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From Inside-out Umbrellas to Soft Robotics

By Matthew R. Francis

Umbrellas are a useful invention with a tragic flaw: In a strong wind, they can turn inside-out, drenching their user and defeating their entire purpose. In scientific terms, the right-side-out and inside-out configurations are known as *elastic instability*, with two states that umbrellas spontaneously—and unfortunately—transition between under certain conditions.

But what if we could control that transition? For umbrellas, turning inside-out is undesirable, but for elastic valves in fluid environments it could prove useful. Finding a way to cause spontaneous snaps between stable configurations would mean that changing the flow of a fluid would no longer require mechanical intervention. As researchers develop soft hydraulic robots and other systems that require sensitive, passive control of fluids, the need for such devices increases.

"In general, we try to avoid elastic instabilities," Matteo Pezzulla, a mechanical engineer at Århus University in Denmark, said. However, he and his colleagues realized that if they could control how an elastic system snaps between configurations, it could lead to a new type of valve. "We wanted a sharp, fast change in the geometry of the channel [where fluid is flowing]. Having something that snaps sounded appealing to us because we could trigger a sudden change in the geometry of the channel just by increasing the fluid flow."

In their study, published in *Physical Review Letters* late last year [1], Pezzulla and his collaborators combined desktop-sized experiments with mathematical modeling to understand how elastic spherical shells snap when embedded in a viscous liquid. They found the threshold for elastic instability, as a function of (i) the geometry of the fluid channel; (ii) the shape and properties of the valves; and (iii) the material properties for the fluid and shells — all of which can be applied to soft robotics and similar fine-control hydraulic systems.

Scientific Progress Goes POP!

Although bistable elastic systems do exist in nature (for example, plant leaves that collect water until they reach a maximum amount at which time they dump their contents onto the heads of unsuspecting passersby), that isn't precisely what the researchers were looking for.

"When we look at these kinds of problems, we are inspired by plants and fungi, [which] do a magnificent job in passively controlling fluid flow," Pezzulla said, though he noted vascular systems do not seem to involve elastic instabilities.

Pezzulla's scientific inspiration partly came from a common toy known as a popper, which consists of a simple rubber suction cup; after inverting the cup and placing it on a table, it will spontaneously return to its original shape with a popping sound and fly into the air. However, the transition between states of the popper is mechanically driven rather than fluid. Combining the biological with the mechanical led to the *umbrella instability*, where forces exerted by fluid lead to the spontaneous snapping between configurations.

To simplify the physical system, the researchers used a viscous fluid with no turbulence — contrary to the classical umbrella inversion problem, which can be very turbulent. In physics terms, this is quantified by a dimensionless parameter known as the Reynolds number:

$$\mathrm{Re} = \frac{2R_c\rho\bar{U}}{\mu}$$

See **Inside-out Umbrellas** *on page 4*

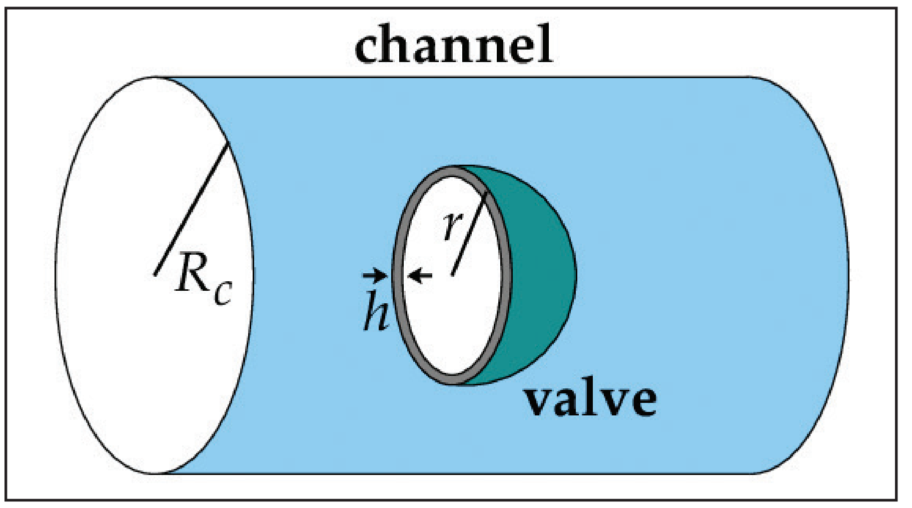

Figure 1. *Geometry for an umbrella-like valve within a larger fluid-filled cylindrical channel, defining the quantities used in the theoretical model for the system.*

Decoding the Neural Enigma: Digital Twins of Neurons Revolutionize Brain Research

By Yongjie Jessica Zhang and Tsung Yeh Hsieh

For years, scientists have relied on traditional cell culture experiments to study the intricate functions of neurons within the brain. Understanding these interactions is key to addressing major neurodevelopmental disorders such as autism spectrum disorder and attention-deficit/hyperactivity disorder (ADHD), as well as neurodegenerative diseases such as Alzheimer's, Parkinson's, and amyotrophic lateral sclerosis (ALS). Despite being the industry standard, conventional experimentation methods are not only time-intensive and burdensome, but also severely limited in the variables and scale they can explore. These limitations have significantly slowed our pace in finding effective treatments for neurodevelopmental and neurodegenerative conditions.

To address this challenge, the scientific community welcomes a profound paradigm shift with the creation of "digital twins" of neurons. These highly realistic virtual models combine advanced computational models with deep learning technologies to provide researchers with unprecedented levels of efficiency at a low cost, allowing them to simulate neuronal growth, development, and organelle transport at speeds and scales previously thought unimaginable. Nevertheless, fundamental challenges with mathematical modeling and computational efficiency remain. We focus on two key aspects of the digital twin paradigm: physics-based foundational modeling and the speed revolution brought by artificial intelligence (AI) surrogate models.

Physics-Based Modeling and Simulation Challenge

To build digital models capable of accurately predicting neuronal behavior, we must first return to our roots: describing the complex dynamics of neurons through precise mathematical and fundamental physical principles. These techniques are not only the cornerstone of understanding neuronal function, but also the solid foundation upon which all subsequent AI acceleration technologies are built.

One such physics-based model—designed to simulate the neuronal growth process—skillfully combines the phase field method with isogeometric analysis (IGA) [7, 9, 10]. The key innovation of this method is that it is not purely theoretical calculation; instead, it deeply integrates experimental data from hippocampal neurons of rats. Mathematically, the morphological evolution of the neuron is described by the governing equation of the phase field ϕ, which captures anisotropy and driving forces:

$$\frac{\partial\phi}{\partial t} = M_{\phi}\Bigg[\nabla\cdot\Big(a(\Psi)^2\,\nabla\phi\Big) - \frac{\partial}{\partial x}\left(a(\Psi)\frac{\partial a(\Psi)}{\partial\Psi}\frac{\partial\phi}{\partial y}\right) + \frac{\partial}{\partial y}\left(a(\Psi)\frac{\partial a(\Psi)}{\partial\Psi}\frac{\partial\phi}{\partial x}\right) + \phi\big(1-\phi\big)\Big(\phi - 0.5 + F_{driv} + 6H\big|\nabla\phi\big|\Big)\Bigg],$$

where $a(\Psi)$ represents the anisotropy coefficient and F_{driv} is the driving force for neuronal growth. Real data serves as driving and constraining conditions, guiding the growth of the simulated neuron to exhibit highly *biomimetic* patterns (see Figures 1a and 1b).

See **Digital Twins of Neurons** *on page 3*

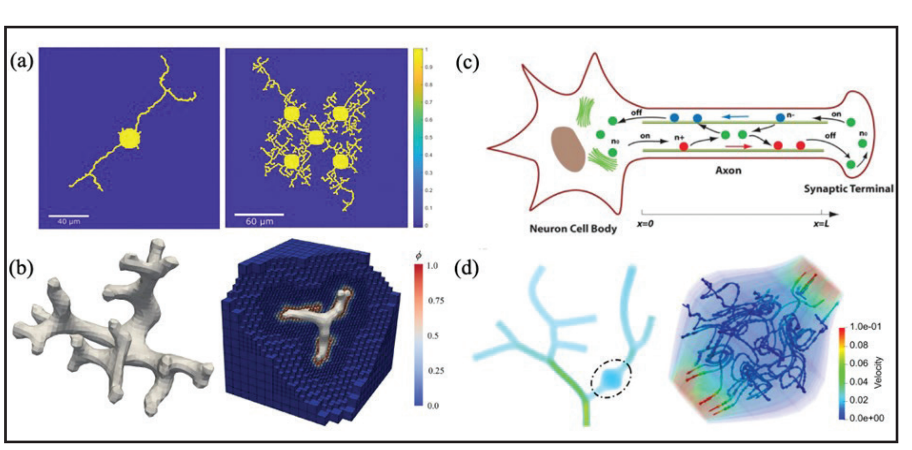

Figure 1. *Simulation results of physics-based modeling.* **1a.** *Two-dimensional phase-field simulation of single and multiple neuron growth.* **1b.** *Branched neuron growth and locally refined truncated hierarchical B-splines in the three-dimensional domain.* **1c.** *Motor assisted transport model.* **1d.** *Simulation results of a neurite tree with microtubule swirls in a local swelling region (black dashed circle) as visualized in the velocity streamlines. Figure courtesy of [4, 5, 7, 10].*

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4 **Colorado SIAM Student Members Visit the National Center for Atmospheric Research Mesa Laboratory**
SIAM student chapters at Colorado State University and the University of Colorado Boulder recently visited the National Center for Atmospheric Research in Boulder, Colo. The visit included seminars from scientists on site, tours of the facilities, and dedicated time for the students to network with researchers.

5 **Mathematizing in Times of Trouble**
Building on their *SIAM News* article published in 2020 that presented eight "Questions of Responsibility" for mathematical modeling, Dennis Müller and Maurice Chiodo offer 10 guiding pillars to inform mathematical practices when navigating rapid changes in society and technology.

6 **On the Clouds**
Inspired by winter snowstorms, Mark Levi explores five questions related to the mathematics of falling snow crystals in his latest installment of "Mathematical Curiosities."

7 **Recent Book About Mathematical Greats Falls Short of Expectation**
Ernest Davis reviews *The Great Math War: How Three Brilliant Minds Fought for the Foundations of Mathematics* by Jason Socrates Bardi. The book recounts the rapid developments in mathematics between the years 1870 to 1930, including the "war" between David Hilbert and L.E.J. Brouwer over non-constructive mathematical proofs.

8 **University of Bath SIAM-IMA Student Chapter Hosts Postgraduate Conference**
In November, the University of Bath SIAM-IMA Student Chapter organized its annual postgraduate conference. Charlie Cameron details the successful event, which attracted graduate students from across the U.K. and Ireland to discuss current research projects and connect with their peers.

Obituary: Robert Vita Kohn

By Kaushik Bhattacharya, Rustum Choksi, and Sylvia Serfaty

Robert Vita Kohn, a leading researcher in the applied mathematics community, passed away on January 12, 2026, at the age of 73. Bob Kohn was an outstanding mathematician whose work, dedication, and support directly impacted countless members of our community. His profound legacy lies in the depth and originality of his scientific vision, his gift for bringing together ideas and people across disciplines, his extraordinary support for students and colleagues, and his untiring service to New York University's (NYU) Courant Institute of Mathematical Sciences and to SIAM.

Bob was born on October 5, 1953, in Shaker Heights, Ohio. His love for mathematics developed early on as a camper, and then a counselor, at an Ohio State University-sponsored math camp. After earning his undergraduate degree in mathematics at Harvard University in 1974, he completed his Ph.D. at Princeton University in 1979, working under the guidance of geometric measure theorist Fred Almgren. He spent his academic career at the Courant Institute of Mathematical Sciences, first as a two-year National Science Foundation postdoctoral fellow, then as a part of the faculty; he ultimately became an NYU Silver Professor of Mathematics.[1] Bob retired in 2022.

Research Contributions

Bob's research began with his thesis on the rigidity of elastic deformations, inspired by the work of Fritz John [4]. Soon thereafter, Bob, together with Luis Caffarelli and Louis Nirenberg, established the landmark partial regularity result for weak solutions of the Navier-Stokes equations [1]. This breakthrough—now known as the Caffarelli-Kohn-Nirenberg theorem—has remained foundational in the field and was honored with the 2014 AMS Leroy P. Steele Prize for Seminal Contribution to Research.[2] During this period, Bob also made significant contributions to the field of semilinear partial differential equations in work with Yoshikazu Giga. In collaborations with Roger Temam, Gilbert Strang, and Michael Vogelius, he made connections between geometric measure theory, the calculus of variations, and applied problems in plasticity, thin plates, inverse problems, and optimal design.

Bob later emerged as a pioneering figure in what is now known as the mathematical aspects of materials science. He identified mathematical issues in various open problems of physics and materials — work that not only led to new insights concerning these applications, but also advances in mathematical methods. Themes of homogenization, relaxation, and Gamma convergence are echoed throughout his work on composite materials, phase transforming materials, and plasticity.

Robert Vita Kohn, 1953-2026. Photo courtesy of the New York University Courant Institute of Mathematical Sciences.

Bob introduced the phrase "*energy-driven pattern formation*," which also served as the title of his plenary lecture at the 2006 International Congress of Mathematicians [3]. As he noted in the introduction to his lectures at a summer school on the topic,[3] "Nature is full of energy-driven patterns. Some represent local or global minimizers of a suitable free energy, others are self-organized transients produced by energy dissipating dynamics." Bob explored phenomena like martensitic phase transformations, magnetic domains, and wrinkling of thin films that lead to nonconvex (often nonlocal) variational problems regularized by singular perturbations at higher order — a topic he elaborated on in *SIAM News* in 2018 [5]. He established scaling laws for the resulting patterns of the solution in the singular limit, leading to new relaxation results. Closely related, Bob demonstrated that motion by mean curvature is the singular limit of the Ginzburg-Landau equation and provided bounds on the coarsening rates on the microstructure.

He also investigated *cloaking*—the problem of designing a medium that could hide an object by diverting electromagnetic waves (light) around it to emerge unperturbed—and, more recently, the analysis of deformation in mechanical metamaterials and kirigami.

Bob's intellectual curiosity extended to many areas, including economics and finance. His notable research on two-person games—originally linked to motion by mean curvature—evolved into influential work on prediction with expert advice. He possessed a rare gift for distilling the essence of any scientific presentation and articulating it with exceptional clarity, often illuminating the core insight even for the speaker.

Bob was a fellow of the American Academy of Arts and Science, American Mathematical Society, and SIAM. In 1999, he received the SIAM Ralph E. Kleinman Prize[4] for work bridging deep mathematics and real-world applications. Along with his coauthors, Bob was a recipient of the Keith Medal from the Royal Society of Edinburgh in 2006 for their paper on the gradient theory of phase transitions [2].

Leadership and Mentorship

Bob worked tirelessly for the Courant Institute, serving as deputy director for many years and as chair of mathematics. Throughout his career, he supervised 36 Ph.D. theses and a vast number of postdocs; moreover, his support extended to the community at Courant and beyond, writing innumerable highly insightful letters of recommendation and serving on many committees. He played a central role in conceiving and leading the master's in mathematical finance program and the curriculum development for both the master's and undergraduate program. He was beloved by students at NYU for the quality of his lectures and for the caring personal attention he gave them. He was one of the few mathematicians to receive the NYU Distinguished Teaching Award.

For more than 40 years, SIAM was Bob's professional home, to which he gave an astonishing amount of himself. Bob combined scholarly distinction with extraordinary service, acting as the founding chair of the SIAM Activity Group on Mathematical Aspects of Materials Science[5] and co-chair for its 2010 meeting. He served six years on the SIAM Board of Trustees and, for the past 15 years, was a central, steady presence on the Financial Management Committee.[6] Across the board, colleagues described

See **Robert Vita Kohn** *on page 3*

[1] https://as.nyu.edu/people/silverprofessors.html
[2] https://www.ams.org/notices/201404/rnoti-p393.pdf
[3] https://www.math.cmu.edu/cna/LectureNotesFiles/kohn-cmu-overview.pdf
[4] https://www.siam.org/programs-initiatives/prizes-awards/major-prizes-lectures/ralph-e-kleinman-prize/
[5] https://www.siam.org/get-involved/connect-with-a-community/activity-groups/mathematical-aspects-of-materials-science/
[6] https://www.siam.org/get-involved/connect-with-a-community/committees/financial-management-committee-fmc/

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Digital Twins of Neurons

Continued from page 1

Simultaneously, the interior of a neuron acts as a bustling material transport network. To deeply investigate this mechanism, we utilized IGA solvers to establish a motor-assisted transport model within complex three-dimensional neuronal tree structures [4, 5] (see Figure 1c, on page 1). This model describes the partial differential equation-constrained optimization system by coupling the Navier-Stokes equations with advection-diffusion-reaction equations. The dynamic change in material concentration is governed by minimizing

$$\mathcal{J}(n_\pm, v_\pm, f_\pm) =$$
$$\frac{1}{2}\int_0^T \int_\Omega (v_\pm - V_\pm)^2 \, d\Omega dt +$$
$$\frac{\alpha}{2}\int_0^T \int_\Omega \|\nabla n_\pm\|^2 \, d\Omega dt +$$
$$\frac{\beta}{2}\int_0^T \int_\Omega f_\pm^2 \, d\Omega dt \text{ in } \Omega \times (0, T],$$

subject to

$$\frac{\partial n_0}{\partial t} = -(k_+ - k_-)n_0 + k'_+ l_+ n_+ + k'_- l_- n_- \quad \text{in } \Omega \times (0, T],$$

$$\frac{\partial l_\pm n_\pm}{\partial t} = -v_\pm \cdot \nabla(l_\pm n_\pm) \pm D_\pm \nabla^2 (l_\pm n_\pm) + k_\pm n_0 - k'_\pm (l_\pm n_\pm) \text{ in } \Omega \times (0, T],$$

$$\frac{\partial v_\pm}{\partial t} + v_\pm \cdot \nabla v_\pm = -\nabla n_\pm + \nabla \cdot (\mu \nabla v_\pm) + f_\pm \text{ in } \Omega \times (0, T].$$

Here, n_0 is the concentration of free material, while $n_\pm$ represents the concentration of material bound to microtubules that are moving either forward or backward. The definition of other parameters can be found in [4, 5]. This high-fidelity simulation can meticulously reproduce material flow inside neurons and successfully simulate the "traffic jam" phenomena caused by microtubule structural anomalies (see Figure 1d, on page 1).

However, despite the immense power of these physics-based simulation methods, their high computational cost has become a major bottleneck for widespread research adoption.

Novel Approaches to Surrogate Modeling

To break through the high cost barrier, the fields of neuroscience and computational science are undergoing an AI-driven revolution. AI surrogate models provide the critical pillars for a digital twin to mirror the full life cycle of a living neuron, from construction and operation to deterioration.

Convolutional neural networks (CNNs) show amazing potential for predicting neuronal growth by utilizing specialized machine learning (ML) techniques that can mimic the human cortex. We established a CNN-based surrogate model centered on a customized convolutional autoencoder [6]. Compared to traditional IGA physics-based simulators, our CNN model reduces computation time by a staggering seven orders of magnitude while maintaining an accuracy of 97.77 percent when predicting complex neurite growth patterns.

When addressing neurological disorders, understanding neuronal deterioration is crucial. Recent research introduces a high-throughput ML framework that utilizes a MetaFormer architecture combined with a gated spatiotemporal attention mechanism to precisely predict neurite deterioration patterns [8] (see Figure 2a). This framework integrates synthetic data generated by IGA phase-field models with experimental imagery, allowing for the capture of long-range temporal dependencies and intricate morphological transformations. This technology achieved low average error rates—1.96 percent on synthetic data and 6.03 percent on experimental data—successfully overcoming the challenge of scarce experimental datasets and providing a powerful predictive tool for studying neural disorders.

In the complex realm of material transport simulation, Graph-Autoencoder-based Latent Dynamics Surrogate (GALDS) has emerged as another innovative surrogate model [1]. GALDS employs an advanced workflow operating in a concise latent space, using neural ordinary differential equations to efficiently predict the system's dynamic evolution over time:

$$\frac{dz(t)}{dt} = f_\theta(z(t), t).$$

This "compress-predict-reconstruct" approach surpasses previous methods such as the physics-informed graph neural network (PGNN), which learns directly in complex physical spaces [3, 5]. By operating in this latent space, GALDS saves over 99 percent of computational resources while maintaining high accuracy (see Figure 2b).

Challenges and Opportunities

Starting from the monumental challenge of understanding brain function, we have witnessed a clear path of technological evolution: traditional physics-based simulations laid the foundation, while deep learning-driven AI surrogate models such as CNNs, MetaFormer, and GALDS thoroughly shattered efficiency bottlenecks.

These advancements do not merely make existing processes faster; they unlock a completely new realm of possibility for neuroscience research. Scientists are no longer limited to long experimental cycles that can only test one hypothesis at a time. Instead, they can conduct large-scale "digital scans" *within* the digital world: systematically testing the effects of thousands of genetic mutations, screening the responses of hundreds of potential drug compounds, or exploring vast parameter spaces to discover unexpected pathological mechanisms.

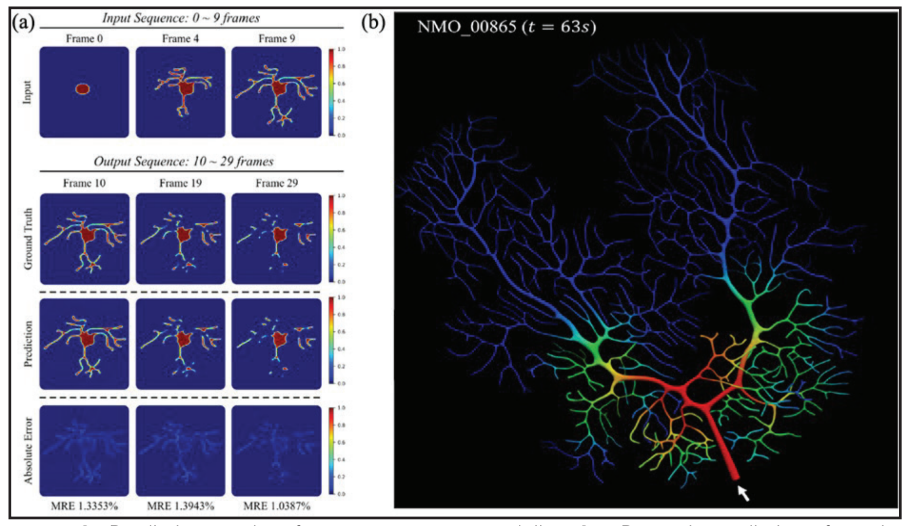

Figure 2. *Prediction results of neuron surrogate modeling.* **2a.** *Dynamic prediction of neurite deterioration.* **2b.** *Graph-Autoencoder-based Latent Dynamics Surrogate predicted concentration field within the complex neurite network. Figure courtesy of [7, 8].*

Looking ahead, as digital twin models of neurons mature and become more widespread, it will vastly accelerate our understanding of the root causes of neurological disorders. This technology offers a powerful *computational microscope*, allowing us to witness the onset and progression of disease at the cellular level, thus unlocking the ability to screen for potential therapeutic targets more rapidly. It represents not just a leap in computational power, but a beacon of hope, promising to illuminate the unknown corners of neuroscience and significantly shorten the long road to finding effective treatments for neurological diseases.

This article is based on Jessica Zhang's[1] AWM-SIAM Sonia Kovalevsky Prize Lecture[2] at the Third Joint SIAM/CAIMS Annual Meetings[3] which took place in Montréal, Québec, Canada.

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Jessica Zhang is the George Tallman Ladd and Florence Barrett Ladd Professor of Mechanical Engineering at Carnegie Mellon University with courtesy appointments in the Departments of Biomedical Engineering and Civil and Environmental Engineering. She was a 2023 SIAM Fellow. Tsung Yeh Hsieh is a Ph.D. candidate in the Department of Mechanical Engineering at Carnegie Mellon University.

[1] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=85273

[2] https://www.siam.org/programs-initiatives/prizes-awards/major-prizes-lectures/awm-siam-sonia-kovalevsky-lecture/

[3] https://www.siam.org/conferences-events/past-event-archive/an25/

Robert Vita Kohn

Continued from page 2

him in the same way: thoughtful, wise, clear-thinking, and kind. In moments of complexity and chaos, he had a gift for cutting to the heart of an issue calmly and humanely. His attention to detail was legendary, never making rash decisions — only careful ones, followed by deep commitment. Last year, he made a major gift to help secure the future of the SIAM John von Neumann Prize,[7] remarking simply, "It is a pleasure to be able to help SIAM this way." That quiet sentence captures him exactly: no fanfare, just purpose and gratitude. Across governance, prizes, mentorship, and philanthropy, Bob's intellect was matched by his judgment and character that one colleague summed up best in three words: "such a mensch."

For so many of us, Bob will be remembered above all as an extraordinarily generous, perceptive, and tireless mentor. His guidance and encouragement reached countless young mathematicians and colleagues throughout many fields. He was a towering figure in applied mathematics, someone who never turned away from a direct—or even unspoken—request for advice, insight, or support. Even so, his generosity was not confined to science; he offered wisdom, warmth, and help just as freely in everyday life. Bob helped several scientists emigrate to the U.S. after the fall of the Soviet Union. He continued to mentor, serve, and work even during his long illness, which he faced with calmness and courage. His influence on successive generations of mathematicians and scientists has been remarkable. Bob was one of a kind and he will be deeply missed. Our deep thoughts go out to Leslie Anker, Bob's beloved wife and life partner.

[7] https://www.siam.org/programs-initiatives/prizes-awards/major-prizes-lectures/john-von-neumann-prize/

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Kaushik Bhattacharya is Howell N. Tyson Sr. Professor of Mechanics and professor of materials science at the California Institute of Technology. Rustum Choksi is a professor and department chair of mathematics and statistics at McGill University. Both Bhattacharya and Choksi were postdoctoral scholars mentored by Bob Kohn. Sylvia Serfaty is a Silver Professor of Mathematics at the Courant Institute of New York University and professor at Sorbonne Université. She was a collaborator and colleague of Bob Kohn's.

Colorado SIAM Student Members Visit the National Center for Atmospheric Research Mesa Laboratory

By Kristina Moen

On February 5, student members of SIAM stepped inside one of the nation's premier hubs for atmospheric science: the National Center for Atmospheric Research[1] (NSF NCAR) in Boulder, Colo. Organized by the SIAM student chapters at Colorado State University[2] and the University of Colorado Boulder,[3] the visit brought together graduate students from both institutions to explore how mathematics informs contemporary atmospheric science and learn about the role of federally-funded research centers in sustaining long-term scientific infrastructure.

The group met at NSF NCAR's iconic Mesa Laboratory,[4] which is set against the foothills of the Rocky Mountains. Designed by architect Ieoh Ming Pei in 1961, the building seems to rise out of the surrounding sandstone cliffs and is a testament to the close connection between science and the environment. Researchers at NSF NCAR work in a variety of disciplines ranging from meteorology and atmospheric chemistry to solar and space weather.

The day began with a seminar on sea ice modeling led by applied mathematician Christopher Horvat of Brown University and visiting researchers from the Polar Climate and Ocean Modeling Working Group.[5] The discussion moved between mathematical theory, numerical computation, and real-world data, offering students a clear example of how mathematicians and atmospheric scientists collaborate to understand polar processes. Following the seminar, students had lunch in the Mesa Cafe, which provided informal time for conversation with NSF NCAR scientists about career paths, interdisciplinary collaboration, and the practical realities of working at a national research center.

In the afternoon, tropical weather researcher and NSF NCAR postdoctoral fellow Quinton Lawton led a guided tour of the Mesa Laboratory. In addition to serving as NSF NCAR's primary research facility, the laboratory also houses a public visitor center that features interactive exhibits[6] on cloud physics, hurricane dynamics, Sun-Earth connections, and weather impacts on aviation and emergency response. Students touched a cloud, stepped into a simulated tornado vortex, and explored how severe winds influence aircraft performance during takeoff and landing. The tour also highlighted how NSF NCAR supports the broader scientific community by providing specialized instruments, research aircrafts, high-performance supercomputing, and open-access Earth science datasets to the public.

The timing of the visit was especially meaningful, as NSF NCAR's funding has faced recent scrutiny, underscoring the

See **Mesa Laboratory** *on page 7*

[1] https://ncar.ucar.edu/
[2] https://www.math.colostate.edu/~siamcsu/
[3] https://www.colorado.edu/amath/organizations/siam-graduate-chapter
[4] https://scied.ucar.edu/visit
[5] https://www.cesm.ucar.edu/events/working-groups/2026/ocean
[6] https://scied.ucar.edu/exhibits/about

Inside-out Umbrellas

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where R_c is the radius of the (cylindrical) flow channel, ρ is the fluid density, $\bar{U}$ is the average fluid velocity, and μ is the dynamic viscosity. Large Reynolds numbers (i.e. $\mathrm{Re} > 10^3$) describe undesirable turbulent flow, while very small values (i.e. $\mathrm{Re} < 1$) mean that viscous forces dominate over the inertia of the fluid — which is a very simple system both mathematically and physically. For water at room temperature, $\rho \approx 10^3$ kg/m^3 and $\mu \approx 10^3$ $\mathrm{Pa \cdot s}$, which will only produce low Reynolds numbers under strict conditions. A better approach for soft hydraulic systems involves choosing a fluid with much higher viscosity.

A second dimensionless parameter is the Cauchy number C_Y, which is the ratio of the stress exerted by the fluid to the elastic properties of the material:

$$C_Y = \frac{\mu \bar{U} r^2}{B},$$

where r is the radius of the spherical shell and the bending stiffness of the shell material

$$B = \frac{2Eh^3}{\sqrt{3(1-\nu^2)}}.$$

This quantity includes the Young's modulus E that measures how a material responds to stresses, and Poisson's ratio $\nu \approx 0.5$ for rubber-like materials that don't compress under stress. The thickness of the shell $h \ll r$ is the final geometric property (see Figure 1, on page 1).

However, because it involves the fluid properties as well as valve properties, the Cauchy number is not simply set by choosing the right material for the valve: it must take the entire system into account. To get the factors right, the researchers performed numerical simulations that would allow them to pick the ideal fluid and valve materials. After all, a workable valve should not break or buckle instead of snapping, nor should it flutter or open too easily under pressure.

"When the Cauchy number is very high, the shell is going to deform quite substantially," Pezzulla said. "When it's very small, the shell is rigid."

The only dynamic quantity at fixed temperatures is the fluid velocity in the linear low Reynolds number regime, which can be controlled experimentally — exactly what the researchers wanted. In other words, they sought both mathematically and experimentally to find the *critical* Cauchy number C_Y^{crit} at which the spherical shell flips itself inside-out and does not snap back even if the flow is reduced to zero (think of it like an umbrella that flips inside-out hard enough to break). By calculating this quantity, researchers could design a valve that would allow the system to reliably snap between states *without* breaking, providing passive control for the fluid.

From Tubes to Soft Robots

With this model of fluid-valve interactions in hand, the researchers selected silicone oil for their fluid — which, despite being almost a thousand times more viscous than water, has a comparable density. They also chose vinyl polysiloxane for the elastic valve material with various coatings to test different tensile strengths under experimental conditions.

The experiment itself utilized coaxial acrylic cylinders between 10 and 21 millimeters in radius, with the valve sitting in front of the inner tube. With the shell in its initial state, the fluid could enter the inner channel, but when snapped into its inverted state, it would close off that tube, thus reducing the total fluid flow and increasing the flow resistance.

"We like to do experiments at the desktop scale," Pezzulla said. "If you have a laser cutter, a pressure sensor, and a syringe pump, you can make it work. If you can tune flow rates and pressures periodically, you can create motion."

Since the only thing governing whether the valve is open or closed is the fluid pressure on it, the entire system is passive, not requiring electronic control or human intervention. That in turn reduces the complexity of soft hydraulic apparatus which could be used for small robots.

"In soft robotics you don't have rigid tubes or valves," Pezzulla said. "If you have a soft robot, at some point you want to reduce the flow inside or towards a certain appendage like a leg or an arm, this is going to reduce the flow rate inside that appendage to reduce its motion. You increase the pressure asymmetrically only on one side, so [the limb] is going to bend, and if you reduce it, it's going to go back to its straight configuration."

The researchers constructed their mathematical model governing the system to be dimensionless, as an experimental setup should scale up or—more importantly for soft robotics—down without affecting the general conclusions. In practice, however, microscopic material properties such as fluid-surface interactions change at smaller length scales. Additionally, Pezzulla and his collaborators used rigid acrylic cylinders, but since soft hydraulic systems must be able to flex without rendering the valves useless, their next steps for the project are to change out the rigid cylinders.

"We like to do math, but we have to be honest about the limitations of the work," Pezzulla said. "So far, these experiments have only been possible at the desktop scale. I think that would be really, really nice if we can scale them down by at least a factor of 10 or 100."

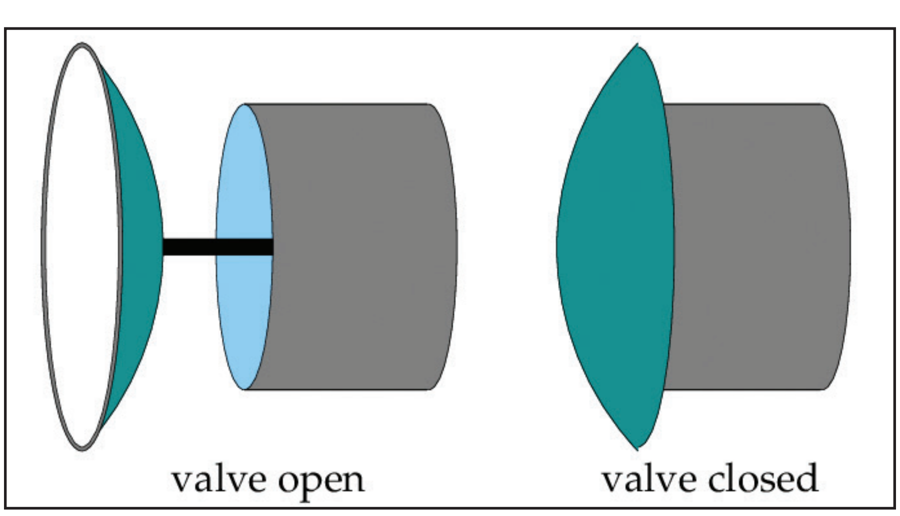

Figure 2. *The bistable valve in open (left) and closed (right) configurations, showing how snapping between positions closes a smaller fluid channel within a larger flow moving from left to right.*

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The figures in this article were provided by the author.

Matthew R. Francis is a physicist, science writer, public speaker, educator, and frequent wearer of jaunty hats. His website is https://bowlerhatscience.org.

Take Advantage of SIAM's Visiting Lecturer Program

Hearing directly from working professionals about research, career opportunities, and general professional development can help students gain a better understanding of the workforce. SIAM facilitates such interactions through its Visiting Lecturer Program (VLP), which provides the SIAM community with a roster of experienced applied mathematicians and computational scientists in academia, industry, and government. Mathematical sciences students and faculty—including SIAM student chapters—can invite VLP speakers to their institutions to present about topics that are of interest to developing professional mathematicians. Talks can be given in person or virtually.

The SIAM Education Committee[1] sponsors the VLP and recognizes the need for all members of our increasingly technological society to familiarize themselves with the applications and achievements of mathematics and computational science.

Points to consider in advance when deciding to host a visiting lecturer include the choice of dates; potential speakers and topics; and any additional or related activities, such as follow-up discussions. Organizers can reach out directly to speakers and must address these points when communicating with them. It is important to familiarize lecturers with their audience—including special interests or expectations—so that they can refine the scope of their talks, but just as crucial to accommodate speakers' suggestions so the audience can capitalize on their experience and expertise. Read more about the program and view the current list of participants on the VLP webpage.[2]

[1] https://www.siam.org/get-involved/connect-with-a-community/committees/education-committee
[2] https://www.siam.org/programs-initiatives/programs/visiting-lecturer-program

Mathematatizing in Times of Trouble

By Dennis Müller and Maurice Chiodo

ETHICS IN MATHEMATICS

More than five years ago, we addressed the immediate ethical challenges that faced the mathematical community amidst the urgency of the COVID-19 pandemic[1] — a crisis that thrust many mathematicians into public service roles. In that environment of post-normal science, which necessitated mathematical contributions under uncertainty and at great speed, we proposed eight "Questions of Responsibility" to serve as guidelines that promote ethical mathematical modeling practices [3]. Although the pandemic has passed, public reliance on applied mathematics in high-stakes decision-making scenarios has only accelerated. In fact, the proliferation of machine learning and data analytics means that mathematical expertise is now embedded in our society more deeply than ever. The lessons and takeaways from COVID-19 were not merely temporary adjustments; instead, they demonstrated that applied mathematics research does not occur in a political or ethical vacuum. This realization highlighted the global need for a more systematic approach to responsibility, which felt urgent back then and has since become a professional necessity for many.

With these realities in mind, we spent the last several years expanding our original eight questions into a more comprehensive, process-oriented framework that we call the *Manifesto for the Responsible Development of Mathematical Works* [4]. This updated framework is centered around 10 pillars, which we present here with slightly reformulated wording:

1. Decide whether to begin: Why are you providing the mathematical product or service in question, and should you even do so?

2. Consider diversity and perspectives: Do you, your coworkers, and your superiors have sufficient perspective on the issues at hand? Do you understand the limitations and biases in your thinking?

3. Handle data and information responsibly: Are you using authorized and morally obtained datasets in a responsible manner?

4. Consider data manipulation and inference: Do you have the expertise to properly manipulate data while ensuring quality and ethics?

5. Review the mathematization of the problem: What optimization objectives and constraints are you choosing, and what are their real-life consequences? Who might be impacted by your mathematics and actions?

6. Communicate and document your work: Are you properly considering how to best comment and document your work and communicate the results to those who need them?

7. Evaluate falsifiability and feedback loops: Is your work falsifiable, and can you handle its large-scale impact and any feedback loops that may arise?

8. Establish explainable and safe mathematics: Is your mathematical output explainable, and have you followed up with proper monitoring and maintenance practices?

9. Acknowledge that mathematical artifacts have politics: Are you aware of other non-mathematical aspects and the political nature of your work? What are you doing to earn public trust in yourself and your product?

10. Identify emergency response strategies: Do you have a nontechnical response strategy for when things go wrong? Do you have an established support network, including peers who support you and with whom you can talk freely?

We taught these pillars in an advanced seminar at the University of Cambridge in 2024, using a worked example of artificial intelligence (AI)-powered bus timetabling and routing. Students were "surprised" by the ethical scope of this public-facing mathematics project [7], realizing that even something as simple as a bus timetable could have "ramifications for citizens, democracy, and the environment" [10]. Since a framework's effectiveness relies on adoption, our involvement with the Ethics in Mathematics Project[2] seeks to translate these principles into both practice and education. In doing so, we found that sustainable and ethical mathematics must be localized to its specific context, as blindly following a general philosophical framework designed to "apply everywhere" risks alienating mathematicians and students alike [7].

We therefore implement a critical pragmatic approach that meets students at their current level of philosophical understanding, rather than frontloading abstract philosophy. Our technique aims to foster ethical responsibility without taking the fun out of mathematics, gradually guiding students toward ethical abstraction by repeatedly showing them a problem from different angles — i.e., employing a "spiral structure" similar to that of standard mathematical curricula. We soon noticed that "leveling up" ethical awareness [2, 7] can happen rather quickly, as long as students refrained from hastily conducting mathematics without the proper initial considerations (Pillar 1) and widened their perspective before working with any data (Pillar 2).

From 2023 to 2025, we also participated in a project titled "Anticipating the Future of War: AI, Automated Systems, and Resort-to-Force (RTF) Decision Making."[3] This domain typically shields mathematicians from scrutiny even as their research impacts one of the most public-facing decisions imaginable: When should a nation go to war? By considering the three primary stakeholder groups in this domain—*developers* who create AI systems, *integrators* who embed them into established decision-making processes, and *users* (including senior political and military leaders, as well as their advisors)—we observed that effective communication requires more than just a shared language [5, 8]. In fact, it is equally critical that mathematicians and political scientists bridge their respective disciplines and discuss their differing perspectives and priorities.

When we presented our framework at two of the project's workshops about AI for RTF decisions, we observed a funda-

See **Times of Trouble** *on page 6*

[1] https://www.siam.org/publications/siam-news/articles/questions-of-responsibility-modelling-in-the-age-of-covid-19/

[2] http://www.ethics-in-mathematics.com

[3] https://bellschool.anu.edu.au/sdsc/our-research-sdsc/anticipating-future-war-ai-automated-systems-and-resort-force-decision-making

On the Clouds

MATHEMATICAL CURIOSITIES
By Mark Levi

While gazing out at the fresh snow, I began to wonder about the order of magnitude of the combined surface area of all the fallen snow crystals. A chain of associations gave rise to a few questions, some of which I mention here.

Question 1: A ball of water of radius $R = 10$ cm is pulverized into a cloud of droplets, each of 10 μm radius.[1] What is the combined surface area of the droplets?

The combined area A of the droplets varies as the inverse power of their radii r:

$$A = 3V\frac{1}{r}, \qquad (1)$$

where $V = \frac{4\pi}{3}R^3$ in the water volume. Indeed, the number n of droplets is in inverse proportion to the volume of an individual droplet, so that $n = R^3 / r^3$. Substituting this into $A = n \cdot 4\pi r^2$ gives (1).

With $R = 0.1$ m and $r = 10^{-5}$ m, we get

$$\boxed{A \approx 1{,}257 \text{ m}^2}$$

— the area of a meter-wide strip over a kilometer long, created out of about a gallon of water.

[1] This is a typical size of droplets in clouds. $1\ \mu\text{m} = 10^{-6}$ m. Average thickness of a human hair is about 70 μm.

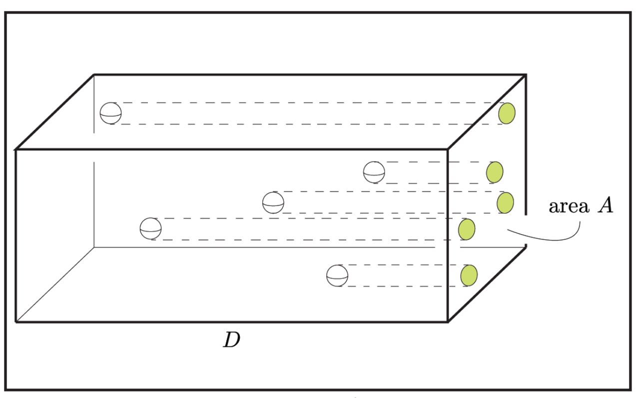

Figure 1. *Estimating visibility in the fog.*

Question 2: Water surface of area A stores potential energy γA, where γ represents the surface tension; this is the work required to stretch the surface to its given area A. What is the combined energy E of the surface tension of all the droplets in the cloud made out of the ball of water?

$E = \gamma A$ together with (1) gives

$$E = 3\gamma V\frac{1}{r}. \qquad (2)$$

With $\gamma = 0.072$ N/m (i.e., newtons per meter), we get $E \approx 90$ J, enough combined energy to lift our ball of water by about two meters. Alternatively, dropping the ball of water from such height releases enough energy to separate the water into these tiny droplets — assuming that this energy is not spent on anything else.

Question 3: Can (2) be used to estimate the size of water molecules?

This question is motivated by the similarity between pulverizing and evaporating: during both processes the water is split into smaller pieces.

Let E be the energy required to evaporate a given volume V of water; substituting this value into (2) we can estimate r, the radius of a molecule. Of course, the resulting estimate is only as good as the similarity mentioned in the previous paragraph, and so should be taken with a grain of salt.

The energy to evaporate a unit mass of boiling water—the specific heat of evaporation—is well known: $L = 2.5 \cdot 10^6$ J. For mass m of volume V, we have $E = mL = \rho VL$, where ρ is the density of water. Substituting the last expression into (2), we get

$$\boxed{r = \frac{3\gamma}{\rho L},}$$

an estimate of the size of a water molecule. Substituting the numbers listed before gives $r \approx 10^{-10}$ m.

The actual[2] size of a water molecule is about $2.5 \cdot 10^{-10}$ m, and although our estimate is about three times less, the order of magnitude is right.

Question 4: How far can one see in a cloud of droplets given their radius r and the volume proportion λ?

Figure 1 shows projections of droplets along the line of sight onto the base of a box. Let us now continually increase the length of the box until these projections cover the base; the length D would then be the maximal visibility distance, since no ray of light of length $> D$ will pass through without hitting a droplet. But covering the base with disks of radius r, assuming no excessive overlaps, implies

$$n \cdot \pi r^2 \sim A, \qquad (3)$$

where n is the number of droplets in our box. By the definition of λ, we have

$$n \cdot \frac{4\pi}{3}r^3 = \lambda AD.$$

Combining this with (3), we get

$$D \sim \frac{r}{\lambda}.$$

In particular, for a fixed proportion λ of water in the air, the smaller the droplets become, the worse the visibility is. This may not be surprising, as small drops don't "waste" their thickness — small droplets have greater ratio $\sim 1 / r$ of cross-sectional area to volume.

[2] Whatever "actual" means, given the quantum mechanical fuzziness.

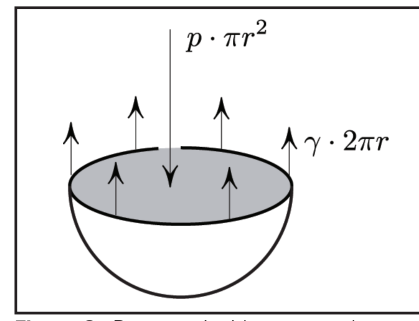

Figure 2. *Pressure inside a water drop.*

Question 5: What is the pressure inside a water droplet of 1 micron radius?

Consider the balance of forces acting on the half-ball of water droplet (see Figure 2). Surface tension pulls the hemispherical surface with force $\gamma \cdot 2\pi r$; this force is balanced by the pressure on the equatorial disk (see Figure 2):

$$\gamma \cdot 2\pi r = p \cdot \pi r^2,$$

so that

$$p = \frac{2\gamma}{r}.$$

Substituting $r = 10^{-6}$m (one micron) and $\gamma = 0.072$ N/m, we discover that the pressure inside the drop is about 1.4 kg/cm^2 over the atmospheric pressure — more than doubling it and making it approximately equal to being 40 feet underwater!

The figures in this article were provided by the author.

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

Times of Trouble

Continued from page 5

mental epistemological divide — that is, a deep gap in technical and non-technical experts' understanding of both the nature of the problem and the required evidence for a solution. Various issues and questions—such as, *When is it okay to treat certain aspects as a black box problem?*—were interpreted differently by different groups. We found that our 10 pillars can challenge traditional assumptions about military accountability by decentralizing ethical responsibility to include developers and integrators, rather than relying solely on political leaders.

This experience left us with several observations that are relevant to the entire mathematical community. First, in 2021, Shoshana Zuboff wrote in The *New York Times* that "[w]e can have democracy, or we can have a surveillance society, but we cannot have both" [11]. This outlook prompted Moshe Vardi to conclude, right here in *SIAM News*,[4] that "the current situation is a crisis of public policy, not a crisis of ethics" [9]. The fact that AI-assisted RTF decision-making has become a public concern—even though many mathematical and technical education tracks only teach a minimum of ethics and almost no policy—demonstrates that the political and moral reality is evolving rapidly and might leave our students behind in that regard, despite their mathematical prowess.

Second, mathematicians and computer scientists wield growing influence that, during emergencies, often transforms into direct power. Governments in crisis may "hand over the keys to the city" [1], granting outside technical experts major decision-making authority and operational control in order to provide a solution. As illustrated in the aforementioned AI-RTF scenarios, scientific and mathematical experts receive technological and scientific "keys" that are vital to infrastructure, policy choices, and (inter)national security [1]. However, great danger can result when these transfers occur with minimal oversight. In such situations, authority shifts from democratic processes toward purely technocratic solutions — potentially eroding the self-correcting mechanisms that safeguard democratic governance [6]. What begins as emergency delegation can ultimately become a gradual, unaccountable concentration of power if either ethics or policy are lacking.

Finally, while ethics alone may not remedy the situation [9], we still believe it to be a crucial component. Without ethical awareness and properly localized process-oriented frameworks, both the individual mathematician and the mathematical community may soon have difficulty navigating the rapid sociopolitical changes in our society.

[4] https://www.siam.org/publications/siam-news/articles/artificial-intelligence-ethics-versus-public-policy/

The ethics of your mathematics is often localized. Image courtesy of SIAM.

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[3] Chiodo, M., & Müller, D. (2020, September 1). Questions of responsibility: Modelling in the age of COVID-19. *SIAM News, 43*(7), p. 6.

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Dennis Müller is a research associate at the Institute of Mathematics Education at the University of Cologne in Germany and a research affiliate at the Centre for the Study of Existential Risk at the University of Cambridge in the U.K. He is a founding member of the Ethics in Mathematics Project. Maurice Chiodo is a research associate at the Centre for the Study of Existential Risk at the University of Cambridge in the U.K. and principal investigator of the Ethics in Mathematics Project. A research mathematician by training, his work now addresses the ethical challenges and risks that are posed by mathematics, mathematicians, and mathematically-powered technologies.

Recent Book About Mathematical Greats Falls Short of Expectation

The Great Math War: How Three Brilliant Minds Fought for the Foundations of Mathematics. *By Jason Socrates Bardi. Basic Books, New York, NY, November 2025. 416 pages, $32.00.*

BOOK REVIEW

By Ernest Davis

Jason Bardi's connection to mathematician Bertrand Russell began before his birth. Bardi's father was an enormous admirer of Russell's politics and activism and wanted to name his unborn son "Bertrand Russell Bardi;" fortunately, Bardi's mother stepped in to veto what would have likely become "Bertie Bardi." Instead, they compromised and gave their son the middle name "Socrates."

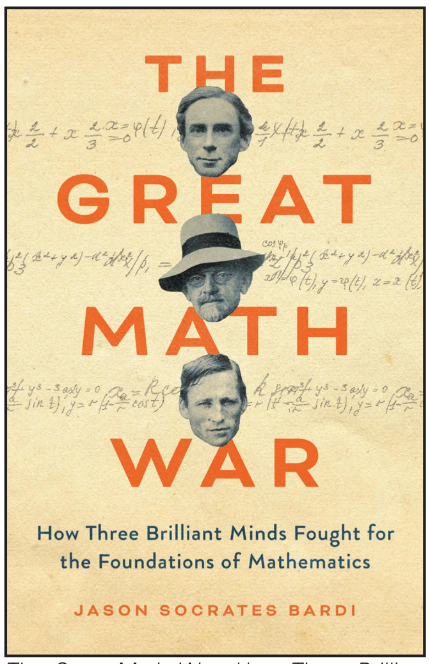
Bardi's latest book, *The Great Math War: How Three Brilliant Minds Fought for the Foundations of Mathematics*, provides an account of the contentious development of the foundations of mathematics between 1870 to 1930. This evolution culminates in a nasty squabble during the 1920s—the "war" in the title book's title—between David Hilbert and L.E.J. Brouwer about the legitimacy of non-constructive mathematical proofs. Beyond this bitter altercation, the book also contains extended commentary on the lives and works of Georg Cantor and Hermann Weyl, with shorter accounts of Leopold Kronecker, Giuseppe Peano, Ernst Zermelo, Ludwig Wittgenstein, Kurt Gödel, Richard Courant, and other notable players.

The Great Math War was clearly a labor of love for Bardi. He emotionally describes his father's love for Russell as inspiration for the book and admits that he worked on the text for over a half a decade. Bardi provides the reader with a *dramatis personae* of 55 individuals; an overview of "Queen Math;" and commentary about 19 axioms, fallacies, hypotheses, paradoxes, and myths. He also includes an annotated bibliography with a 12-page guide to the literature and more than 600 references; very regrettably, there are no footnotes.

Despite this extensive effort, I am sorry to say that the book is flawed in multiple ways.

Errors of Fact

Bardi gets some important things wrong, particularly when it comes to the mathematics. He correctly states the continuum hypothesis in the *dramatis personae* but misrepresents it several times in the text by writing that "All infinite sets … come in two and only two sizes: aleph-naught and aleph-one … The continuum hypothesis says all infinite sets fall into one bucket or another and never in between the two." He also misstates Gödel's theorem that the consistency of arithmetic is unprovable in this bewildering formulation: "If a system is inconsistent, it cannot be proven consistent using its own inconsistent means."



The Great Math War: How Three Brilliant Minds Fought for the Foundations of Mathematics. By Jason Socrates Bardi. Courtesy of Basic Books.

Additionally, Bardi claims that "In 1924, with his new intuitionist constructive methods, [Brouwer] pushes ahead, proving thorny theorems where classical methods have failed." This claim would be fascinating if it were true, but as far as I can determine, it is not. In and around 1924, Brouwer indeed had some remarkable successes in using constructive methods to establish results about the continuum; however, these victories were not "theorems where classical methods had failed." Since Bardi's book has no footnotes, it is hard to know what he had in mind.

Bardi makes mistakes in the non-mathematical parts of his narrative as well. When Russell visited the U.S. in 1914, he met T.S. Eliot, who was a Harvard philosophy student at the time. Bardi writes that "Bertie loves T.S., but more than that, he loves T.S.'s wife, with whom he would later have an affair." However, Eliot was unmarried in 1914 and had not yet met his first wife, Vivienne Haigh-Wood, who spent all her life in England. Furthermore—based on what I can tell from biographies of Russell and Eliot—the claim that Russell loved Eliot is baseless hyperbole. Russell's description in his autobiography was as follows [1]: "The students … were admirable. I had a post-graduate class of twelve, who used to come to tea with me once a week. One of them was T.S. Eliot … He was extraordinarily silent and only once made a remark which struck me. I was praising Heraclitus, and he observed, 'Yes, he always reminds me of Villon.' I thought this remark was so good that I always wished he would make another."

Bardi makes another faux pas when he writes that "The other places comparable [to Göttingen] in terms of prestige are all located in major cities — Paris, Berlin, London, Zürich, Moscow." Apparently Cambridge and Oxford slipped his mind. He also consistently misspells Paul Gordan's last name, though many people have made that error.

Significant Omissions

While some of Bardi's omissions are admittedly matters of judgment and taste, a few examples were particularly striking. *The Great Math War* includes an extended discussion of Russell's paradox and a short discussion of the Zermelo-Fraenkel axiomatization of set theory, but it does not explain the clever way in which the axiomatization sidesteps the paradox. When addressing the ZFC axiomatization of set theory, Bardi explains that "Z" stands for "Zermelo" and "C" stands for "choice," but there is no mention of Abraham Fraenkel, who was the "F." And

See **Mathematical Greats** *on page 8*

Mesa Laboratory

Continued from page 4

importance of public understanding and support for foundational atmospheric scientific research. Several students said that they had not realized how deeply mathematics shape the tools used for disaster forecasting, policy decisions, and societal resilience during severe weather events.

Another joint laboratory tour took place a month later on March 5; students from both chapters visited the CSU Energy Institute's Powerhouse Campus[7] in Fort Collins, Colo., and attended a seminar on mathematical modeling of methane emissions with Energy Institute mathematician Michael Moy. In previous years, the Colorado SIAM chapters have also toured the National Oceanic and Atmospheric Administration facilities[8] in Boulder, the National Laboratory of the Rockies[9] (formerly National Renewable Energy Laboratory) in Golden, Colo., and the NCAR-Wyoming Supercomputing Center[10] in Cheyenne, Wyo. These visits continue a tradition of connecting mathematics students with leading scientific research centers across the Rocky Mountain region.

Kristina Moen is a Ph.D. student at Colorado State University (CSU), where she studies shape and texture in weather satellite imagery at the Cooperative Institute for Research in the Atmosphere. She served as president of the CSU SIAM Student Chapter in 2024-2025 and is the current liaison officer connecting SIAM students to other institutions.

[7] https://energy.colostate.edu/powerhouse/
[8] https://www.boulder.noaa.gov/
[9] https://www.nlr.gov/
[10] https://www.cisl.ucar.edu/ncar-wyoming-supercomputing-center

Members of Colorado State University (CSU) and the University of Colorado Boulder SIAM Student Chapters tour the National Center for Atmospheric Research in February 2026. Photo courtesy of the CSU SIAM Student Chapter.

University of Bath SIAM-IMA Student Chapter Hosts Postgraduate Conference

By Charlie Cameron

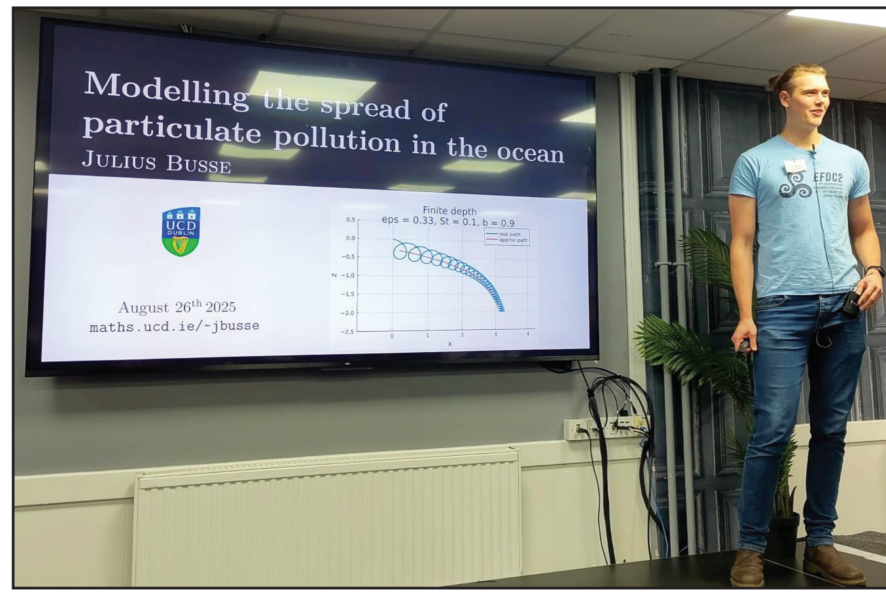
The University of Bath SIAM-IMA Student Chapter[1] recently organized its annual postgraduate conference,[2] which brought together graduate students from across the U.K. and Ireland to share their research and build connections within the applied mathematics community. The chapter—which is affiliated with both SIAM and the Institute of Mathematics and its Applications[3] (IMA)—aims to unite research groups and institutions across the region, providing valuable networking opportunities for Ph.D. candidates in all areas of applied math and computational science.

In late November, roughly 60 doctoral students gathered at the Engineers' House in Bristol, England, for a full day of presentations and discussion. The University of Bath SIAM-IMA Student Chapter—led by myself (president), John Carlo Dimaculangan (secretary), and Amin Sabir (treasurer)—worked closely with Ph.D. students from the University of Bristol in a collaborative organizational effort that yielded a well-organized, engaging, and enjoyable meeting.

The program, which included 10 student talks and two plenary lectures by Ph.D.-level mathematicians, reflected the range and diversity that characterize all SIAM events. Plenary speaker Rachel Bennett of the University of Bristol opened the conference with a presentation about the intricate mechanics of cilia, after which Eric Hester of the University of Bath discussed innovative approaches to model melting icebergs. Both plenary addresses sparked lively discussions amongst the audience.

Student talks spanned a wide range of topics, including fluid mechanics, network theory, epidemiological modeling, and radiation modeling. Julius Busse of the University College Dublin spoke about his efforts to model the transport of ocean-borne debris, Neha Bansal of Cardiff University explored disease spread across different network structures, and Michael Nguyen of the University College London shared numerical models of ocean currents. All of the presenters demonstrated a high quality of research and technical prowess while clearly communicating complex ideas to an interdisciplinary audience. Every student speaker also adhered to the strict 15-minute time limit, allowing ample time for questions and discussion.

One of the most valuable aspects of the conference was the opportunity for Ph.D. students to present their ongoing work beyond the confines of their immediate research groups, and many attendees appreciated the chance to receive feedback from peers in different scientific areas. This robust exchange of ideas was evident in the question-and-answer sessions after formal presentations, during informal conversations that continued throughout the breaks, and at the afternoon poster session.

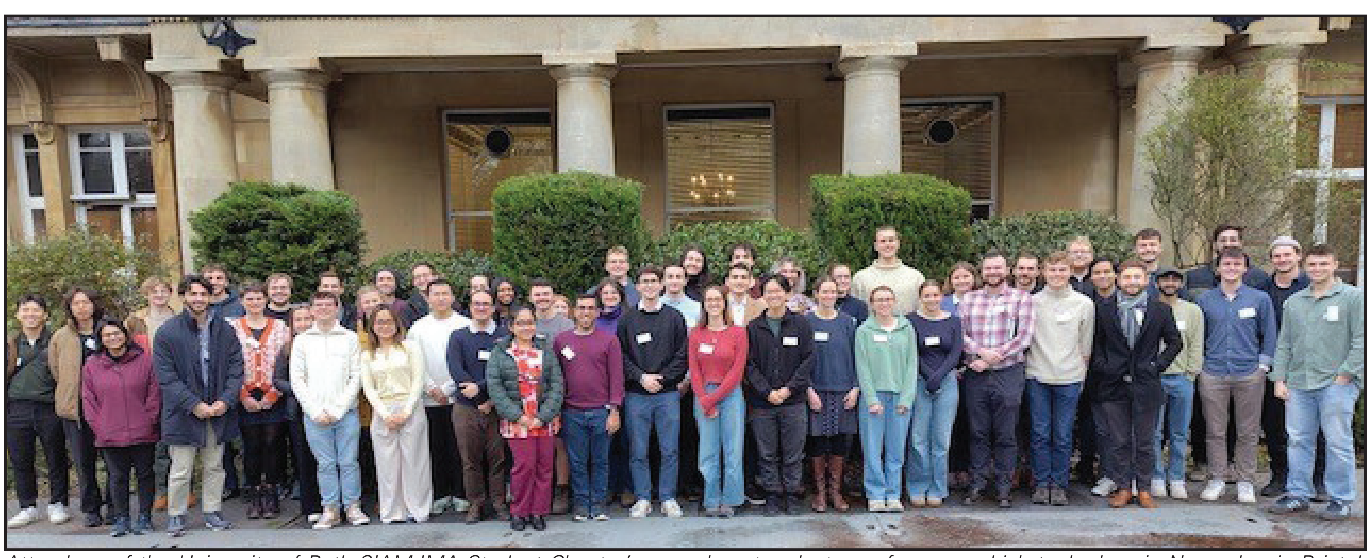


Student Julius Busse of the University College Dublin speaks about his work to model the transport of ocean-borne debris during the University of Bath SIAM-IMA Student Chapter's annual postgraduate conference, which was held in Bristol, England, in November. Photo courtesy of Vaishnudebi Dutta.

The interdisciplinary nature of the event's program highlighted the breadth of applied mathematics and computational science and created a supportive environment for intellectual cross-pollination. Students who are actively pursuing seemingly disparate problems—from ocean currents to disease networks—found common ground in shared mathematical approaches and numerical techniques, ultimately reinforcing the value of sustained connections between diverse research communities.

Building upon the success of this event, the University of Bath SIAM-IMA Student Chapter is planning additional activities to further strengthen collaborations within the applied math community. In particular, we hope to broaden participation by involving more undergraduate students and engaging with institutions that may have fewer opportunities to attend large research conferences.

The success of the daylong meeting would not have been possible without the generous support of SIAM—which provided essential funding—and the IMA, which continues to encourage the chapter's activities. Looking ahead, we remain committed to providing platforms for students to share their research and strengthening connections between student chapters and universities across the U.K.



Attendees of the University of Bath SIAM-IMA Student Chapter's annual postgraduate conference, which took place in November in Bristol, England, gather for a group photo. Photo courtesy of Vaishnudebi Dutta.

Charlie Cameron is a Ph.D. student in the Department of Mathematical Sciences at the University of Bath. He is president of the University of Bath SIAM-IMA Student Chapter.

1 https://bath-siam-ima.github.io
2 https://bath-siam-ima.github.io/events.html
3 https://ima.org.uk

Mathematical Greats

Continued from page 7

while the text addresses the continuum hypothesis at length (albeit inaccurately), it does not mention Gödel's 1938 proof that the hypothesis is consistent with ZFC, or Paul Cohen's 1964 proof that its negation is likewise consistent with ZFC.

Bardi offers detailed accounts of Russell's work on logic and math, which culminated in *Principia Mathematica* (coauthored with Alfred North Whitehead); his political activism in World War I and beyond; and his personal life up to and during the war. However, Russell's later great philosophical works—technical books such as *An Inquiry Into Meaning and Truth* and *Human Knowledge: Its Scope and Limits*, as well as popular titles like *Sceptical Essays, Unpopular Essays,* and *A History of Western Philosophy*—remain entirely unmentioned; Bardi does not even note them in the bibliography.

Additionally, Bardi twice apologizes for not including a longer account of Zermelo due to lack of space. In my opinion, more content about figures like Zermelo and less information on Lady Ottoline Morrell and the Boer War—two largely irrelevant topics that each get a chapter—would have improved the book.

Unwarranted Hostility

Bardi's writing exhibits over-the-top aggression at several points, the most conspicuous of which is his account of Wittgenstein. There is no denying that Wittgenstein was somewhere between difficult and impossible in his personal relations, and legitimate differences of opinions exist as to the value of his philosophies. However, passages like the following seem entirely unfair:

> [Wittgenstein] is a compositional lazybones, to begin with. With the possible exception of E.E. Cummings, never has any writer in history become more famous with fewer words. Some would apologize for this by insisting that Wittgenstein is a perfectionist. But I say, hooey. With Wittgenstein, the perfect is not just the enemy of the good. The perfect is a psychopath who grabs the good by the throat, throttles the good into silence, and slowly chokes the good's life away while laughing and eating good's dinner. Wittgenstein and Russell are fundamentally different in this regard. Russell is a verbal fire hose of helpful tonic. Wittgenstein is a fickle trickle of foul poison. His work is confusing, difficult, unapproachable, and reminiscent of Thomas Hobbes' view of humanity — *nasty, brutish, and short.*

This sentiment is not only defamatory toward Wittgenstein but entirely unfair to Cummings, whose collected poems form a volume of more than 1,000 pages. It also misrepresents the subject of Hobbes' famous quotation.

Writing Style

While personal tastes may differ, I am not a fan of Bardi's writing style. He writes almost entirely in the historical present, with a lot of "chatty" verbiage, quasi-poetical wordings, extended metaphors, and corny plays on words. The aforementioned quote about Wittgenstein is one example, as is the following passage:

> For Brouwer, finding a new mathematical proof should be like feeling your way through an unfamiliar landscape in the dark. You stumble here. You touch the squishy ground there. You find a place where the mud hides a sunken plank, like those mucky duckwalks in the trenches on the Western Front. You walk. Stay low. Have no idea where to go but keep going. See where the path leads you. Step by step. Squish by squish. Across the gooey mess.

When Bardi occasionally stops this literary posturing and writes simple narrative prose in the past tense, it comes as a huge relief:

> My father had just started graduate school in Ohio then [in 1969]. Vietnam protests were in full swing, and like so many in their generation, my parents were part of the antiwar movement. My father had stirred controversy on his undergrad campus some months before by writing an antiwar editorial as editor-in-chief of his college paper. A number of students on campus objected to his essay and organized a protest calling for him to step down. My dad defied the call and attended his own protest.

Final Thoughts

All that said, I did find some value in *The Great Math War.* In particular, it provided me with a much clearer idea of Brouwer and Weyl and their interactions with Hilbert. Unfortunately, in light of the many errors in Bardi's book and its slanted viewpoints, I can't be confident that I have the correct idea — either in general terms or of specific facts.

Ultimately, I would not recommend *The Great Math War* for the general lay reader. Someone who has a basic knowledge of the development of mathematical foundations and wishes to delve more deeply into the corresponding debates and fights may find it useful; however, they should be very cautious of accepting Bardi's viewpoint and should carefully check any fact before disseminating it further.

References

[1] Russell, B. (1967). *Bertrand Russell: Autobiography*. London, U.K.: George Allen & Unwin.

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

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Upcoming Deadlines

siam 2026

SIAM Conference on Nonlinear Waves and Coherent Structures (NWCS26)

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HOTEL AND TRANSPORTATION INFORMATION
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siam.org/op26 | #SIAMOP26

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HOTEL AND TRANSPORTATION INFORMATION
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The following conferences will be held jointly:

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June 2–5, 2026
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SIAM Conference on Discrete Mathematics
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SIAM Conference on Mathematics of Planet Earth
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November 16–19, 2026
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November 19–20, 2026
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All prizes listed below will be awarded at the 2027 SIAM Conference on Applied and Computational Discrete Algorithms (ACDA27) and 2027 SIAM Conference on Computational Science & Engineering (CSE27), scheduled to be held jointly in Pittsburgh, Pennsylvania, U.S. This will be the first time that the Nicholas J. Higham Prize will be awarded.

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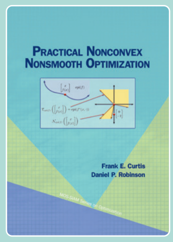

Frank E. Curtis and Daniel P. Robinson

This book provides a clear and accessible introduction to an important class of problems in mathematical optimization: those involving continuous functions that may be nonconvex, nonsmooth, or both. The authors begin with an intuitive treatment of theoretical foundations, including properties of nonconvex and nonsmooth functions and conditions for optimality. They then offer a broad overview of the most effective and efficient algorithms for solving such problems, with a focus on practical applications in areas such as control systems, signal processing, and data science. This book focuses on problems in finite-dimensional real-vector spaces and introduces concepts through nonconvex smooth optimization, making the material more accessible.

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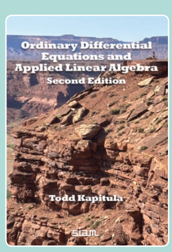

Todd Kapitula

This book helps students master linear algebra and ODEs in a one-semester course. The second edition of Ordinary Differential Equations and Applied Linear Algebra expands the learning experience by introducing case studies at the end of every chapter that examine SIR models, a model for lead poisoning, and the dynamics of strongly damped forced oscillators, among others. It adds end-of-chapter projects that allow students to explore the interplay between the creation of a mathematical model, the solution of the model, and the physical implications of the mathematical solution. Also new to the second edition is access to over 300 online homework problems embedded within the CMS *myOpenMath*.

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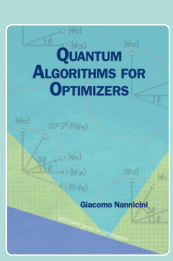

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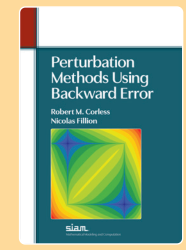

Robert M. Corless and Nicolas Fillion

Perturbation methods are old but powerful, and they remain in widespread use. Rather than producing numbers or pictures, they yield formulas whose value depends on the skill of the person (or machine!) interpreting them. This unique book presents several classical methods for solving perturbation problems. To ensure a uniform presentation and more reliable, interpretable results, it consistently uses backward error analysis. This provides a systematic way to assess the validity of approximate solutions while encouraging the modeler to examine how small changes in the data or model affect the result. To support this, the book uses the concept of a condition number, familiar from numerical analysis.

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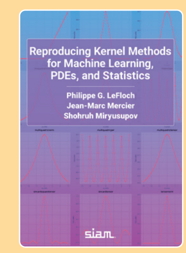

Philippe G. LeFloch, Jean-Marc Mercier, Shohruh Miryusupov

This monograph develops a unified, application-driven framework for kernel methods grounded in reproducing kernel Hilbert spaces and optimal transport. The primary goal is to tackle industrial cases from computational physics and mathematical finance and discuss applications across various areas, such as statistics, or artificial intelligence (physics-informed systems, reinforcement learning, machine learning, generative methods, etc.). This book is divided into two parts, theoretical principles and the techniques employed in their applications; contains numerous applications in engineering, finance, and machine learning; and provides a framework for designing numerically efficient, large-scale dataset strategies.

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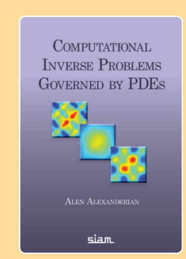

Alen Alexanderian

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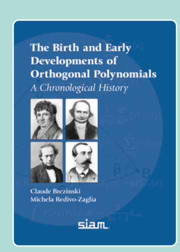

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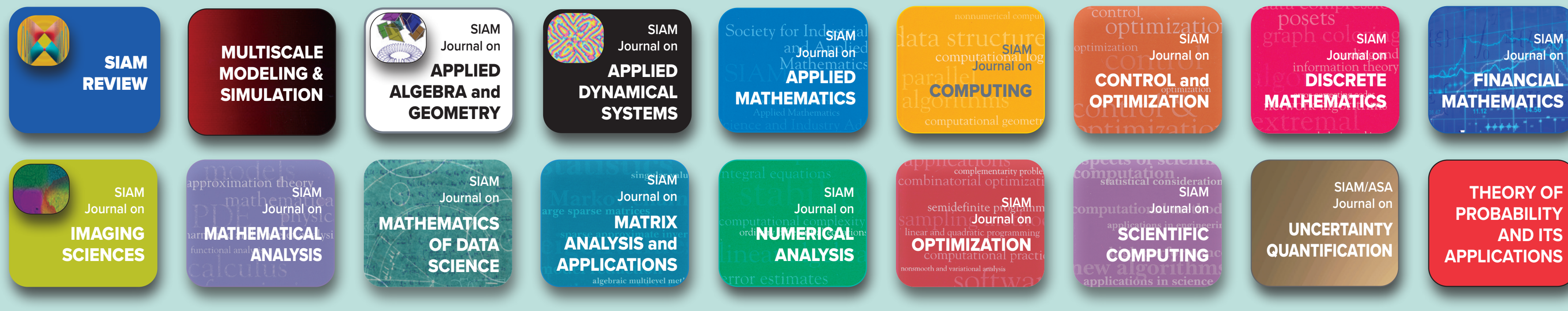

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