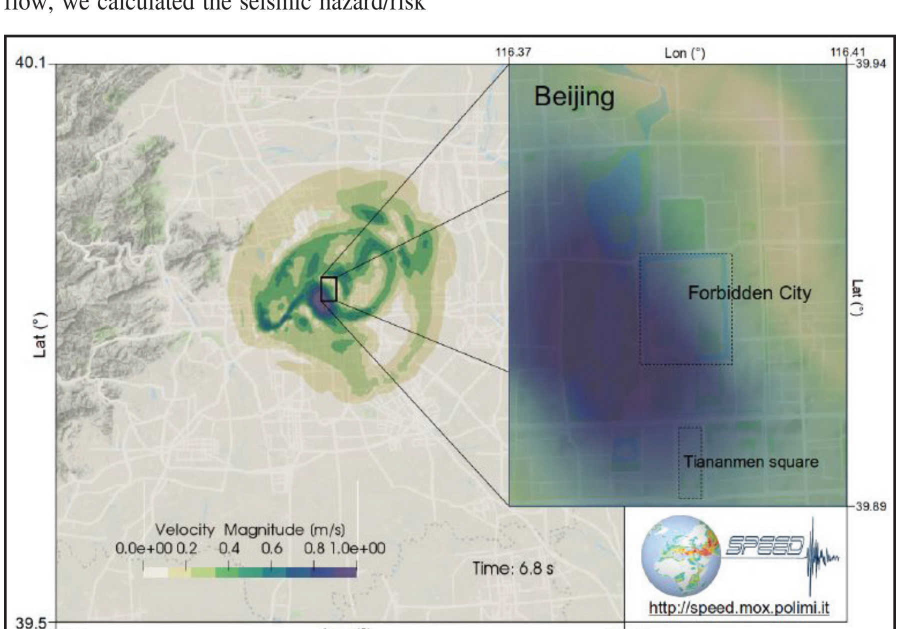

Figure 3. *Snapshots of the peak ground velocity obtained for a 6.5 Mw scenario. Figure courtesy of Ilario Mazzieri.*

The computational domain, 4,900 square kilometers in area and 30 kilometers deep, consists of approximately 200 million degrees of freedom (see Figure 2, on page 2). To capture the variability of earthquake ground motion based on different fault rupture scenarios, we performed 30 distinct simulations by varying the magnitude (from 6.5 to 7.3 Mw), hypocenter location, kinematic slip distribution on the fault, and rupture area location. Figure 3 offers a snapshot of the computed peak ground velocity wave-field for a target scenario with magnitude 6.5 Mw. We combined the results of the simulations with the fragility curves for Beijing's high-rise buildings — the most representative class of structures for seismic risk evaluation. We specifically focused on the so-called super high-rise buildings, which stand over 100 meters tall.

Figure 4 (on page 1) illustrates the probability of exceeding different damage states as a function of the closest distance to the fault rupture for a selected scenario (6.5 Mw). We note a rapid decrease of probability associated with different damage states with respect to fault rupture, and observe a large dispersion around the mean value. Our analysis demonstrates that in the near-field region—especially for rupture distances less than approximately 10 kilometers—the probability of exceeding the life safe and collapse prevention states may be significant, at least based on results obtained within the measured scenarios.

Acknowledgments: This research is conducted in collaboration with Paola F. Antonietti, Ilario Mazzieri, and Laura Melas at the Laboratory for Modeling and Scientific Computing MOX in the Dipartimento di Matematica del Politecnico di Milano. More details are available online.[2]

References

[1] Antonietti, P.F., Ferroni, A., Mazzieri, I., Paolucci, R., Quarteroni, A., Smerzini, C., & Stupazzini, M. (2018). Numerical modeling of seismic waves by discontinuous spectral element methods. *ESAIM: Proc. Surv., 61*, 1-37.

[2] Antonietti, P.F., Mazzieri, I., Quarteroni, A., & Rapetti, F. (2012). Nonconforming high order approximations of the elastodynamics equation. *Comput. Meth. Appl. Mech. Eng., 209-212*, 212-238.

[3] Ferroni, A., Antonietti, P.F., Mazzieri, I., & Quarteroni, A. (2017). Dispersion-dissipation analysis of 3D continuous and discontinuous spectral element methods for the elastodynamics equation. *Geophys. J. Int., 211*, 1554-1574.

[4] Melas, L., Antonietti, P.F., Mazzieri, I., Paolucci, R., Quarteroni, A., Smerzini, C., & Stupazzini, M. (2019). *Three-dimensional physics-based earthquake ground motion simulations for seismic risk assessment in densely populated urban areas* (MOX-Report No. 34/2019). Retrieved from https://www.mate.polimi.it/biblioteca/add/qmox/34-2019.pdf.

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[2] http://speed.mox.polimi.it

Feynman's Flying Saucer Explained

MATHEMATICAL CURIOSITIES

By Mark Levi

To quote Richard Feynman [2]:

"I was in the cafeteria and some guy, fooling around, throws a plate in the air. As the plate went up in the air I saw it wobble, and I noticed the red medallion of Cornell on the plate going around. It was pretty obvious to me that the medallion went around faster than the wobbling. I had nothing to do, so I start to figure out the motion of the rotating plate. I discover that when the angle is very slight, the medallion rotates twice as fast as the wobble rate — two to one.[1] It came out of a complicated equation! Then I thought, 'Is there some way I can see in a more fundamental way, by looking at the forces or the dynamics, why it's two to one?' I don't remember how I did it, but I ultimately worked out what the motion of the mass particles is, and how all the accelerations balance to make it come out two to one."

Feynman later writes that "The [Feynman] diagrams and the whole business that I got the Nobel Prize for came from that piddling around with the wobbling plate" [2].

[1] Actually it is the other way around; the wobble is twice as fast as the spin.

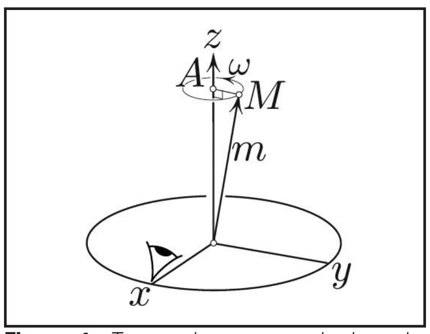

Figure 1. *To an observer attached to the plate,* **m** *spins around the plate's* z*-axis with angular velocity* ω*. And to the ground observer, this entire picture spins as well — at the rate* $\approx\omega$ *and with angular velocity closely aligned with the* z*-axis (assuming small wobble). In short, the combined angular velocity of the* z*-axis around the angular momentum direction—i.e., the rate of wobble—is* $\approx 2\omega$*. This explains Feynman's observation.*

Here I offer a quick explanation of Feynman's observation. Figure 1 gives a summary.

Watching a Star from the Flying Saucer

The angular momentum of the plate in flight is fixed because the torque that acts on the plate is zero, neglecting the effect of air. Let $\mathbf{m}=(m_x,m_y,m_z)$ be the expression of the angular momentum in the xyz-frame that is glued to the plate (see Figure 1). As the plate wobbles, $\mathbf{m}$ changes; we will show that $\mathbf{m}$ spins around the z-axis as in Figure 1, where ω actually turns out to be precisely the angular velocity ω_z of the plate's spin around the z-axis. This fact is of independent interest and demonstrates two roles of ω: (i) the rate of the plate's spin (as viewed by someone on the ground), and (ii) the rate of $\mathbf{m}$'s spin around the z-axis in the eye of the observer stuck to the plate. Postponing the proof that $\mathbf{m}$ moves like in Figure 1, here is an explanation of Feynman's observation.

Explaining the 1:2 Spin-to-wobble Ratio

Segment AM in Figure 1 rotates at the angular velocity $\omega\equiv\omega_z$ relative to the plate, according to the claim in the previous paragraph. And the plate itself rotates with an angular velocity of magnitude $\approx\omega$ and closely aligned with the angular momentum if the wobble is small (see Figure 2). The sum of these angular velocities is $\approx 2\omega$; it is the angular velocity of the z-axis around the fixed direction of the angular momentum in the ground frame. This completes the explanation of the 1:2 ratio; it remains to be proven that $\mathbf{m}$ indeed moves as Figure 1 indicates.

Explaining the Motion of m in Figure 1

The plate's angular velocity $\boldsymbol{\omega}$ is related to $\mathbf{m}$ via $\boldsymbol{\omega}=\mathbf{I}^{-1}\mathbf{m}$, where $\mathbf{I}=\mathrm{diag}(I_x,I_y,I_z)$ is the tensor of inertia whose diagonal entries are the moments of inertia with respect to the corresponding axes. Since the moment of inertia around the z-axis is twice that around the diameter, we have $\mathbf{I}=I_z\mathrm{diag}(\frac{1}{2},\frac{1}{2},1)$. Now $\mathbf{m}$ satisfies Euler's equation

$$\dot{\mathbf{m}}=\mathbf{m}\times\mathbf{I}^{-1}\mathbf{m}. \qquad (1)$$

The derivation of (1) is immediate by a creative application of the familiar formula $\mathbf{v}=\boldsymbol{\omega}\times\mathbf{r}$. Indeed, to the observer on the flying saucer, the surrounding space is rotating with angular velocity $-\boldsymbol{\omega}$ and the tip of the angular momentum vector is like a particle affixed to the surrounding space. The apparent velocity of this "particle" is thus given by

$$\dot{\mathbf{m}}=(-\boldsymbol{\omega})\times\mathbf{m},$$

which amounts to Euler's equations (1) upon substitution $\boldsymbol{\omega}=\mathbf{I}^{-1}\mathbf{m}$ (a standard derivation of Euler's equation in [1] or [3], for example, takes a little over half a page).

Finally, Euler's equations (1) become

$$\begin{cases}\dot m_x=-m_y(m_z/I_z)\\ \dot m_y=\ \ m_x(m_z/I_z)\\ \dot m_z=0\end{cases}. \qquad (2)$$

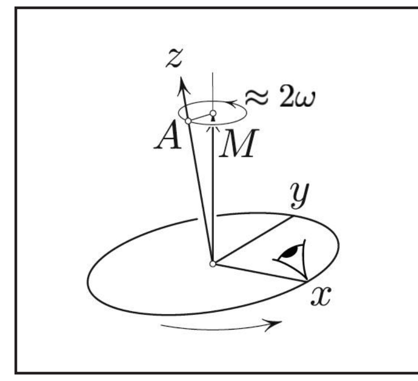

Figure 2. *View for the ground observer. The plate's rotation is added to the rotation of* AM *relative to the plate, yielding the rate of rotation of* AM *in space.*

Now $m_z/I_z=\omega_z$ is exactly the angular velocity around the z-axis, and is constant according to the last equation. Based on the first two equations, the vector (m_x,m_y) executes circular motion with angular velocity ω_z. This completes the explanation of $\mathbf{m}$'s motion that is sketched in Figure 1.

The figures in this article were provided by the author.

References

[1] Arnold, V.I. (1989). *Mathematical Methods of Classical Mechanics*. New York, NY: Springer-Verlag.

[2] Feynman, R. (1997). *Surely You're Joking, Mr. Feynman!* New York, NY: W.W. Norton & Company.

[3] Goldstein, H. (1980). *Classical Mechanics*. Reading, MA: Addison-Wesley.

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Research Software

Continued from page 5

culture of sharing and collaboration—similar to the culture of open science and open research toward which the community is moving—enhances these efforts.

Consequently, we must address cultural issues in scientific software and social concerns in software communities. Determining value metrics for research software; increasing rewards for developers of open-source, reliable, extensible, and sustainable software; and expanding career paths for expert research software developers all require work. We have to create funding models for software sustainability, as well as models for software citation and credit (including approaches for publication and peer review). Finally, students and researchers need training about best practices in research software.

Community-led Culture Change in Research Software

To address these circumstances and promote research collaboration in emerging software ecosystems, community members have established a variety of grassroots organizations and projects inspired by the growth of the internet, shareable digital resources, and collaborative tools such as GitHub and Slack. Groups that focus on a particular discipline, technology, or functional skill set can help researchers understand relevant parts of the ecosystem, including the various available software packages and how they compare. These community organizations can support ecosystem health by encouraging policies, reuse, and collaboration that urge best practices for software development. Below are a few organizations and ideas that should be of interest to the SIAM community.

- **The Software Sustainability Institute (SSI):** Cultivating better and more sustainable research software to enable world-class research for the U.K. research community.[2]
- **Conceptualization of a U.S. Research Software Sustainability Institute (URSSI):** Planning an institute to improve science and engineering research by supporting the development and sustainability of research software in the U.S.[3]
- **Interoperable Design of Extreme-scale Application Software (IDEAS) Productivity Project:** Catalyzing advances in software productivity and sustainability that are driven by the needs of extreme-scale computational science.[4]
- **Better Scientific Software (BSSw):** Encouraging the exchange of information on practices, techniques, experiences, and tools to improve developer productivity and software sustainability for CSE and related areas of technical computing.[5]
- **Apache Software Foundation:** Fostering the growth of open-source software communities and providing the necessary technical infrastructure and support mechanisms.[6]
- **Software Carpentry:** Teaching foundational coding skills to researchers and empowering them to develop research software, automate research tasks and workflows, and perform reproducible science.[7]
- **Working Towards Sustainable Software for Science: Practice and Experiences (WSSSPE):** Promoting sustainable research software by addressing challenges related to the full lifecycle of such software via shared learning and community action.[8]
- **NumFOCUS:** Promoting open code for better science while emphasizing sustainable high-level programming languages, open code development, and reproducible scientific research.[9]
- **rOpenSci:** Enabling open and reproducible research by creating technical and social infrastructure and advocating for a culture of data sharing and reusable software.[10]
- **Extreme-scale Scientific Software Development Kit (xSDK):** Promoting collaboration and commitment to independent numerical library efforts through community-based policies for quality improvement, better infrastructure, and the use of diverse libraries for large-scale CSE.[11]
- **Research Software Alliance (ReSA):** Bringing communities together to collaborate on the advancement of research software.[12]

Further information on best practices and reusable software that spans multiple disciplines and organizations is available in a special issue of IEEE's *Computing in Science and Engineering* on "Accelerating Scientific Discovery with Reusable Software" [1].

Get Involved

The aforementioned organizations act in their respective spheres of influence to nurture communities, change research culture, and promote the growth of software ecosystems. They provide information about effective approaches for creating, sustaining, and collaborating via scientific research software while simultaneously articulating key issues to stakeholders, agencies, and the broader research community. These actions inspire changes in policies, funding, and reward structure, and advance understanding of the importance of high-quality software to the integrity of computational research. We encourage you to explore the resources provided by groups that are relevant to your research, and consider joining them so we can collectively tackle these issues.

References

[1] Lahtrop, S., Folk, M., Katz, D.S., McInnes, L.C., & Terrel, A. (2019). Introduction to accelerating scientific discovery with reusable software. *Comp. Sci. Eng.*, *21*, 5-7.

[2] Rüde, U., Willcox, K., McInnes, L.C., & De Sterck, H. (2018). Research and education in computational science and engineering. *SIAM Rev.*, *60*(3), 707-754.

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[2] https://www.software.ac.uk

[3] http://urssi.us

[4] https://www.ideas-productivity.org

[5] https://bssw.io

[6] https://apache.org

[7] https://software-carpentry.org

[8] http://wssspe.researchcomputing.org.uk

[9] https://numfocus.org

[10] https://ropensci.org

[11] https://xsdk.info

[12] http://www.researchsoft.org

Pitfalls in Computation

Humble Pi: A Comedy of Maths Errors. *By Matt Parker. Allen Lane (Penguin Books), London, U.K., November 2018. 313 pages, £20.00.*

Bits and Bugs: A Scientific and Historical Review of Software Failures in Computational Science. *By Thomas Huckle and Tobias Neckel. Society for Industrial and Applied Mathematics, Philadelphia, PA, February 2019. 251 pages, $44.00.*

BOOK REVIEW
By Nicholas Higham

We all inevitably make errors when doing mathematics or writing computer programs. Most of the time we catch our mistakes and correct them before others notice them; if not, a co-author or referee usually spots the problem. It can be frightening to think that we might make an error that goes undetected and has serious consequences for a real-life situation.

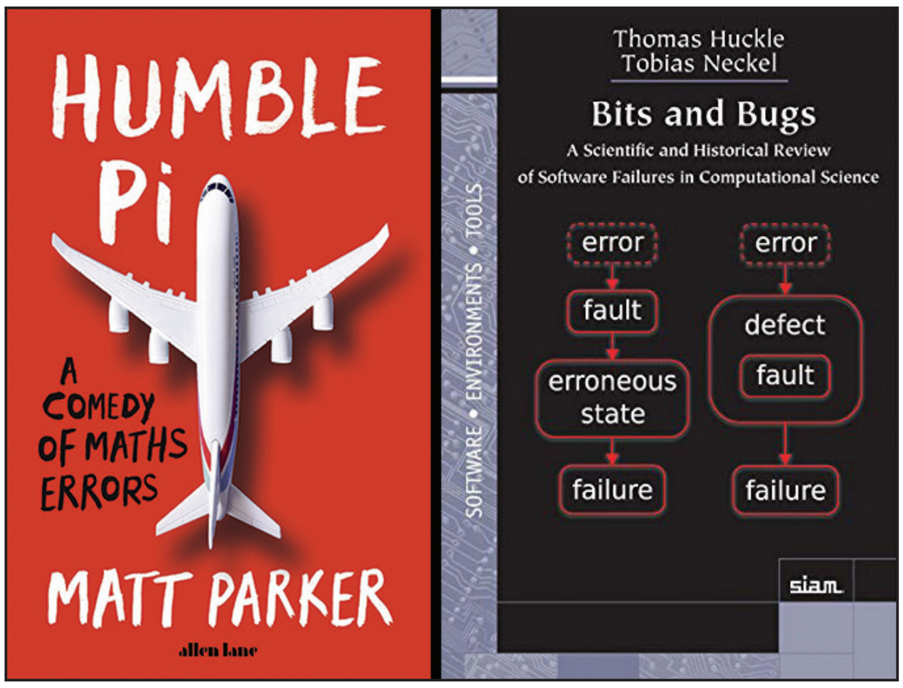
Certain examples of the impact of erroneous computations are well known, such as the Vancouver Stock Exchange's miscalculation of its index and the Patriot missile software problem [1-3]. But there are many other instances that are little known outside their particular fields. The two books under review discuss a wide variety of mathematics and software failures, but do so in different ways and for different audiences.

Matt Parker, winner of the 2018 Joint Policy Board for Mathematics Communications Award, is known for his math-themed stand-up comedy and YouTube videos (his channel "standupmaths" has nearly half a million subscribers). Parker's book, *Humble Pi*, is a tour of all kinds of situations in which errors in math, computing, and engineering have led to strange or undesirable outcomes.

Several of the stories he recounts relate to incorrect unit conversions. In 1983, an Air Canada Boeing 767 ran out of fuel en route to Edmonton because of a mixup between pounds and kilograms during calculation of the fuel required for the trip. Remarkably, the pilot was able to glide the plane in to land. In 1999, NASA's Mars Climate Orbiter disintegrated in the atmosphere of Mars because of confusion in its software between pound force and Newtons. In discussing these and other incidents, Parker provides enough technical detail to explain what went wrong without overwhelming the lay reader.

The book taught me a new acronym: OBOE, which stands for off-by-one error. The meaning will be clear to anyone who has switched between a programming language whose array indexes start at 0 and one whose indexes start at 1. Parker's examples relate to fence posts and musical intervals.

I particularly like *Humble Pi*'s material on spreadsheets. Parker naturally discusses rounding errors (for example, why `=0.5-0.4-0.1` yields a different answer than `=(0.5-0.4-0.1)*1` in Excel). After noting that "there is one thing that Excel is not, and that is a database system," he spends several pages explaining how spreadsheet data can be misinterpreted. Parker cites research indicating that many Excel files in a collection associated with published genome research contained gene names that had been autocorrected to something else, such as a date (the gene "`MARCH5`" became `03/01/05`, for example). Over 40 percent of spreadsheets recovered from Enron after its 2001 accounting scandal contained not a single formula, and about 24 percent of the spreadsheets with a formula included Excel error messages, such as `=#DIV/0!`



Humble Pi: A Comedy of Maths Errors. By Matt Parker. Bits and Bugs: A Scientific and Historical Review of Software Failures in Computational Science. By Thomas Huckle and Tobias Neckel. Images courtesy of Penguin Books and SIAM.

Parker is also spot on when he declares, "Precision and accuracy often get jumbled together, but they are two very different things." He illustrates this point with the 100-meter sprint world record and a BBC News story on employment figures.

Incidentally, I found an error in this book about errors: the formula for Black-Scholes option pricing is missing a parenthesis. In the Acknowledgments section, Parker says that "all remaining errors are hilarious jokes I've demanded be left in," so perhaps this is one of those.

One thing I found disconcerting is the page numbering system, which counts pages in reverse order from 314 to 0 and then wraps around to 4,294,967,295 (which equals $2^{32}-1$ and features in the discussion of wraparound errors). This makes the index more difficult to use. With indexing fresh in my mind—having just written a new chapter on the topic for the third edition of my *Handbook of Writing for the Mathematical Sciences*[1]—I find *Humble Pi*'s index to be an inadequate route into the book's rich content. For instance, it does not list "Excel" or "spreadsheet."

Overall, *Humble Pi* is thoroughly entertaining and contains many stories that *SIAM News* readers will most likely not have heard before. When Parker had flyers printed for his *Humble Pi* show, they did not turn out as intended. Either the printer made an error or the printing instructions were unclear. Scan the following QR code with your phone to watch the video[2] and decide for yourself.

Bits and Bugs covers similar ground to *Humble Pi*, but with an emphasis on software and scientific computation. The first author, Thomas Huckle, has been collecting information about software bugs on his website[3] since 2000. The book aims to provide a broad picture of bugs and incidents, recognizing that existing accounts may focus on particular aspects and can even contradict each other. Huckle and Tobias Neckel describe a number of episodes in great detail, including the 1996 explosion of the Ariane 5 rocket shortly after takeoff and the 1991 loss of the gas rig Sleipner A, which is attributed to poor use of finite element software in the rig's design. They also illustrate automotive examples, such as autonomous driving.

The book is nicely presented with color images, sidebars that offer background information, and QR codes that link to illustrative videos. It is carefully researched, with many references to the literature. I am not aware of any other book that focuses on numerical software errors and their explanations. *Bits and Bugs*' thorough index (freely downloadable from the SIAM Bookstore, should you wish to check it out before buying the book) gives an excellent overview of the book's range of topics.

Erroneous computations and programming errors will always be with us, but *Humble Pi* and *Bits and Bugs* provide readers with an appreciation of the pitfalls to avoid. Both read like mathematical detective stories and are difficult to put down.

References

[1] Einarsson, B. (Ed.). (2005). *Accuracy and Reliability in Scientific Computing*. Philadelphia, PA: Society for Industrial and Applied Mathematics.

[2] Higham, N.J. (2002). *Accuracy and Stability of Numerical Algorithms* (2nd ed.). Philadelphia, PA: Society for Industrial and Applied Mathematics.

[3] Oliveira, S., & Stewart, D. (2006). *Writing Scientific Software: A Guide to Good Style*. New York, NY: Cambridge University Press.

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[1] https://my.siam.org/Store/Product/viewproduct/?ProductId=31300058

[2] https://www.youtube.com/watch?v=-1snXHsIbrA&feature=youtu.b

[3] https://www5.in.tum.de/~huckle/bugse.html

Resilience in the Digital Age

Scientific Session at the 2020 AAAS Annual Meeting

Seattle, Washington

Saturday, February 15, 2020

8:00 am to 9:30 am

"Resilience" has emerged as an organizing principle for understanding, managing, and governing complex linked systems of nature and people. The notion of resilience is central to international agreements, such as the United Nation's Sustainable Development Goals[1] and the Paris Agreement[2] on climate change. Yet while the general concept of resilience is apparent—a system's ability to recover from setbacks, adapt to change, and avoid catastrophic collapse—no clear framework exists for measuring resilience in complex linked systems.

Today's digital world of big data, massive computing capacity, artificial intelligence, and machine learning creates an extraordinary opportunity to transform approaches for building resilience in complex linked systems. For the first time, we can dream of conceptualizing and operationalizing resilience by (i) defining its characteristics, (ii) quantifying the resilience capacity of a complex linked system, (iii) determining the critical links between the social and natural components of a resilient system, and ultimately (iv) indicating how to build resilience into such systems.

A scientific session[3] organized by Fred Roberts (Rutgers University) and Christiane Rousseau (University of Montreal) at the 2020 Annual Meeting of the American Association for the Advancement of Science (AAAS)—to be held February 13-16 in Seattle, Wash.—will focus on the theme of resilience. The session, which is part of the track on "Digital Futures," features three speakers.

• **Amy Luers** (Future Earth) will address the global framework for measuring resilience in complex linked systems, as well as opportunities offered by the digital age to characterize resilience and establish guidelines for both building and evaluating resilient societies.

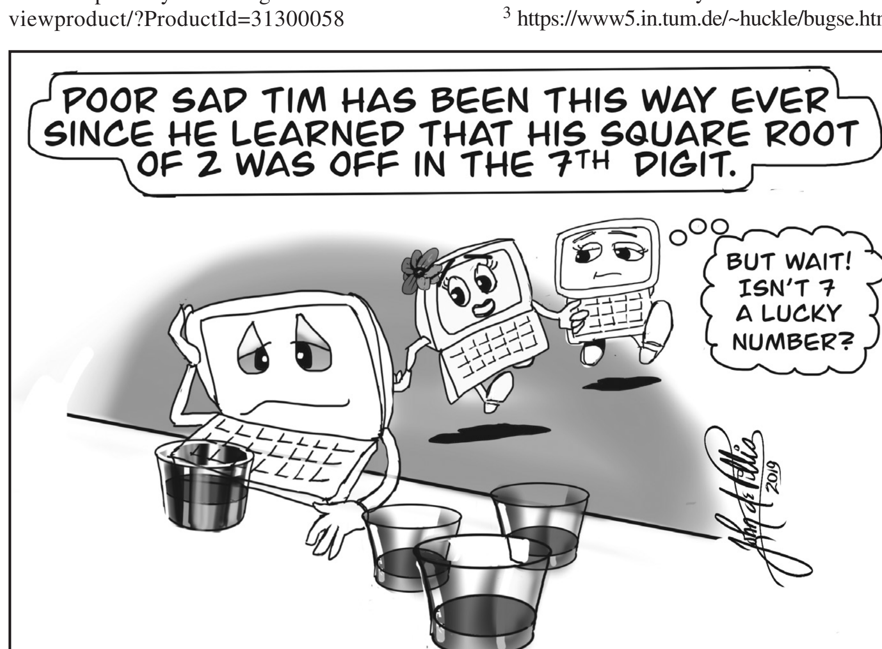
• **Hans Kaper** (Georgetown University) will focus on the issue of resilience in the context of food security and describe proposals to measure the resilience of food systems to shocks and stressors.

• **Wayne Getz** (University of California, Berkeley) will review four problems that result from the global climate crisis: emerging zoonotic diseases, diminishing resources, warming-induced casualties, and catastrophic natural disasters. He will discuss digital means that counter these problems.

[1] https://www.un.org/development/desa/disabilities/envision2030.html

[2] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

[3] https://aaas.confex.com/aaas/2020/meetingapp.cgi/Session/24316



Cartoon created by mathematician John de Pillis.

The Unique Aspects of Writing a Book

By Elizabeth Greenspan

I recently received a proposal for a book titled *A Hands-on Primer on Mathematical Methods in Materials Science* by Maria Emelianenko, David Kinderlehrer, Patrick Shipman, and John Gemmer. I was excited; SIAM has not published many books in this important discipline, and a textbook that is accessible to undergraduate and graduate students would fill a void in both the literature and SIAM's offerings. However, the manuscript received mixed reviews from referees. The problem concerned the audience — the book was meant to aid researchers and practitioners, as well as serve as a textbook for undergraduate and graduate students. As a result, it was not exactly a textbook but not quite a monograph either.

The authors proceeded to refine their vision and reconfigure the material, ultimately narrowing their primary audience to senior undergraduate and graduate students.

Know Your Audience

Authors of successful books (and sales are not the only measure of success) know their prospective readers and tailor content specifically to them. Manuscripts that lack a coherent point of view because the author did not identify the audience will likely receive negative reviews. Some questions to consider when determining one's audience are as follows: Who comprises the intended audience? Is the text directed at researchers or students? If meant for the latter, for what level is it best suited? Textbooks come with their own sets of requirements, such as classroom exercises. Monographs should constitute more than a collection of papers, most of which your audience can probably already access — they are opportunities to synthesize one's research and present a cohesive and coherent discussion on the topic at hand.

Publishers do not subscribe to the notion that all topics have been fully exhausted in existing literature. There is always room for another book or two (or three). That said, if a proposed book is intended for a market that falls within a crowded specialty or subspecialty (linear algebra, for example), it is important that the author's approach differ from already-published manuscripts. He/she must provide readers with reasons to purchase the book. Daniela Calvetti of Case Western Reserve University elaborated on this requirement. "There are two thoughts that would make me consider writing a book," she said. "One is to say something new and exciting that cannot be found in other books or easily grasped from articles, and the other is to propose a very different point of view on something that has been covered over and over."

Instructing a class on a topic that lacks a proper textbook is another potential source of inspiration. "If I have a reliable book for a class I'm teaching, I would never dream of writing another one," Calvetti continued. "But if I find myself having to put together the material from scratch time and again, then I may decide to convey that effort into writing a book."

Submitting a Book Proposal

SIAM's book proposal form requests information about the book's aim, scope, and audience, and asks how it differs from existing texts on the topic. It also solicits details about the estimated length and number of figures.

While filling out the form can be tedious, senior researchers with multiple books under their belts vouch for its use. Seasoned authors admit that although some of the questions might seem obvious, the queries often raise issues about which they had not previously thought, thus helping to develop the book, focus their motivations, and refine their thinking.

In addition to the form, SIAM asks prospective authors to submit—at minimum—a preface and table of contents. This is a standard requirement for most publishers. While it is not necessary to finish a complete draft of one's book before sending in a proposal, we do encourage prospective authors to submit at least one chapter because most reviewers want to base their evaluations on actual text rather than an abstract concept. This is especially true when the author does not have a lengthy publication history. Whether submitting one chapter or an entire book, authors should proofread the material carefully. Sloppy presentation frustrates some referees, causing them to dismiss an otherwise worthwhile manuscript.

Calvetti noted the benefits of finishing much of the text prior to submission. "I like to have a book very near completion before sending it to SIAM for consideration," she said. "This way I am less likely to underestimate how long I will need to complete it, and the publication team will have a clearer idea of what the finished product will look like."

Once the proposal—including the form and other necessary materials—is in hand, referees provide comments that are then passed along to the author; as with journal publishing, these reviewers are anonymous. SIAM reviews most books in their completed or nearly-complete form. Additionally, a manuscript is much more likely to be successful when looked at by someone other than the author prior to publication. Moreover, feedback helps authors further cultivate and improve their ideas.

"Why do I like writing books for SIAM?" Calvetti mused. "The organization is great to work with, has copyeditors who know their job very well, can accommodate cover artwork provided by the authors, and does a wonderful job advertising the books. The fact that I can elect to have part of the royalties go toward supporting student travel expenses to attend SIAM conferences is definitely a plus for me, as are the reasonable prices and substantially discounted rates for students."

Elizabeth Greenspan is the executive editor of SIAM Books. She is responsible for book acquisitions and the book program at SIAM.

Heidelberg Student Chapter of SIAM Visits Lufthansa Systems

Who wouldn't dream about flying more safely, efficiently, and comfortably? The Heidelberg Student Chapter of SIAM—together with members of Upstream (a network that promotes young female mathematicians)—organized a field trip to the headquarters of Lufthansa Systems in Raunheim, Germany. Such field trips allow chapter members to experience real-world applications of mathematics at big companies. They are also excellent platforms for networking, and provide information about job opportunities for mathematicians and computer scientists.

Lufthansa Systems is one of the leading information technology (IT) service providers for the aviation industry. The company digitalizes the airline enterprise by supporting all processes of aviation, including network and route planning, overbooking and revenue management systems, navigation, and on-board entertainment systems.

The trip to Lufthansa began with a delicious breakfast and an introduction to the company's goals, services, clients, and values. Staff members then took us on a tour through the offices, presented Lufthansa's modern workspaces, and explained how they shape the organization's future with passion and innovation. We even got to meet Pepper, their friendly robot.

Lufthansa employees believe that IT is critical to the airline industry. Therefore, the first technical talk addressed ways in which the company tackles problems regarding route planning and copes with arising difficulties, like continually-changing route restrictions and unpredictable weather patterns.

During lunch, we chatted informally with staff and learned more about the work environment and culture at Lufthansa. For example, a component of company development is the desire to not only earn money but also be socially engaged.

We attended several more talks in the afternoon, some of which were given by members of our group. Having already learned how to optimize a single plane's route, we were excited to hear about the creation of flexible schedules and assignment of crews to flights. Our group was eager to learn and had the opportunity to discuss developments and trends that will determine the improvement of passenger transport in the coming years. We also had a chance to inquire about current career openings at Lufthansa.

Ultimately, this field trip inspired a greater understanding of mathematics' application to the field of aviation. The Heidelberg Student Chapter of SIAM is grateful to Lufthansa Systems for hosting us and making this day a huge success.

— Heidelberg Student Chapter of SIAM

Members of the Heidelberg Student Chapter of SIAM at the headquarters of Lufthansa Systems in Raunheim, Germany. Photo courtesy of Iris Ehrenbrand of Lufthansa Systems.

"Understanding the Rules of Life"

An NSF Big Idea for the Mathematical Sciences

By Adriana Dawes, Marisa Eisenberg, and Padmanabhan Seshaiyer

In 2019, the National Science Foundation (NSF) is expected to have invested $30 million in "Understanding the Rules of Life," one of the agency's 10 Big Ideas.[1] How can we identify and support emerging opportunities for the mathematical sciences community to contribute to this big idea and help serve the nation's future?

To identify these opportunities, we received a grant from the NSF titled *Collaborative Research: RoL: FELS: Workshop – Rules of Life in the Context of Future Mathematical Sciences* (DMS1839608).

We gathered input from researchers in a variety of fields spanning mathematics and biology, and defined emerging research challenges and priorities in mathematical biology in response to "Understanding the Rules of Life." Participants provided specific suggestions and feedback to the prompt, "*What should the strategic priority areas of mathematical biology be under the NSF's Rules of Life?*" The six key topic areas that we identified are as follows:

1. Understanding the Rules of Life in Integrative Biological Systems: Transients and Noise. The recommendation is to foster new solicitations or programs that focus on developing a broad dynamical theory for transients and quasi-stationary states in biological systems. This includes research examining the relationships between transients, noise, heterogeneity, and the distinct effects of experimental and biological variation, including the high risk/high reward of creating new theory and mathematical approaches to account for these disparities.

2. The Mathematical Foundations of Data-Inspired Biology: Learning Rules of Life from Data. This topic seeks to develop programs or solicitations that support the necessary foundational and methodological work pertaining to model and data dimension reduction methods; rigorous estimation in network analysis; the linking of models with big data; and a unified theoretical framework for parameter estimation, parameter identifiability, and model selection. It also requires close collaboration between data collection and theory to ensure relevance and impact. Thus, a focus on programs that link theoretical predictions with data collection is strongly recommended for this priority area.

3. Bridging Scales to Understand New Rules of Life. The suggestion here is to create programs that help develop an understanding of how the rules of life transition across scales; one can do so by building models and approaches that span spatial and temporal scales to uncover consistent biological principles. This theme encompasses multiscale phenomena, wherein dynamics at one scale directly affect those at other scales. It thus requires the collection of biological data across scales and the construction of unifying multiscale models.

4. A New Fitness Landscape for Mathematical Theory: Quantifying Adaptation and Selection in Understanding Fundamental Rules of Life. Researchers recommended programs or solicitations that support further development of analytical techniques, including modeling trait tradeoffs, trait plasticity, and complex traits. They also proposed the incorporation of high-dimensional data, such as that from sequencing and gene expression. These programs would support efforts to address important open questions, including the following: What is the most appropriate way to define fitness? How do we reconstruct phylogenetic evolutionary histories of species with new data? How do we understand community genomics and eco-evolutionary dynamics across species and timescales? These questions can help build the genotype-to-phenotype map and generate insight into the fundamental rules of life.

Ami E. Radunskaya of Pomona College (left) and Marisa Eisenberg of the University of Michigan (right) present ideas, suggestions, and feedback on strategic priority areas of mathematical biology at the "Rules of Life in the Context of Future Mathematical Sciences" workshop. Photos courtesy of Padmanabhan Seshaiyer.

5. Mathematics for the Anthropocene Era: Rules of Life in the Context of Human Impact on Natural Systems. Obtaining a thorough understanding of human impact and developing forecasting, prediction, and control methods will require a range of analytical approaches (e.g., dynamical systems, optimization, game/decision theory, etc.) and data (satellite, sensors, social media, cell phone data, etc.). Programs that integrate or develop mathematical and data-based methods for understanding interactions between humans and natural systems are thus desirable. Also recommended was the expansion and development of interdisciplinary programs or solicitations that

See **Rules of Life** *on page 11*

[1] https://www.nsf.gov/news/special_reports/big_ideas/

Announcing the International Day of Mathematics

The International Mathematical Union is leading the project of urging the United Nations Educational, Scientific and Cultural Organization (UNESCO) to proclaim **March 14** (Pi Day) as the **International Day of Mathematics** (IDM). This proclamation was accepted by UNESCO's Executive Board at its 205th session in October 2018. It was part of the agenda for the 40th General Conference of UNESCO, which occurred in November 2019. If adopted, the official launch will take place in 2020.

IDM will be a worldwide celebration. Every year on March 14, all countries will be invited to participate through activities for both students and the general public in schools, museums, libraries, and other spaces. Because March 14, 2020 is a Saturday, the IDM launch at UNESCO Headquarters in Paris, France will take place on Friday, March 13. A simultaneous African launch will be held at the Next Einstein Forum in Nairobi, Kenya.

Each year will feature a new theme to flavor the celebration, spark creativity, and bring light to connections between mathematics and a variety of fields, concepts, and ideas. The 2020 theme is "**Mathematics is Everywhere**."

- Mathematics is everywhere in science and technology
- Mathematics is everywhere in the organization of civilization
- Mathematics is essential to meet the United Nation's Sustainable Development Goals
- Mathematics is everywhere in whatever you do.

How will you celebrate? Will you celebrate in your classroom? Do you wish to organize a small exhibition and/or interactive activities with your local community? Will your national mathematical society or mathematics teachers association coordinate national activities? Will you celebrate with a neighboring country?

Visit the IDM website[1] to do the following:

- Access open-source material related to this year's theme, including projects, ideas, and software for use in classrooms, at large events, or in small activities for children and the general public
- Find instructions on how to organize an event
- Post your activities on an interactive map
- Explore activities around the world.

Start thinking about how you will partake! We look forward to hearing about your festivities in the coming months.

[1] http://www.idm314.org

INTERNATIONAL DAY OF MATHEMATICS
MARCH 14

Synergy of Math and Art

Mathematicians and scientists have used graphs, diagrams, and other visuals to advance understanding in their disciplines from at least the time of Euclid; Leonardo da Vinci was one such practitioner. Last month, Italy celebrated the 500th anniversary of da Vinci's death. *SIAM News*'s resident cartoonist, John dePillis, presented invited talks at Politecnico di Torino, the University of Verona, the University of Ferrara, and the University of Bologna in honor of the occasion. In the spirit of the national celebration, he described how his own artistic skills led him to a deeper understanding of special relativity.

*"Lazy? Me? On the contrary! According to Einstein, I am a mass, which equates to **a lot** of energy." John dePillis created and presented this cartoon as part of his talks at four Italian universities on the occasion of the 500th anniversary of Leonardo da Vinci's death.*

Rules of Life

Continued from page 10

meaningfully draw from the range of disciplines involved in the interactions of human and natural systems. These interactions span both mathematics and biology, as well as adjacent fields like behavioral and social sciences, economics, health sciences, and environmental sciences.

6. Broader Impacts: Convergence of Research and Education for the Rules of Life. Another recommendation included the creation of programs to enhance student training and research at the intersection of biological and mathematical sciences. These programs will help broaden student experiences and prepare them for undergraduate, graduate, and post-graduate study, in addition to careers at the interface of mathematics and biology. Evaluation and impact assessment of these programs will lead to increased workforce effectiveness and improved understanding of the rules of life. Programs for faculty development—including long-term training grants, conferences, and workshops to connect scientists, mathematicians, and educational researchers—will enable innovative, cross-disciplinary solutions to grand challenge problems at the junction of mathematical and biological sciences.

All six priority areas identified several common themes in terms of *recruitment*, *training*, and *retention*. In particular, participant input reinforced the importance of interdisciplinary instruction to provide integrated depth in mathematics and biology. Multiple groups noted *statistical training* and *working with data* as key elements of this preparation. They also emphasized the need for programs at all levels (student and faculty), and remarked that diverse perspectives are important for deeply interdisciplinary research. All participants agreed that developing integrated programs that blend mathematics, statistics, and biology is particularly critical for success in every topic area.

The intellectual impact of supporting research in these emerging priority areas is clear. Advances at the interface of mathematics and life sciences urgently need rigorous and comprehensive quantitative methods. In addition to furthering our understanding of the rules of life, these efforts will grow convergent research and make the most of the data revolution.

These ideas were gathered at a workshop that brought together a highly diverse group of individuals in mathematical biology in November 2018.

Adriana Dawes is an associate professor in the Departments of Mathematics and Molecular Genetics at The Ohio State University. She is also an associate director at the Mathematical Biosciences Institute and a member of the Society for Mathematical Biology's mentoring committee. Marisa Eisenberg is an associate professor in the Departments of Epidemiology, Complex Systems, and Mathematics at the University of Michigan. She is also co-chair of the Doctoral Program in Epidemiologic Science. Padmanabhan Seshaiyer is a professor of mathematical sciences and the Associate Dean for Academic Affairs in the College of Science at George Mason University. He currently serves as chair of the SIAM Diversity Advisory Committee, and was formerly a program director in the Division of Mathematical Sciences at the National Science Foundation.

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" at the SIAM website (****www.siam.org****) or proceed directly to* ***www.siam.org/careers****.*

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 tenure-track faculty positions in all areas of applied mathematics, computer science, and related disciplines.

Areas of interest include (but are not limited to) algorithms, data assimilation and inverse problems, dynamical systems and control, geometry, machine learning, mathematics of data science, networks and graphs, numerical linear algebra, optimization, partial differential equations, probability, scientific computing, statistics, stochastic modeling, and uncertainty quantification. Application foci include computational physical and life sciences, distributed systems, economics, graphics, quantum computing, and robotics and autonomous systems. The CMS Department is part of the Division of Engineering and Applied Science (EAS), comprising researchers working in and between the fields of aerospace, civil, electrical, environmental, mechanical, and medical engineering, as well as materials science and applied physics. The institute as a whole represents the full range of research in biology, chemistry, engineering, physics, and the social sciences.

A commitment to world-class research, as well as high-quality teaching and mentoring, is expected, and appointment as an assistant professor is contingent upon the completion of a Ph.D. degree in applied mathematics, computer science, engineering, or the sciences. The initial appointment at the assistant professor level is four years and is contingent upon completion of a Ph.D. degree. Reappointment beyond the initial term is contingent upon successful review conducted prior to the commencement of the fourth year.

Applications will be reviewed beginning November 15, 2019, but all applications received before January 15, 2020 will receive full consideration. For a list of required documents and full instructions on how to apply online, please visit **https://applications.caltech.edu/jobs/cms**. Questions about the application process may be directed to **search@cms.caltech.edu**.

Caltech is 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.

A New Possible Solution to the 3x + 1 Problem

I will welcome comments on a new, very short, possible solution. See "Possible Strategy for 1-Tree-Based Proof: Lemma 3.0 Approach" in Appendix C of "A Solution to the $3x+1$ Problem" on **occampress.com.** The paper contains two other solutions that were discovered in the past two years.

— *Peter Schorer,* peteschorer@gmail.com

THE J.H. WILKINSON POSTDOCTORAL FELLOWSHIP IN SCIENTIFIC COMPUTING

Argonne NATIONAL LABORATORY

The Mathematics and Computer Science Division of Argonne National Laboratory invites outstanding candidates to apply for the 2020 J. H. Wilkinson Postdoctoral Fellowship in Scientific Computing. The Wilkinson Fellowship is intended to encourage early-career scientists actively engaged in state-of-the-art research in scientific computing. The benefits of the appointment include competitive salary, moving expenses, and a generous professional travel allowance. For more details, including past recipients, see https://www.anl.gov/mcs/wilkinson-fellowship-in-scientific-computing.

The application must include a CV with publications, significant presentations, and links to preprints and software; a statement of research plan; and contact details for three references. Reference letters should be submitted directly to wilkinson@mcs.anl.gov. For full consideration, applications and letters should be submitted by December 15, 2019; application materials will continue to be reviewed until January 15, 2020. Apply at http://bit.ly/363SJqn.

Argonne National Laboratory is an equal employment opportunity and affirmative action employer.

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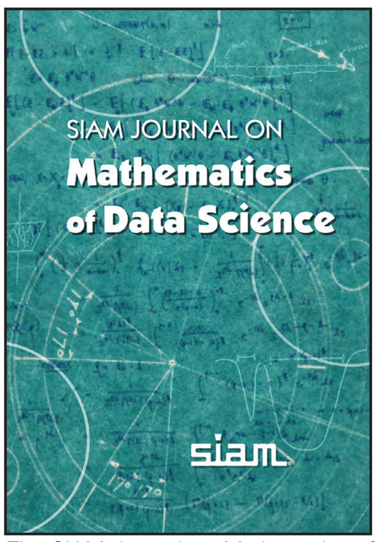
A Successful Year for SIAM Publications

By Kivmars Bowling

2019 has been another busy and successful year for SIAM Publications, thanks in no small part to the many volunteers, editors, authors, referees, and readers who support the program. As the year draws to a close, I want to reflect on recent achievements and highlight some new initiatives.

Submissions to SIAM journals continue to be robust, and 2019 submissions are keeping pace with 2018's record-breaking numbers. The median time to publication after receipt of an author's TeX files is now a month faster than it was in 2017. We continue to refine the production process to further increase speed while maintaining SIAM's established publication standards.



The SIAM Journal on Mathematics of Data Science, under the direction of editor-in-chief Tammy Kolda, published its first batch of articles in 2019.

This year, the new *SIAM Journal on Mathematics of Data Science* (*SIMODS*)[1] published its first issues under the leadership of editor-in-chief Tammy Kolda and her highly-engaged editorial board. Community response to *SIMODS* has been incredible and is reflected in the record number of submissions since the journal's launch. *SIMODS* will continue to be freely available to everyone in 2020 as part of the launch period, before becoming a subscription journal in 2021.

SIAM also reinforced its commitment to data science with the new *Data Science* book series,[2] founded with a distinguished editorial board that is led by editor-in-chief Ilse Ipsen. We have already signed the first titles, and I encourage any members with ideas or proposals for the series to reach out to either Ilse or Elizabeth Greenspan (executive editor of SIAM Books) at greenspan@siam.org.

SIMODS, the *Data Science* book series, and the inaugural SIAM Conference on Mathematics of Data Science[3]—to be held in Cincinnati, Ohio, in May 2020—have generated a strong interest that bodes well for the future of SIAM in this space. This has allowed us an opportunity to grow and further engage our membership.

SIAM Books has likewise had a robust year, with the institutional e-books program performing well and further expanding the global reach of our publications. We continue to sign a selective list of high-quality monographs and textbooks, and enhanced our textbook promotion this year to ensure that SIAM books are being adopted into curricula and impacting education.

Like many society book programs, we are able to sustain more niche topics by also publishing titles with broader appeal, such as textbooks.

We encourage you to think of SIAM for your next—or maybe first—book project. Past-President Nick Higham's *SIAM News* article on "Why to Write a Book"[4] and our video[5] about publishing books with SIAM offer valuable insight. Of course, feel free to contact Elizabeth if you have questions or would like to discuss an idea.

The new Data Science book series reaffirms SIAM's commitment to the growing field of data science.

Additionally, SIAM is piloting the following new author and reviewer services:

- **Peer review recognition for referees:** SIAM has launched a pilot program with a service called Publons. Three journals—the *SIAM Journal on Scientific Computing* (*SISC*), the *SIAM Journal on Mathematical Analysis* (*SIMA*), and the *SIAM Journal on Optimization* (*SIOPT*)—offer referees the opportunity to earn recognition for reviews on their Publons profiles. Individual referees choose whether to opt in, and while the review itself is not shared with Publons, the fact that the referee has completed a review for the journal is noted. Interestingly, SIAM referees have already added more than 1,000 reviews to their profiles without SIAM involvement. The formal pilot will gauge the number of SIAM referees who opt in to the service and consider it worthwhile.
- **Language editing service for authors:** SIAM has partnered with Charlesworth Author Services to provide non-native English-speaking authors (and others) with language-editing and manuscript preparation assistance. Authors, members, and anyone in the applied math community can take advantage of a 10% SIAM discount on Charlesworth's services, which they can use for journal article editing as well as conference presentations, grant proposals, or other projects. When partnering with other societies, Charlesworth has found that native English speakers also choose to utilize its services to polish their manuscript texts. The SIAM/Charlesworth site will launch soon, at which point we will share the URL with members.

Finally, SIAM wishes to extend its sincere thanks to Mike Miksis, outgoing Vice President for Publications, for his work and commitment to the SIAM publishing program during his tenure. Howard Elman, former *SISC* editor-in-chief and member of the Journal Committee, will succeed Mike in 2020. The SIAM Publications team and I look forward to working closely with Howard in the coming years.

In another key transition, we welcome Liliana Borcea as the new editor-in-chief of *Multiscale Modeling and Simulation* starting January 1. Jack Xin steps down as editor-in-chief after two terms in that role. We thank Jack for his work and leadership over the last six years.

Kivmars Bowling is the director of Publications at SIAM.

[1] https://epubs.siam.org/loi/sjmdaq

[2] https://my.siam.org/Store/Home/BookSeries/18

[3] https://www.siam.org/conferences/cm/conference/mds20

[4] https://sinews.siam.org/Details-Page/why-to-write-a-book

[5] https://www.youtube.com/watch?v=eCmREqW4TWM

2019: A Year of Many Milestones for Marketing and Communications at SIAM

By Becky Kerner

It has been a year of transition for the SIAM Marketing and Communications team; while we've welcomed new faces, Michelle Montgomery—our leader of 30 years—retired from her position as full-time director. But don't worry, she is still involved at SIAM as project director of MathWorks Math Modeling Challenge. I have the honor of filling her (very large!) shoes on the Marketing side.

So, who comprises SIAM Marketing and what do we do? We are the folks behind www.siam.org, the monthly "Unwrapped" e-newsletter,[1] design and brand management, video projects, social media, sponsorships, promotion of new products and programs, and even the SIAM Job Board. We set the brand vision. We put strategies in place to help make SIAM profitable, successful, and better able to serve its members. We work to ensure that SIAM's position as a key thought leader in the applied mathematics space is consistent and well established. We make sure that members have access to the resources they need. And we share information about the value of math and individual members' work with the larger mathematics community. Here are some ways that we have worked to accomplish these goals this year:

- **Video:** In 2019 alone, the videos on our YouTube page[2] were viewed a whopping 4,500+ hours to date. This year also saw the launch of 11 new videos (check out the seven-part animation series on YouTube,[3] plus four additional informational videos shot at the 2019 SIAM Conference on Computational Science and Engineering).[4]
- **News and Media:** We landed coverage *twice* in *Forbes* this year; both instances focused on research that came from our community. SIAM and our members have also been specifically cited in more than 90 U.S.-based news articles in 2019, primarily pertaining to research that was featured in a SIAM journal or at a SIAM conference.
- **SIAM Website:** In April, we distributed a member survey that solicited feedback on the newly-revamped www.siam.org website, which launched in June 2018. Nearly 800 members offered their input, and the survey feedback will drive future changes to the site. You will likely see some improvements in 2020, so keep an eye out.
- **Email:** SIAM has partnered with a marketing automation software company to refine its management of mass email. The goal is to send out targeted, tailored content that is most relevant to you based on your area of research, stage of career, location, and so on. As an aside, members have opened Unwrapped more than 75,000 times in 2019. Thank you for reading!
- **Design and Merchandise:** SIAM's top-notch, in-house designers create hundreds of design and marketing materials each year. These products include digital and printed materials (like *SIAM News* inserts), SIAM t-shirts, branded flashlights, luggage tags, and more. Next time you are representing SIAM out in the world, post pictures on social media and tag us! We have seen our members proudly wear SIAM t-shirts at professional sporting events, in Spanish cathedrals, and on mountaintops in Utah. Where in the world will you rep your SIAM shirt?
- **Social Media:** Do you follow us on Facebook,[5] Twitter,[6] LinkedIn,[7] and YouTube? We now have a combined 49,000 followers on these channels who are keeping up-to-date with SIAM happenings and general math in the news. Join the online conversation!

The SIAM community is continuously moving and shaking, and it is our duty to make sure the world knows. Thank you for the work you are doing, which provides important research and helps us spread the word about the value of mathematics. We are thrilled to have clocked a milestone year and look forward to further successes in 2020. Cheers!

P.S. Got quotes? If you love SIAM, let us know. We're always looking for testimonials to share from members. Whether it is membership, journals, books, conferences, or another specific program that tickles your fancy, tell us how SIAM has impacted your life for the better. Send quotes to marketing@siam.org and they will go into our repository.

Becky Kerner is the director of Marketing and Communications at SIAM.

SIAM t-shirts and merchandise have popped up all over the world, including in the snowy Rocky Mountains of Utah. SIAM photo.

[1] https://sinews.siam.org/Happening-Now/Unwrapped

[2] https://www.youtube.com/user/SIAMConnects

[3] https://www.youtube.com/watch?v=oWiRRUmJyfg&list=PLf_ipOSbWC87dcfqYBRAh4u_KuFpNHngn

[4] https://www.youtube.com/user/SIAMConnects/videos

[5] https://www.facebook.com/SocietyforIndustrialandAppliedMath/

[6] https://twitter.com/TheSIAMNews

[7] https://www.linkedin.com/company/societyforindustrialandappliedmathematicssiam