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The Cognitive Origins of Human Abstract Geometry

By Moira R. Dillon

Philosophers throughout history have debated the relation between the *abstract geometry* in our unique human minds and the *physical geometry* in the world that humans share with other animals. Unlike other creatures, humans can conceive of abstract spatial entities—like infinitely small points and never-ending lines—regardless of culture or formal education [6]. These concepts help students learn formal geometry, such as Euclidean geometry. As with other animals, humans also intuitively interact with geometry in everyday life to navigate places and recognize objects. Are uniquely human abstract geometric concepts—like infinitesimal points and lines—rooted in evolutionarily ancient, everyday, and spatially finite experiences of places and objects? What are the cognitive origins of abstract geometry?

Two proposals address this question by appealing to the everyday spatial experiences that we share with other animals. One idea—based on decades of research in the psychological, cognitive, and neural sciences—suggests that the mental representations that support our everyday interactions with places and objects are not as unitary as they may seem. For example, seminal work on the search behavior of disoriented animals—from fish and chickens to rats and humans—has found that when humans and other animals navigate simple rectangular environments, they tend to keep track of only the distances and directions of the environment's boundaries [1, 5] (see Figure 1). In contrast, when they recognize objects, how far away an object is or what direction it is facing is less important than whether it has the right shape [9]. Facilitated by the combinatorial capacities of uniquely human symbol systems like language and pictures, the complementary geometries of these two foundational systems for navigation and object recognition may merge in every human's development to support an intuitive natural geometry that combines distance, direction, and shape. This natural geometry allows us to comprehend abstract geometry and learn Euclidean geometry [10].

A related proposal for the cognitive origins of abstract geometry suggests that noisy, dynamic mental simulations of navigation—akin to a correlated random walk of a navigating insect—approximate Euclidean principles and ground abstract geometric reasoning. A series of behavioral experiments with children and adults suggest that by late childhood, humans can visualize planar figures like triangles and reason about these figures' Euclidean properties (e.g., the fact that a triangle's angle sizes sum to a constant) using dynamic mental simulations that can be modeled as a correlated random walk [3] (see Figure 2, on page 4). For example, when children and adults are shown the bottom two corners of a series of fragmented planar triangles, they can intuitively estimate the locations of the triangles' missing third corners. The slope of the log of the standard deviation of these estimates can then be calculated as a function of the log of triangle side length. This slope, or *scaling exponent*, is equivalent to the power law by which the standard deviation of localization estimates scales with triangle side length. The scaling exponent represents the global correction of the local noise that is associated with maintaining smooth motion in the direction of the given angle sizes:

See **Abstract Geometry** *on page 4*

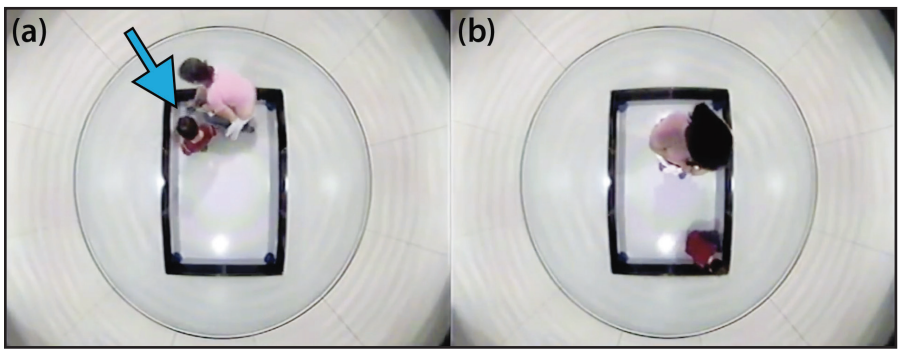

Figure 1. *Young children who are disoriented in a rectangular environment use the environment's distance and directional information to regain their heading.* **1a.** *A young child is shown a sticker that is hidden under a disk at one of the rectangle's corners (indicated by the blue arrow). The child is then blindfolded and slowly spun in the center of the environment to disorient them. When the blindfold is removed, the disoriented child is asked to find the sticker. The child is likely to search either in the correct corner of the rectangular environment or the geometrically equivalent, diagonally opposite corner.* **1b.** *Children intuitively go to the left of a far wall. Non-human animals also exhibit this same use of distance and directional information to regain their heading. Figure courtesy of [7].*

SIAM Engages Young Minds at the 2023 New York City Math Festival

By Manuchehr Aminian, Tim Chartier, and Wesley Hamilton

On July 15th, the National Museum of Mathematics[1] (MoMath) hosted the seventh annual iteration of its highly popular New York City (NYC) Math Festival.[2] During this free daylong event—which brings MoMath's hands-on exhibits and entertaining mathematical games, puzzles, and brain teasers to an outdoor setting—the SIAM Education Committee[3] sponsored a booth that featured two activities with an applied mathematical bent. Manuchehr Aminian (California State Polytechnic University, Pomona) and Wesley Hamilton (MathWorks) collaborated with Tim Chartier (Davidson College and Distinguished Visiting Professor at MoMath) to organize these exhibits. They received generous assistance from the following volunteers of local SIAM student chapters:[4] Kate Knyazeva and Amrit Parmar (Montclair State University) and Rachael Park, Anastasia Polina, and Jerry Yao (New York University).

MoMath is the premier North American cultural institution that focuses on the wonders of mathematics and its many connections to the real world. It houses more than 40 interactive exhibits and has welcomed over 1.2 million visitors since opening in December 2012. The 2023 NYC Math Festival featured MoMath's iconic 120-foot number line; mathematical juggler John Chase (Walter Johnson High School); mathematical mimes Tim and Tanya Chartier; an outpost of MoMath's shop, *Additions*, which sold mathematical books and activities; and much more.

To complement MoMath's numerous displays, various groups with a passion for popularizing math hosted their own booths. In addition to SIAM, these organizations included the Julia Robinson Mathematics Festival;[5] New York University's Lab for the Developing Mind;[6] and the award-winning robotics team[7] at Stuyvesant High School, which displayed a competitive ball-throwing robot called Excelsior.[8]

One of the activities at SIAM's booth explored the Monty Hall problem — a famously misunderstood conditional probability scenario based on the U.S. game show *Let's Make a Deal*. During the television show, a contestant is presented with three closed doors; behind one of these doors is a car, and behind the other two are live goats. When the contestant selects a door, the host opens another door to reveal a goat. The contestant can then choose to stick with their original choice or switch to the remaining unknown door; unintuitively, changing their pick gives them a 2/3 probability of winning the car (versus a 1/3 probability when staying with the original door). At the festival, we helped attendees partake in Monty Hall simulations with toy goats and cars and kept a running tally of their choices and results throughout the day. Aside from traditional explanations of conditional probability, visualizing the statistics helped participants gain a "frequentist" perspective on the logic of switching doors.

See **Math Festival** *on page 3*

[1] https://momath.org
[2] https://momath.org/nyc-math-festival
[3] https://www.siam.org/about-siam/committees/education-committee
[4] https://www.siam.org/students-education/student-chapters
[5] https://jrmf.org
[6] https://www.labdevelopingmind.com
[7] https://stuypulse.com
[8] https://stuypulse.com/about/history/2022

SIAM volunteers gather at the 2023 New York City Math Festival, which was hosted by the National Museum of Mathematics (MoMath) on July 15. From left to right: Amrit Parmar (Montclair State University), Jerry Yao (New York University), Manuchehr Aminian (California State Polytechnic University, Pomona), Wesley Hamilton (MathWorks), Anastasia Polina (New York University), Kate Knyazeva (Montclair State University), and Tim Chartier (Davidson College and Distinguished Visiting Professor at MoMath). Volunteer Rachael Park (New York University) is not pictured. Photo courtesy of Tim Chartier.

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A Bifurcation in Moore's Law?

By Nick Trefethen

LETTER TO THE EDITOR

According to the TOP500 list,[1] the speed of the world's fastest computer has increased over the past 25 years from 10^{12} to 10^{18} flops — from teraflops to exaflops, or six orders of magnitude.

What about the desktop machine that I actually use? It's gone from around 10^8 to 10^{11} flops. For example, the computation that was originally reported to take one second on page 178 of *Numerical Linear Algebra* [1] now takes me half a millisecond. That's just three orders of magnitude.

It would seem that some kind of Moore's law bifurcation is taking place between the ordinary and the high end of computing. Computational scientists talk exaflops, but most of us are living teraflops.

The hardware basis of the bifurcation is clear: the top machines have thousands or even millions of processors, and most of us don't work in that mode. But I'm more interested in the scientific and sociological aspects. Throughout my career as a numerical analyst, I've had the sense that although many of us don't use the top machines, that kind of computing was our ultimate motivation. Now I'm not so sure. High-performance computing is certainly indispensable in some applications, but is it becoming a less accurate model of the heart of computational science?

I mentioned these thoughts during a recent "26 years at Oxford" valedictory talk to the Numerical Analysis Group at the University of Oxford. I showed the plot in Figure 1 and asked, "How many of you are playing the high-performance game?" Just one person raised their hand out of roughly 60 attendees. I'm guessing that more hands might have gone up in an American audience, but still a small number.

If others have thoughts about this trend, I'd be glad to hear from you.

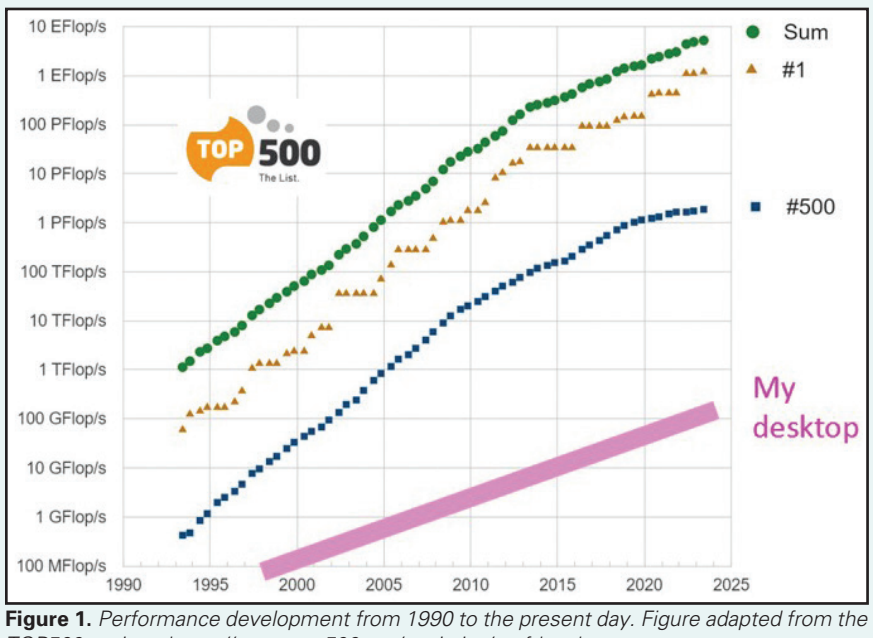

Figure 1. *Performance development from 1990 to the present day. Figure adapted from the TOP500 project: https://www.top500.org/statistics/perfdevel.*

[1] https://www.top500.org/lists/top500/2023/06

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Nick Trefethen is a professor of applied mathematics in residence at Harvard University, prior to which he was a professor of numerical analysis at the University of Oxford. He served as president of SIAM during 2011-2012.

CT23 Panel Explores Future Directions of Applied Mathematics and Control Theory

By Lina Sorg

Though applications of control theory were initially limited to process regulation for engineering and the physical sciences, concepts from this field now contribute directly to computer science, biology, and the social sciences. In recent years, the utilization of control theory has continued to expand to automotive systems, aerospace engineering, energy systems, nanotechnology, cellular regulation, and even the smart grid. During an interactive discussion[1] at the 2023 SIAM Conference on Control and Its Applications,[2] which took place in Philadelphia, Pa., this July, six panelists shared their thoughts on the future of applied mathematics and control. Eduardo Casas (Universidad de Cantabria), Eduardo Cerpa (Pontificia Universidad Católica de Chile), Hélène Frankowska (Sorbonne Université and CNRS), Sonia Martinez (University of California, San Diego), Robert McCann (University of Toronto), and Benedetto Piccoli (Rutgers University) all contributed to an insightful dialogue about the potential directions of these disciplines.

Casas opened the conversation by affirming that control theory still boasts plenty of interesting open problems. He noted that researchers in the 1960s originally focused on control problems with linear partial differential equations (PDEs), whereas present-day practitioners primarily investigate the control of nonlinear PDE systems — which are more complicated. "As science evolves, the models become more complex," Casas said. "They are going to introduce many new open questions, so we need to develop methods and ideas in both control and applied mathematics."

Frankowska echoed Casas' comments, adding that numerous questions still remain from the 1960s. In light of the intricacy of current problems, she spoke about the value of straightforward models that allow researchers to quickly propose efficient solutions. Frankowska also touched on the importance of teamwork, since many control problems require input from engineers, doctors, and experts in other domains.

Piccoli agreed with Frankowska's remarks on the necessity of interdisciplinary partnerships. As scientists explore novel ideas and tackle issues with higher levels of complexity and dimensionality, the nature of research and collaboration must change accordingly. In general, groups that embody a wide variety of skillsets can more successfully address problems at larger scales. "What you see happening is that you're moving from the single person to team science in many different terms," Piccoli said. "We are a group of people with different expertise, and we are exchanging ideas to progress our own opinions."

Martinez concurred with the need for multidisciplinary approaches that yield novel techniques for complex systems, and specifically identified data science as an influential field with potential opportunities for control and other applied math subsets. "We now live in a world of data science, and we can contribute a lot to this literature as applied mathematicians," she said. "The tools that we work with—such as stochastic systems and differential equations—are going to lead to algorithms that are tractable and can learn and provide solutions to these complex systems, which will be very useful."

McCann, who considers himself to be both a pure and applied mathematician, brought an alternative perspective to the discussion. "It's exciting to see the progress that technology brings, but also the basic insights that pure math was able to offer before the technology was accessible," he said. He touted the existing space for creative insight in the control domain but expressed some apprehension about the influence of artificial intelligence (AI). "Human understanding is really important," McCann continued. "Humans are very interested in the question of 'why.' I don't care if the machine understands, I'm not satisfied until humans understand too. I love using mathematics to tell stories and I think that there is a boundless future as long as we don't allow machines to take over from us."

See **CT23 Panel** *on page 5*

[1] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=77869

[2] https://www.siam.org/conferences/cm/conference/ct23

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Reflecting on and Reinventing SIAM Conferences

By James Nagy and Sven Leyffer

Since more of the world has emerged from the COVID-19 pandemic, we felt that now is a good time to reflect on the past three years of conferences, share our experiences, and outline SIAM's developing plans for 2024 and beyond. The stress, heartache, and overall impact of the pandemic cannot be overstated, even as memories of school and workplace shutdowns, stay-at-home ordinances, and supply chain breakdowns begin to fade. We are tremendously grateful to SIAM's members and volunteers for their amazing adaptability, patience, and continued engagement with our conferences and community during these challenging times. We thank the conference co-chairs and organizing committees that persevered to hold and execute meetings in previously unexplored formats, as well as the SIAM staff who worked relentlessly (and mostly behind the scenes) to find solutions for the many technological challenges that were associated with virtual and hybrid conferences. Their combined efforts ensured that SIAM's conference program remained a strong focal point for the applied math community throughout the pandemic.

The planning process for each SIAM conference begins about two years before the meeting's scheduled date and involves a lot of decision-making, from selecting and contracting the site to choosing the organizing committee and identifying invited speakers. The rapidly changing and unpredictable nature of COVID-19 complicated all of these steps. At the pandemic's onset in the U.S. in early 2020, SIAM pivoted to a completely virtual format and waived all registration fees for its remaining 2020 conferences — despite potential financial losses due to staff costs and canceled hotel contracts. When it quickly became clear that the lockdowns would continue, SIAM's Conferences Department—under the leadership of Richard Moore, Director of Programs and Services at SIAM—worked tirelessly to develop more sophisticated virtual platform options for the 2021 meetings. In late 2021, we had to face the reality of future surges in COVID-19 variants and enduring travel uncertainties. SIAM therefore decided that all 2022 U.S.-based SIAM conferences would take place in a fully hybrid format (excluding SIAM section meetings) to allow for a more seamless transition to online-only configurations if necessary. This agile approach turned out to be an excellent decision; when the Omicron variant struck in early 2022 and other professional organizations were forced to postpone their in-person events, we continued to hold our meetings. Unfortunately, the fully hybrid model is not financially sustainable in the long term because it almost doubles operating costs (due to additional technical support requirements at the conference venue) without increasing revenue.

Feedback from the SIAM community on the hybrid conferences in 2022 was mixed. While the hybrid model provided much-needed flexibility during uncertain times, in-person participants felt that the large number of virtual talks diminished the energy of the physical conference, significantly reduced the chance for impromptu discussion, and limited networking opportunities for students and postdoctoral researchers. As a result of both these comments and the additional costs of hybrid meetings, SIAM decided to return to fully in-person conferences in 2023 and take time to consider feasible format options for 2024 and beyond.

We recognize that many factors might prevent individuals from attending a SIAM conference in person, such as family obligations, visa restrictions, financial considerations, carbon footprint concerns, and illness. As such, we believe that the implementation of virtual options is critically important. Over the next few years, SIAM will continue to innovate and iteratively refine our approach to conferences.[1] Our goal is to develop a model that preserves the energy of in-person activities, minimizes uncertainties, and offers some engagement opportunities for those who cannot travel. SIAM is not alone in this effort; plans for the 2027 International Congress on Industrial and Applied Mathematics,[2] which will take place in the Netherlands, include live broadcasts of a small number of sessions for mathematicians who are unable to physically attend the meeting.

Again, we are incredibly grateful to the dedicated SIAM volunteer community and staff. We are honored to work with all of you and feel enormously proud of SIAM's adaptability throughout the pandemic. The Society is well positioned to lead the way for professional organizations that are engaging a broad community in their conferences and educational activities, and we look forward to working with you—our members—to make this a reality. Please send your suggestions and comments on current and future SIAM conferences to us at **jnagy@emory.edu** or **leyffer@anl.gov**.

SIAM conferences and events have experienced major shifts in format over the last several years due to the COVID-19 pandemic. On the left, attendees of a SIAM activity group webinar network via Zoom. On the right, audience members at the fully in-person 2023 SIAM Conference on Applications of Dynamical Systems—which took place in Portland, Ore., this May—listen to Nicole Abaid of Virginia Tech deliver an invited presentation about models of collective motion. SIAM photos.

James Nagy is a Samuel Candler Dobbs Professor and chair of the Department of Mathematics at Emory University. He is also SIAM's Vice President for Programs. Nagy's research focuses on numerical linear algebra, structured matrix computations, numerical solution of inverse problems, and image processing. Sven Leyffer is a senior computational mathematician at Argonne National Laboratory and the current President of SIAM. He holds a Ph.D. from the University of Dundee in Scotland and works on nonlinear and mixed-integer optimization problems.

[1] An article on page 11 of this issue recaps a panel discussion about the future of academic conferences at the 2023 SIAM Conference on Applications of Dynamical Systems.

[2] https://iciam.org/news/22/1/11/hague-site-iciam-2027

Math Festival

Continued from page 1

SIAM's second exhibit featured nonograms — a Japanese logic puzzle that is similar to Sudoku or Minesweeper, where players must use given information to fill in the pixels of a two-dimensional black and white image by row and column (see Figure 1). Nonograms are somewhat like X-ray computed tomography, in that the puzzle's numbers indicate what the X-rays "detect" within a medium; the player then has to piece together the original image. Booth volunteers guided participants through basic nonogram strategies—such as edge-case analysis and overlapping runs—and discussed their connection to medical imaging and inverse problems.

The 2023 NYC Math Festival was an enriching experience for curious students, parents, and volunteers alike. SIAM volunteer Jerry Yao particularly appreciated the way in which children and parents worked together on the games and puzzles. "The most rewarding thing for me was seeing so many families value education for their children," Yao said. "It was interesting to see children confused by certain problems—like I used to be—and then gradually understand what was going on after we explained the math."

In addition to engaging young minds, the festival also united students from different universities who share a passion for applied math and outreach. "For me personally, this was the first time I had an opportunity to connect with my SIAM peers outside of our own chapter at Montclair State University," SIAM volunteer Kate Knyazeva said. "I'm grateful for festivals like this for allowing me to be part of a beautiful equation of passion, purpose, and community."

One of the SIAM Education Committee's broader goals is to provide SIAM members and student chapters with support for interacting with their local communities. As such, the committee is packaging, polishing, and sharing the two activities from the SIAM booth as part of a "festival in a box." SIAM members are welcome to submit their own tried-and-true resources to the SIAM Education Committee by contacting Wesley Hamilton at **whamilto@mathworks.com**. These submissions will then become available to all SIAM student chapters and members who are planning to partake in and contribute to future events.

Despite the blistering heat and humidity, the 2023 NYC Math Festival was a phenomenal success. SIAM looks forward to participating again in 2024!

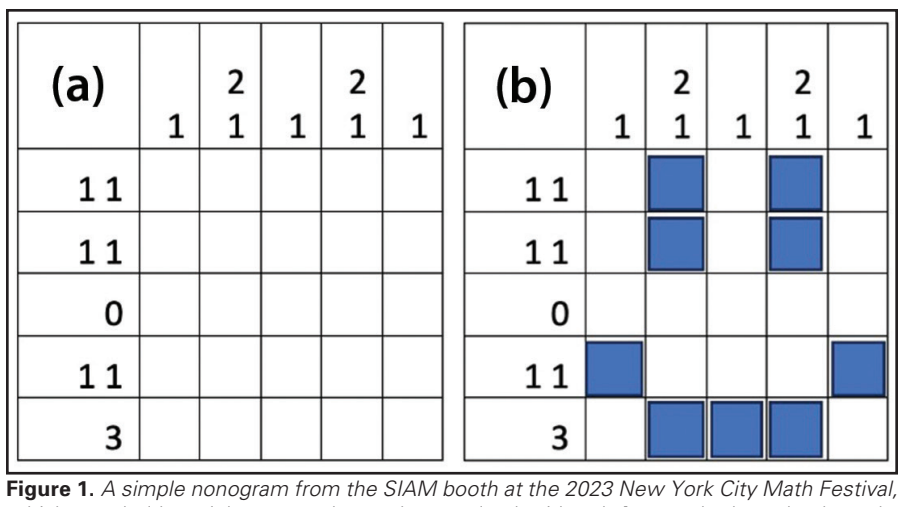

Figure 1. *A simple nonogram from the SIAM booth at the 2023 New York City Math Festival, which was held on July 15.* **1a** *shows the unsolved grid and* **1b** *reveals the solved puzzle. The digits along the left and top of the grid indicate the number of contiguous boxes that the solver must fill in the corresponding row or column. For instance, the notation "2 1" indicates that the row or column has two contiguous filled boxes, some amount of blank space, and then one filled box. Figure courtesy of Wesley Hamilton.*

SIAM volunteer Anastasia Polina (New York University) uses toy goats and cars to explain the Monty Hall problem to attendees of the New York City Math Festival, which took place on July 15. The SIAM Education Committee sponsored a booth at the festival that featured two interactive math-based activities. Photo courtesy of Manuchehr Aminian.

Manuchehr Aminian is an assistant professor in the Department of Mathematics and Statistics at California State Polytechnic University, Pomona. His research interests include mathematical modeling, partial differential equations, and mathematical methods in data science. Tim Chartier is the 2022-23 Distinguished Visiting Professor at the National Museum of Mathematics and the Joseph R. Morton Professor of Mathematics and Computer Science at Davidson College. He received an Alfred P. Sloan Research Fellowship and a national teaching award from the Mathematical Association of America. Wesley Hamilton works at MathWorks on STEM outreach and workforce development initiatives, prior to which he was a Wylie Assistant Professor at the University of Utah. He also serves on the SIAM Education Committee.

Copper Mountain Conferences: A Long History and a Bright Future

By Susanne C. Brenner, Robert D. Falgout, and Scott P. MacLachlan

2023 marks 40 years since the first instance of the Copper Mountain Conferences on Iterative and Multigrid Methods,[1] which take place annually at Copper Mountain, Colo. This conference series has become a fixture in the iterative and multigrid methods research communities and is known for its friendly atmosphere, high-quality program of interesting talks, and opportunities for a bit of skiing on the side. The meeting upholds many longstanding traditions, beginning with tutorials on day one that introduce first-time attendees (who might not be as familiar with the field) to the methods and jargon that await them throughout the week. A typical day starts with early-morning talks and proceeds with parallel sessions until midday (there are no plenary speakers). A lengthy lunch break allows time for skiing, networking, and research discussions with colleagues; additional talks then commence in the evening.

[1] https://grandmaster.colorado.edu/copper

Steve McCormick and Ulrich Trottenberg organized the first of these gatherings at Copper Mountain from April 5 to 8, 1983. This inaugural meeting focused on multigrid methods (it was advertised as an "International Multigrid Conference") and attracted 80 attendees. Given its success, the organizers held subsequent multigrid conferences in 1985, 1987, and 1989. The iterative methods conference then joined the lineup in 1990. Moving forward, the series was hosted annually in an alternating fashion—with multigrid methods in odd-numbered years and iterative methods in even years—until the COVID-19 pandemic forced its cancellation in 2020. The conferences convened virtually in 2021 and 2022, and the 21st Copper Mountain Conference on Multigrid Methods[2]—which took place from April 16 to 20, 2023—marked the meeting's return to its traditional in-person format. The 2023 rendition was the 20th multigrid conference to occur in person and the 37th meeting of the joint series.

[2] https://grandmaster.colorado.edu/copper/2023

Student participation is a key element of both the iterative and multigrid conferences. At the in-person meetings over the past decade, students comprised nearly 40 percent of the total attendees. Remarkably, more than 30 percent of these students hailed from institutions outside of the U.S. The unique format of the Copper Mountain Conferences aims to place students on

See **Copper Mountain** *on page 7*

Program committee members of the 2023 Copper Mountain Conference on Multigrid Methods, which took place in April, gather for a group photo. From left to right: Tom Manteuffel, Kirk Jordan, Hans De Sterck, Ulrike Meier Yang, Eric Cyr, Robert Falgout, John Ruge, Scott MacLachlan, David Moulton, Susanne Brenner, Jacob Schroder, James Adler, Luke Olson, and John Shadid. Photo courtesy of Susanne Brenner.

Abstract Geometry

Continued from page 1

$$d^2\theta/dt^2 = 1/\tau(1/\xi(\theta-\theta_0)- d\theta/dt)+\eta(t) \quad (1)$$

$$dx/dt = v_p\cos(\theta) \quad (2)$$

$$dy/dt = v_p\sin(\theta). \quad (3)$$

Overall, this proposal suggests that our reasoning—consistent with Euclidean geometry—may emerge in every human's development when children begin to adopt this mental simulation strategy in response to novel questions about planar figures. Ultimately, this strategy might underlie our intuitive grasp of abstract geometry and facilitate our capacity to learn Euclidean geometry [3, 4].

Our work supports elements of both of these proposals. In a recent experiment, we investigated whether educated adults' representations of abstract points and lines reflect the foundational geometry that humans and other animals use for navigation and object recognition (see Figure 3). Consistent with the first proposal, we found that representations of distance and direction for navigation—as well as shape for object recognition—are still present and active in the minds of human adults; in fact, they are even individually accessible through simple and minimally contrastive language that describes the very same simple planar figures [8]. And consistent with the second proposal, we discovered that a verbal description of a navigating agent uniquely elicits the same geometric information (e.g., distance and direction for navigation) as a verbal description of abstract points and lines. This latter finding suggests an intimate link between uniquely human abstract geometric intuitions and the specific geometric intuitions that we and other animals call upon in navigational contexts; we wander the abstract Euclidean plane like we wander the physical world [8].

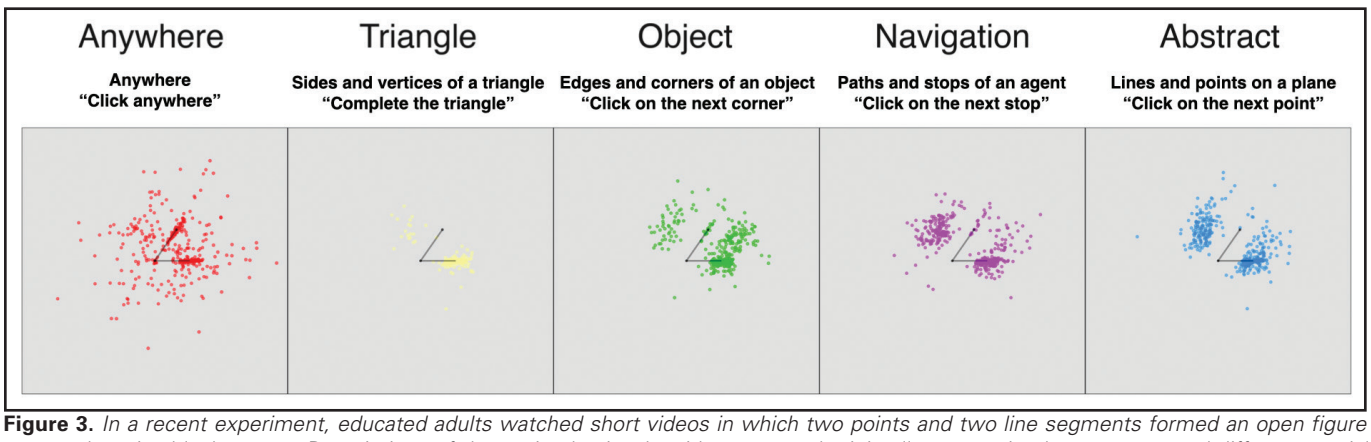

Figure 3. *In a recent experiment, educated adults watched short videos in which two points and two line segments formed an open figure on an otherwise blank screen. Descriptions of these simple visuals with sparse and minimally contrasting language created different spatial contexts. After watching each video, participants had to click on the screen as indicated by the following prompts: anywhere (**anywhere** condition); to complete the triangle (**triangle** condition); on the next corner of the object (**object** condition); on the next stop on the agent's path (**navigation** condition); or on the next point on the abstract plane (**abstract** condition). Participants produced strikingly different sets of geometric representations across spatial contexts. In particular, they tended to preserve distance and direction for open paths in the **navigation** condition but maintain length and angle for closed shapes in the **object** condition. The elicited geometry was nevertheless remarkably similar across the **navigation** and **abstract** conditions. Figure adapted from [8].*

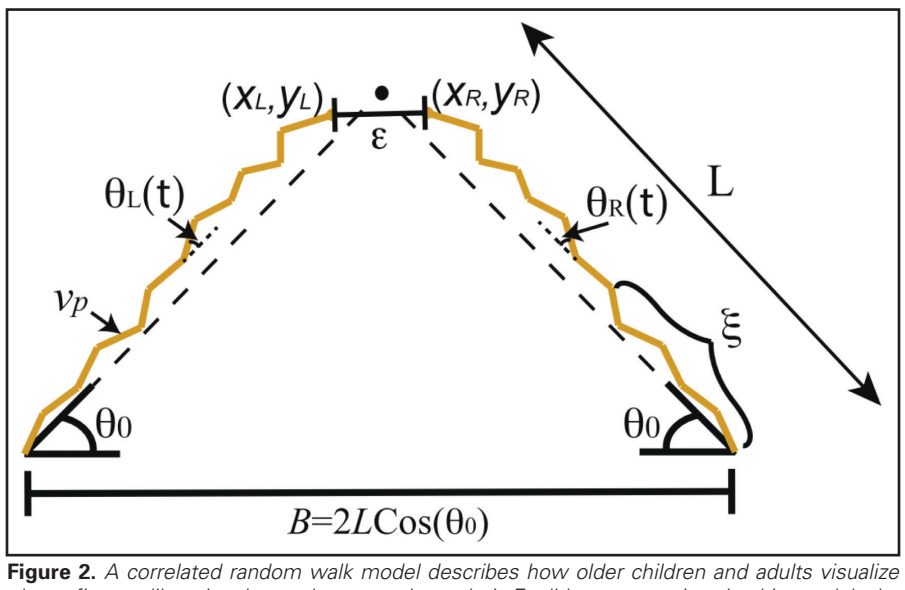

Figure 2. *A correlated random walk model describes how older children and adults visualize planar figures like triangles and reason about their Euclidean properties. In this model, the local angle evolves with accompanying noise as the triangle's side is extrapolated. The model parameters are as follows: an inertial relaxation timescale τ for local smoothness; a characteristic speed v_p with which the coordinates progress; a timescale ξ for global error correction (illustrated as the number of segments between error-correction events); and a noise term $\eta(t)$ with noise amplitude $D\langle\eta(t)\eta(t')\rangle = D\delta(t-t')$ (not shown in the figure). The stopping threshold is denoted by ε, and the base angle is denoted by θ_0. The right and left extrapolations are simulated independently and are not necessarily symmetrical. Figure adapted from [3].*

The relation of our recent findings to theories about the origins of human abstract geometry has implications for the development of geometry pedagogy and other educational approaches. The use of navigational frameworks to teach abstract geometry might better serve mathematics instruction [2], but lessons should also account for the ways in which an individual's navigational experiences may affect their capacity for learning. Future experiments could examine the specific properties of navigation that might support the acquisition of foundational Euclidean concepts of linearity, parallelism, perpendicularity, and symmetry. If our explorations of abstract geometry often rely on spatial navigation, then the worlds in which we live and think coincide in ways that we can ultimately enhance to encourage more students to investigate the domains of geometry.

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Moira R. Dillon is an assistant professor of psychology at New York University and director of the Lab for the Developing Mind. She uses cognitive, developmental, and computational approaches to gain insight into the origin and development of uniquely human cognition — from the basic sensitivities of infants to children's untutored use of symbols and language to the high-level concepts of adults.

Hidden Figures Revealed: Black Math History at The Ohio State University

By Ranthony A.C. Edmonds, Katherine Lovelace, and Hannah McDavid

In 2021, an interdisciplinary team at The Ohio State University (OSU) received a $50,000 racial justice seed grant to study the history of Black mathematicians at the institution. The resulting project—titled "Hidden Figures Revealed: Dynamic Narratives and History of Black Mathematicians from The Ohio State University"[1]—aimed to utilize storytelling to address the lack of representation of Black faculty-level academics in mathematics. Nearly 200 mathematicians who identify as Black have earned degrees from the Department of Mathematics at OSU. These alumni have gone on to become prolific researchers, high school teachers, authors, economists, department chairs, lawyers, and university presidents; yet despite their successes, nearly all of them remain "hidden figures."

Principal investigator Ranthony A.C. Edmonds—a 2022 MGB-SIAM Early Career Fellow[2]—led the team, which consisted of six OSU faculty and staff members and 10 undergraduate student fellows from OSU and Central State University, a historically Black college in Wilberforce, Ohio. Community partners included the Ohio History Connection's[3] National Afro-American Museum and Cultural Center[4] and the Math Alliance,[5] an organization that seeks to increase the number of doctoral degrees earned by traditionally underrepresented students in the mathematical sciences.

The undergraduate communication fellows created alumni profiles[6] and conducted historical research on key time periods in OSU history. Meanwhile, the undergraduate math fellows worked with Monica Delgado Carrillo, the Math Outreach Lead, to develop lesson plans for K-12 teachers that are inspired by the scholarship of notable Black OSU alumni.

[1] https://hiddenfigures.osu.edu

[2] https://sinews.siam.org/Details-Page/siam-announces-the-2022-class-of-mgb-siam-early-career-fellows#Ranthony

[3] https://www.ohiohistory.org

[4] https://www.ohiohistory.org/visit/browse-historical-sites/national-afro-american-museum-cultural-center

[5] https://mathalliance.org

[6] https://hiddenfigures.osu.edu/alumni-profiles

Student Reflections

OSU students Katherine Lovelace and Hannah McDavid recently developed a linear algebra lesson plan based on the scholarship of William McWorter, Jr. — the first Black person to receive a Ph.D. in mathematics from OSU (he earned his degree in 1963). Here, they reflect on their experiences with the Hidden Figures project as a whole.

Ranthony Edmonds: The Hidden Figures project focused on storytelling from a historical perspective. Tell us about your efforts to learn the stories of Black math alumni from OSU.

Katherine Lovelace: Between 1963 and 1984, seven Black students earned Ph.D.s in mathematics from OSU. I was tasked with researching three of them: Guy Hogan (class of 1970), Rada Higgins (class of 1974), and Charles Chidume (class of 1984). Chidume, who passed away in 2021, served as president of the African University of Science and Technology, and a lot of information about his life and research is publicly available. Higgins was only the 20th Black woman in the U.S. to hold a Ph.D. in mathematics. And Hogan is a group theorist who earned a J.D. from Suffolk University Law School in 1985.

Hogan's story particularly piqued my interest because of the way in which he connected his mathematical and legal backgrounds. I hope to use my mathematical background in a similar way, extending it beyond science, technology, engineering, and mathematics (STEM) into the social sciences. After obtaining his law degree, Hogan discussed math and law together in talks such as "The Evolution of the Common Law Towards Fairness," "Comparative Negligence Converges to No-fault," "Infinite Series and the Income Tax," and "A Legal System as a Pseudo-metric Space."

RE: What other types of historical research did you conduct?

KL: I specifically investigated OSU's transition from open to selective admissions to understand its potential impact on the number of Black students who were pursuing math degrees. I used a keyword search tool to find articles in OSU's archives that discussed changes to admissions policies in order to create a timeline. The first real mention of this switch appeared in OSU's 1956 *May Monthly*, which mentioned an increase in required high school credit hours for incoming first-year students. In 1981, OSU introduced a conditional admissions program that permitted the admission of students without the required high school credits if their counselors completed a form that let them take the missing credits at the college level. OSU later announced its official transition to selective admissions in February 1986.

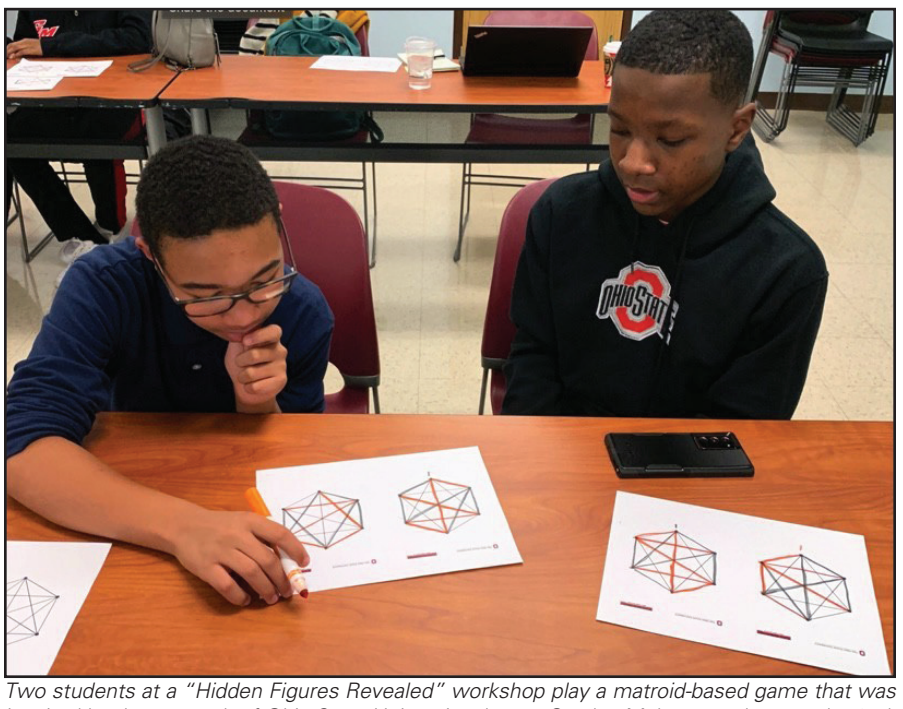
RE: How did you use storytelling to create educational resources based on the research of Black mathematicians at OSU?

Hannah McDavid: The most difficult aspect of creating lesson plans was condensing a mathematician's thesis or paper—the result of years of effort—into a simple activity that explains some of the basic ideas. Once I selected a topic that embodied the work of a particular mathematician, I constructed a collaborative activity for students. To encourage interaction and engagement among the students, I tried to turn every lesson into a tactile game that involved some form of competition or challenge. Each lesson plan comprised group activities or puzzles, followed by an explanation that linked the exercise back to both real-life applications and the Black alumni whose work inspired it.

One successful lesson plan was based on Carolyn Mahoney's 1983 dissertation, which considered matroid theory with a focus on several conjectures related to sequences that arise from the number of independent sets of a certain cardinality. A *matroid* M is a pair $M=(E,\mathscr{I})$, where E is the ground set of M and $\mathscr{I}$ is a collection of subsets of E called independent sets. Given an undirected graph $G=(V,E)$, we can associate to it a *graphic matroid* $M(G)=(E,\mathscr{I})$, where $\mathscr{I}$ is the set of subsets of E that are acyclic. One can use matroids that arise from bipartite graphs to study linear assignment problems; more generally, matroids find many uses in topology and algebraic and computational geometry.

The game "Dots and Boxes"—in which partners take turns drawing lines on a grid to enclose a box and claim the enclosed area—inspired the matroid activity. In our game, students take turns drawing lines

See **Hidden Figures** *on page 6*



Two students at a "Hidden Figures Revealed" workshop play a matroid-based game that was inspired by the research of Ohio State University alumna Carolyn Mahoney, who was the 25th Black woman in the U.S. to earn a Ph.D. in mathematics. Photo courtesy of Erica Womack.

CT23 Panel

Continued from page 2

Cerpa emphasized education as a necessary pathway to preserve existing knowledge and advance the future of control. He encouraged teachers to challenge their students with forward-thinking coursework that will prepare them for demanding, real-world scenarios. He also reiterated McCann's thoughts on AI. "We need to transmit the message that AI isn't everything," Cerpa said. "We can do other things that are very valuable — AI isn't taking over everything that we do."

Next, a panel attendee inquired about the future of theoretical versus applied aspects of control theory, which complement each other but require different kinds of expertise. Frankowska stated that researchers should ideally be familiar with both types in order to effectively move forward. "That's why you need to work with a group where some people are more applied and some are more theoretical," she said, but admitted that it can be hard to coalesce the personal approaches of different researchers. "It's probably the most difficult thing in the scientific lab — to be open to everything. Most of us can't always do it because mathematics is so time consuming."

Frankowska proceeded to comment on the possible challenges that are associated with interdisciplinary partnerships at universities, where faculty promotions are predominantly based on published papers rather than long-term interdisciplinary projects. "Teams are difficult to have when you're in a university because people are working in different directions," she said, adding that she would like to see a favorable attitude shift towards leadership and teamwork in science and mathematics departments.

McCann mentioned that pure and applied mathematics are often housed in different academic departments, which is not necessarily a structural advantage. "Everyone at the university is enthusiastic about interdisciplinary research until you try to publish it," he said. "When you talk to physicists and economists, they're not always particularly open to input from mathematicians. And I don't know what we can do as a discipline to try to change that."

Nevertheless, the panel concluded positively with a brief overview of the many current and future opportunities for modeling in control — including potential contributions to climate change studies. "The future is related to the evolution of science and the new models that are going to appear," Casas said. "There's work here for everybody."

Lina Sorg is the managing editor of SIAM News.

A panel of researchers discussed future directions of control theory and applied mathematics at the 2023 SIAM Conference on Control and Its Applications, which took place in Philadelphia, Pa., this July. From left to right: Eduardo Casas (Universidad de Cantabria), Benedetto Piccoli (Rutgers University), Sonia Martinez (University of California, San Diego), Robert McCann (University of Toronto), Hélène Frankowska (Sorbonne Université and CNRS), and Eduardo Cerpa (Pontificia Universidad Católica de Chile). SIAM photo.

Hidden Figures

Continued from page 5

from node to node; when they create a cycle, they lose a point because that set is no longer independent.

RE: What was it like to work with students using the lessons that you designed?

HM: I remember one student asking, "What does this even have to do with math?" The student was trying to solve a rope puzzle that pertained to group theory and inverses for a lesson that was inspired by the thesis of Guy Hogan. After completing the activity, that individual was able to provide examples of inverses. Our workshops demonstrated the accessibility of math when students go in with an open mind. It was also extremely empowering for participants to realize that Black mathematicians had thoroughly studied the mathematics that they were currently exploring.

RE: What are your biggest takeaways from this project?

HM: From an outreach perspective, the Hidden Figures project has boosted students' confidence and helped them understand that they can be both brilliant mathematicians and also Black. Academia has historically excluded such individuals, so highlighting the stories of those who have broken the mold can convince students who are just beginning their educational journeys that they are equally as capable.

In my experience, one-on-one interactions with students are the most impactful. Participants would arrive at our workshops after a full day of classes, sports, and club meetings and still bring their full attention and interest; their inspiring resilience to learn has encouraged me to pursue my own education with the same vigor. Students then left the workshops with a deeper knowledge of mathematics, broader world views, and a newfound confidence to explore STEM because they knew that previous Black academics had found success.

KL: I am often the only Black woman in my math classes. I have loved mathematics for as long as I can remember, but I struggled to maintain my passion after my first year of undergraduate study because I felt unworthy of being in math spaces. During my first summer home from school, I joined the Hidden Figures project. Researching and revealing the stories of other Black mathematicians at OSU enabled me to visualize myself in their shoes and envision my own mathematical future. For the first time, I experienced the impact of my love for math outside of the classroom.

Throughout my two years with this project, I have found my place in the math world. I attended the Field of Dreams Conference[7] and interacted with well-established Black mathematicians and peers from universities across the country; connecting with people who are on the same journey as me was both informative and uplifting. My goal is to pursue statistics in graduate school to ultimately analyze and study data in order to contribute to social change. I want be part of the conversations that identify inequities, then strive to create equitable solutions.

Call to Action

"Hidden Figures Revealed" was the first comprehensive study of Black mathematicians at a single U.S. institution, and we do not want it to be the last. We believe that a local approach in which institutions examine their own demographic histories can help address the global issues surrounding a lack of representation in quantitative communities.

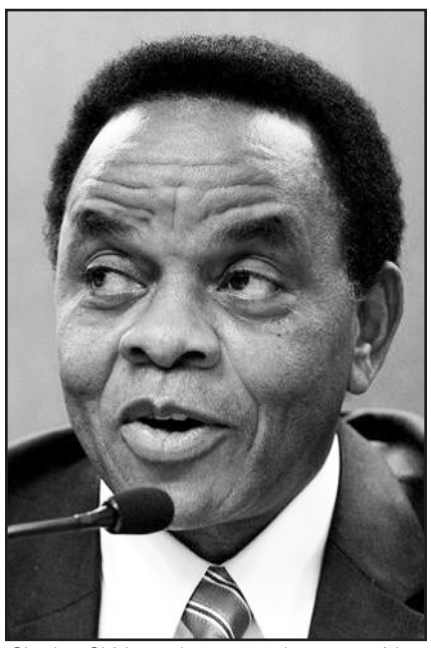
Specifically, we advocate for inclusive pedagogy — the creation of courses, modules, and projects that promote the scholarship of Black and other underrepresented individuals in STEM fields. By centering on these hidden figures, students learn about a wide variety of research areas, gain confidence in their advanced math skills, and envision more diverse quantitative research communities. We also advocate for outreach. Our workshops introduced students to the myriad possible career paths in mathematics. Individuals and/or departments that would like to support local outreach initiatives should connect with established community members or organizations that serve students who intend to pursue future careers in STEM, as well as local STEM professionals from underrepresented backgrounds. Educators who are interested in using the materials that we developed can find them online[8] and are welcome to contact our team at **BlackMathStory@osu.edu**.

Our Hidden Figures project brought lesser-known contemporary and historical mathematicians to the forefront, combatted isolation by increasing students' sense of belonging, and encouraged individuals to connect with their own STEM stories. We hope that our efforts serve as a call to action about storytelling's power for outreach and pedagogy, as well as the necessity of a more inclusive professoriate. This approach can support new generations of mathematicians and provide quantitative learning environments where talented individuals of all races, genders, and socioeconomic backgrounds can thrive.

Ranthony A.C. Edmonds is currently a Berlekamp Fellow at the Mathematical Sciences Research Institute/Simons Laufer Mathematical Sciences Institute and is affiliated with Duke University. In 2026, she will begin an appointment as an assistant professor of mathematics at The Ohio State University (OSU). Edmonds' research interests include applied algebraic topology, commutative algebra, math education, and quantitative justice; her career mission is to increase access to mathematics through community-engaged scholarship. Katherine Lovelace is a rising senior at OSU, where she is majoring in mathematics and African American and African studies. She plans to attend graduate school for either statistics or data science/analytics, with the goal of studying and analyzing data for social change. Hannah McDavid recently graduated from OSU with a B.S. in mathematics and is currently pursuing a M.S. in environmental metrology and policy at Georgetown University. She is thrilled to have been part of the Hidden Figures project.

[7] https://mathalliance.org/field-of-dreams-conference

[8] https://hiddenfigures.osu.edu/educational-resources



Charles Chidume (1947-2021) was president of the African University of Science and Technology and the seventh Black person to earn a Ph.D. in mathematics from The Ohio State University. Figure courtesy of the Nigerian Mathematical Society.

Intelligence: Whence and Whither

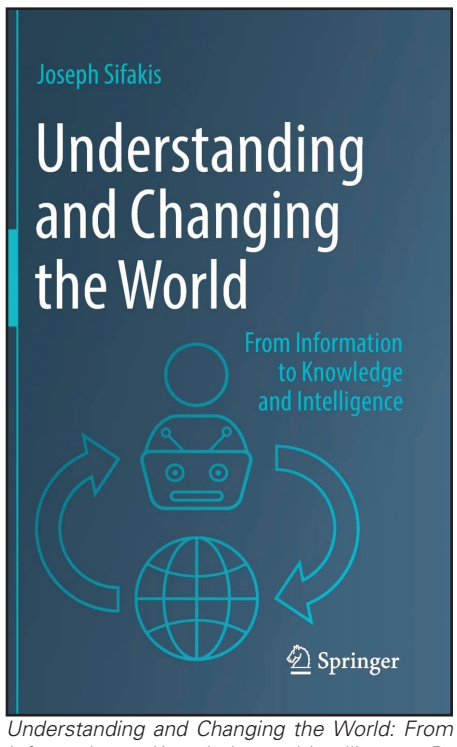
Understanding and Changing the World: From Information to Knowledge and Intelligence. *By Joseph Sifakis. Springer Nature, Singapore, May 2022. 171 pages, $49.99.*

BOOK REVIEW
By Akash Deshpande

Both scientific and general interest in artificial intelligence (AI) have recently exploded around the world. While transformer neural networks and generative AI—exemplified by tools such as ChatGPT and Google Bard—are promising new technologies, it is important that we understand how they fit into the overall scheme of the physical and informational worlds. In *Understanding and Changing the World: From Information to Knowledge and Intelligence*, Joseph Sifakis (a 2007 Turing Award recipient) amasses a lifetime of knowledge as a deep thinker and effective practitioner of computer science—indeed, collecting a civilization's wisdom—to provide a valuable framework that is rooted in the philosophy of science and society.

This densely rich yet concise book is hard to summarize. I recommend that interested persons read it thoroughly for its thematic development, insightful observations, and relevant sidelights on diverse topics. Here, I'll attempt to describe a few key ideas to whet the reader's appetite.

Sifakis follows the dualist tradition of separating physical reality from its models, the latter of which fall into the category of *information*. Information itself is purely logical in this context. It is a semantic relationship between a symbolic language and a set of concepts (not a statistical measure as in quantum mechanics or communication theory). Logical information requires a symbolic alphabet with rules of syntax that govern the combination of symbols. These combinations codify concepts and provide representations; rules of semantics then help us decode the representations and glean the referenced concepts. Together, these elements form a language. Physical reality exhibits a level of continuity and robustness that enables us to generalize observations into laws, thus making reality comprehensible. However, information and its transformation through computation are discrete, brittle, and therefore difficult to understand.



Understanding and Changing the World: From Information to Knowledge and Intelligence. By Joseph Sifakis. Courtesy of Springer Nature.

Knowledge is useful information that helps us understand a situation and act in order to achieve a goal. *Understanding and Changing the World* focuses on the *how* of knowledge and not on the *why* and *what*, which—as Sifakis explains—rest on rhetoric, mythology, and belief. He considers knowledge to be the *how* of things — e.g., how does a clam reproduce? How do you build a house? How can we avoid inflation? The answers to these questions are relationships between observations and concepts, and are the same irrespective of one's belief system.

Sifakis' text provides a hierarchy of knowledge: (i) Empirical (data-based) knowledge from observations of events and conditions in the real world, which may be processed by algorithmic or machine learning computation; (ii) scientific and technical (model-based) knowledge from reasoning and application; (iii) non-empirical knowledge from idealized concepts such as mathematics; and (iv) meta knowledge, or knowledge *about* knowledge that may be called wisdom. Empirical knowledge helps us predict, scientific knowledge helps us explain, and non-empirical knowledge helps us prove the validity of knowledge itself. Sifakis expands considerably on the development and application of knowledge at each level, including the roles of induction, generalization, modeling, abstraction, formalization, hierarchy, modularity, and emergence. He also discusses pitfalls like scientism, mystification of expertise, and research via vision (versus research via challenge), and examines the need for innovation ecosystems with research, industry, and startups.

Sifakis characterizes human intelligence as having two ways of thinking: slow and conscious or fast and automatic. Humans exhibit common sense and adaptability for assessing a situation and adjusting goals and plans, but we are constrained by cognitive complexity and can only conceive of relationships between a handful of parameters. On the other hand, weak AI (such as deep neural networks) has only fast and automatic "thinking" and limited (if any) common sense and adaptability, but it can access practically unconstrained parameter space to discover relationships between data.

To go beyond weak AI, we must pursue *autonomous systems*. These systems require perception (the ability to interpret sensory information), reflection (the ability to construct a model of the environment), and decision-making through strategic goal formulation and tactical planning — each of which is based on a knowledge repository

See **Intelligence** *on page 8*

Copper Mountain

Continued from page 4

equal footing with all other participants; winners of the annual student paper competition deliver the only plenary-like talks of the week during a special session right before the conference banquet. In fact, many of the established researchers at each conference first attended the meeting as students — including much of the current program committee. During the banquet, the conference chairs routinely ask current students to stand, then invite everyone who initially attended the meeting as a student to rise as well. At the conclusion of this exercise, most people in the room are standing; the 2023 meeting was no exception.

The Copper Mountain Conferences have a long history of cooperation with SIAM. SIAM published a proceedings volume for the 1989 multigrid meeting, and the *SIAM Journal on Scientific Computing (SISC)* released its first special issue in 1992 in response to the 1990 iterative methods conference. Since then, *SISC* has housed a Copper Mountain iterative methods special issue in even-numbered years; it even published a special section in 2021[3] with the work of would-be conference attendees for the canceled 2020 meeting. In 2022, the multigrid methods conference also began to publish a special section in *SISC*.[4]

Steve McCormick and Tom Manteuffel (now both professor emeriti at the University of Colorado Boulder) chaired the conferences from their inception and provided management services through their company: Front Range Scientific Computations, Inc. The duo played a major role in the conferences' growth and within associated research communities over the years, first as conference co-chairs (until 2002) and then as members of the program committees. The series' continued popularity and vibrancy is a testament to McCormick and Manteuffel's dedication to both the academic quality of the meetings and the welcoming atmosphere that encourages repeat attendance year after year.

With the completion of the 2023 meeting, we look forward to wherever the conferences may take us! The current co-chairs of the iterative methods series—Luke Olson (University of Illinois Urbana-Champaign) and John Shadid (Sandia National Laboratories)—are already planning for the 2024 in-person meeting; more details will be announced in the coming months.

[3] https://epubs.siam.org/toc/sjoce3/43/5

[4] https://epubs.siam.org/toc/sjoce3/0/0

Tom Manteuffel (left) and Steve McCormick—founding chairs of the Copper Mountain Conference series—unite at the 2023 Copper Mountain Conference on Multigrid Methods, which took place in April. Photo courtesy of Susanne Brenner.

Susanne C. Brenner is a professor of mathematics at Louisiana State University and a Past President of SIAM. Robert D. Falgout is a distinguished member of technical staff at Lawrence Livermore National Laboratory and current co-chair of the Copper Mountain Conference on Multigrid Methods. Scott P. MacLachlan is a professor of mathematics at Memorial University of Newfoundland and current co-chair of the Copper Mountain Conference on Multigrid Methods.

The Center for Forecasting and Outbreak Analytics: A Nexus of Applied Mathematics, Computational Science, and Public Health

By Jason Asher

Since its launch in 2022, the Center for Forecasting and Outbreak Analytics[1] (CFA) at the U.S. Centers for Disease Control and Prevention[2] (CDC) has sought to make transformative advancements in modeling, forecasting, and outbreak analytics. CFA is working to increase the responsive capacities of both the CDC and the nation during emerging public health threats by expanding partnerships with academia, the private sector, state and local public health departments, other public health organizations, and professional societies. Mathematical modeling is at the heart of CFA's mission and is essential to its three primary functions: predict, inform, and innovate.

As we reflect on the lessons and fundamental takeaways of COVID-19, it is evident that the innovative, nimble, and quick response of the applied mathematics and computational science community contributed significantly to society's understanding of the pandemic; provided decision-makers with crucial, real-time public health data; and ultimately saved lives. Applied mathematicians and computational scientists coordinated closely with state health departments to compile and analyze local health data; assist with locating outbreaks; and assess shortages in access to care, diagnostics, therapeutics, and vaccines. The community also collaborated with federal agencies to aid in the rapid development of simulations that leverage high-performance computing to forecast disease spread and explore the uncertainty of future transmission dynamics.

I believe that SIAM and its members can help us maintain this momentum and generate new tools that will comprise critical components of future disease and outbreak response infrastructure. CFA has already been instrumental in the development of scenario analyses to predict the caseload from COVID-19's Omicron variant, ultimately providing an early warning that allowed local, state, and federal leaders to prepare for the eventual surge in cases. In response to the 2022 mpox outbreak in the U.S., CFA developed a first-of-its-kind "technical reports" product[3] that quickly made scientific information about the situation available to the public. These reports offered vital insights into the mpox outbreak, including estimates of key epidemiologic quantities and assessments of the potential future outbreak trajectory. In addition, CFA is continuing to team up with other CDC programs to produce a virtual analyst platform that will serve as a common suite of software, tools, and file and code-sharing capabilities for modeling collaborations. This platform is currently in the pilot phase, but the final version will allow modelers to work with public health data in real time and create a trusted, connected pathway for data analysis that is accessible to local, state, and federal public health decision-makers.

In the research and development space, CFA has contracted with several universities on efforts to improve forecasting and outbreak analytics for emergency decision-making. It also launched a funding opportunity[4] that aims to establish a network of innovators who will design, prototype, test, refine, evaluate, and implement new and enhanced capabilities for disease modeling and analytics to ultimately improve decision support during infectious disease outbreaks. Though this funding opportunity recently closed, I encourage SIAM members to stay tuned for subsequent chances to get involved.

As CFA grows its extramural community engagement, we continue to make internal hires and look to the SIAM community for data scientists and information technology specialists who can support its mission. We are especially interested in individuals who are developing and deploying novel modeling methods and tools, high-quality open-source software, and other capabilities that support public health decision-makers. The next phase of public health advances will necessitate robust participation from applied mathematicians and computational scientists. I therefore urge SIAM members to explore collaborations with the public health and infectious disease research community, pursue funding opportunities through CFA and CDC programs, and even consider a career[5] at CFA to help develop next-generation models, transformative forecasting tools, and outbreak analytics. Applied mathematics and computational science—as well as mathematical and computational research and education—are already critical components of an effective public health infrastructure and will only increase in their importance. I look forward to working with the SIAM community to build upon the successes of CFA and ensure its longevity.

Jason Asher is director of the Predict Division of the Center for Forecasting and Outbreak Analytics at the Centers for Disease Control and Prevention.

[1] https://www.cdc.gov/forecast-outbreak-analytics/index.html
[2] https://www.cdc.gov
[3] https://www.cdc.gov/poxvirus/mpox/cases-data/technical-report.html
[4] https://www.cdc.gov/forecast-outbreak-analytics/nofo.html#funding-opportunity
[5] https://www.cdc.gov/forecast-outbreak-analytics/cfa-career-paths.html

Intelligence

Continued from page 7

of concepts, properties, and methods that is constantly updated via self-learning. Sifakis addresses the technical and social risks of strong AI systems that arise from issues of trust, explainability, and validity. He does not comment on whether strong AI can evolve from weak AI or if it must be designed from the outside, but his thoughts on this subject would no doubt be enlightening.

The second half of the book explores consciousness in great detail. Relevant to this section is the role of needs and feelings to help humans (and perhaps other living beings) formulate goals and prioritize actions. Needs—whether biological, psychological, or other—subconsciously translate to feelings of different types and intensities, which in turn actuate an individual towards consciously achieving an emotional equilibrium. Regarding consciousness, I'll quote three rather beautiful passages from *Understanding and Changing the World*:

"How do we strike a balance and self-control between the conscious and the subconscious? For an athlete or artist, the subconscious is a key factor for their performance. All transcendental experiences are characterized by this temporary loss of the conscious, whether they are religious, erotic, artistic, or relating to creativity, where the subconscious play[s] an important role. An intervention by the conscious could lead to confusion and hesitation and damage the quality of performance … No emotion seems authentic when it is fully controlled by the conscious."

"We must reassess the role of consciousness in our lives. Many of the wonderful things that people do go beyond conscious control. We can develop skills through intuition and practice in order to communicate with the world and access cosmic mystery."

"Know thyself. It is a prerequisite for harmony with ourselves in order to achieve a happy life. It is the first and last major imperative for humans. All the others follow, the way theorems follow from axioms. In our personal lives, knowing is not enough. Unmanageable knowledge can become an unnecessary burden that not only does not help, but also sometimes clouds our judgment. Gaining knowledge through the game of freedom is the meaning of life. When the cycle of life closes, our conscience must have discovered and fully understood the rules."

In the final sections of the text, Sifakis dwells on society and its gnoseological, technical, ethical, and economic values; on institutions, democracy, meritocracy, and bureaucracy; and on the decline of societies through the depreciation of values, decay of language, degradation of concepts, and tendencies like lying, self-convenience, and corruption — "leading to the triumph of idiots."

Understanding and Changing the World is a highly accessible, must-read work for both the computer scientist and the general reader. The book provides context for recent advances in AI and offers a roadmap for its future direction, both technically (through autonomous systems) and socially (through regulatory considerations). Most of all, it presents the reader with a framework for understanding the individual and society within a complex technological world that continually evolves towards the future.

Akash Deshpande holds a Ph.D. from the University of California, Berkeley and currently works on internet infrastructure at Google. He first met Joseph Sifakis 30 years ago and the two have kept in touch sporadically ever since.

Algebraic and Geometric Computations in OSCAR

By Mara Belotti, Michael Joswig, Chiara Meroni, Victoria Schleis, and Johannes Schmitt

OSCAR (Open Source Computer Algebra Research)[1] is a new open-source computer algebra system that is written in the Julia programming language [6]. Wolfram Decker, Claus Fieker, Max Horn, and Michael Joswig currently lead this collaborative project, which has many contributors; its ongoing development can be monitored on GitHub.[2] OSCAR is funded by the German Research Foundation within the collaborative research center on "Symbolic Tools in Mathematics and their Application."[3]

One of OSCAR's most important features is its ease of installation, which is a direct consequence of its inclusion within the rapidly growing Julia ecosystem as a registered package. On the Julia interactive command line, users can simply type

```
import Pkg; Pkg.add("Oscar");
using Oscar
```

to download the relevant data from the internet and print a banner; OSCAR is then ready for action. This works on every operating system (Linux, macOS, and Windows), though one should nevertheless budget sufficient time for the initial installation.

SOFTWARE AND PROGRAMMING

OSCAR rests on the combined functionality of the GAP[4] (group and representation theory), Nemo/Hecke[5] (number theory), polymake[6] (polyhedral and tropical geometry), and Singular[7] (commutative algebra and algebraic geometry) packages but extends them considerably. The user interface is inspired by Donald Knuth's "literate programming" paradigm [10]; it should be as close to standard textbooks as possible. In contrast to Magma,[8] OSCAR is an accessible platform for interoperable and reproducible computations due to its open-source nature. And compared to SageMath,[9] it is smaller but more tightly knit. As a result, some computations that are possible in OSCAR are not currently achievable elsewhere — at least not in other open-source software; the computation of Galois groups of arbitrarily high degree is one such example [7]. To provide a more precise idea of OSCAR's present capabilities, we will discuss specific computations that have arisen in four Ph.D. projects. The associated code examples are available as Jupyter notebooks[10] that require OSCAR v0.12.0 or a later version.

Parametric Volume of Polytope Slices

Polytopes and *convex bodies* are geometric objects that occur naturally as feasible domains in linear and convex programming, and *volume computations* have been the subject of wide interest and application since the early days of mathematics in ancient Egypt. These two distinct concepts converge in the study of *intersection bodies*, which arose in convex geometry settings to help solve the famous Busemann-Petty problem [8]. This question investigated whether a symmetric convex body with larger central hyperplane sections must similarly have a larger volume. Intersection bodies also appear in open problems such as Bourgain's slicing conjecture [9]. Our example Jupyter notebook[11] presents an experimental approach to these problems by computing explicit instances of intersection bodies. The methods exploit the fact that intersection bodies of polytopes are semi-algebraic — i.e., describable in terms of polynomial inequalities.

The crucial step is a parametric volume computation [4] that requires methods from polyhedral geometry and commutative algebra, all of which exist in OSCAR. The algorithm in our notebook takes a polytope P as input; we are interested in slicing P with arbitrary central hyperplanes. The slice volume function is actually a piecewise quotient of two polynomials, and the algorithm's output is its explicit computation. Our method involves triangulating P—a standard task in polyhedral geometry—and subsequently adding determinants of matrices whose entries are multivariate rational functions; doing so requires basic linear algebra and an efficient implementation of arithmetic operations in polynomial rings. For conciseness, the notebook demonstrates the computation for one specific polytope: the truncated tetrahedron, which is an Archimedean solid (see Figure 1, on page 10).

Combinatorics of Hurwitz Numbers

In this project,[12] we tackle a problem from enumerative algebraic geometry in both a combinatorial and algorithmic manner. *Hurwitz numbers* of degree d and genus g count the number of degree d covers of the complex projective line by algebraic curves of genus g. This tally does not distinguish isomorphic covers, which can be described combinatorially in terms of behavior around the branch points. Such a *monodromy representation* is encoded as a list of permutations, with one permutation for each branch point. *Plane Hurwitz numbers* only count covers that arise via projections. For example, we have explicitly computed the Hurwitz and plane Hurwitz numbers of degree 3 and genus 1, as well as degree 4 and genus 3 (with simple ramification), then analyzed their structures [1].

We constructed the 7,528,620 (representatives of) monodromy representations (out of a total of 2,176,782,336 candidate lists of permutations) that exist for degree 4. This part of the computation is purely topological and only exploits the structure of the Riemann surface that underlies a complex algebraic curve. Furthermore, all of the computed monodromy representations can be combinatorially analyzed for the geometric and algebraic properties of the covers that they symbolize.

See **OSCAR** *on page 10*

[1] https://www.oscar-system.org
[2] https://github.com/oscar-system
[3] https://gepris.dfg.de/gepris/projekt/286237555
[4] https://www.gap-system.org
[5] https://www.nemocas.org
[6] https://www.polymake.org
[7] https://www.singular.uni-kl.de
[8] http://magma.maths.usyd.edu.au/magma
[9] https://www.sagemath.org
[10] https://github.com/micjoswig/oscar-notebooks/blob/master/SIAM-News
[11] https://github.com/micjoswig/oscar-notebooks/blob/master/SIAM-News/Parametrized_volume_of_slices.ipynb
[12] https://github.com/micjoswig/oscar-notebooks/blob/master/SIAM-News/Hurwitz_Combinatorics.ipynb

OSCAR

Continued from page 9

While each individual computation is neither hard nor time-consuming, their sheer collective volume makes analysis impossible without the aid of a computer algebra system. Fortunately, the fact that `OSCAR` is written in `Julia` simplifies the processing of the output of `HomotopyContinuation.jl`[13] [5]: a system that solves polynomial equations via analytic methods that can compute the monodromy representation of a given cover.

Cox Rings of Point Blow-ups

To fully understand the geometry of varieties, one must describe their algebraic invariants. An example of this concept is the *Cox ring* of a projective algebraic variety. This universal homogeneous coordinate ring algebraically encodes all possible embeddings of the given variety into projective space. We recently solved a formerly open question by demonstrating that quadrics generate the ideal I of relations of the Cox ring of the blow-up of seven points in three-dimensional complex projective space [3]. The primary result relies on an `OSCAR` computation in an essential way. This scenario is interesting because only a few Cox rings of such blow-ups are finitely generated, and the scenario in question had been one of only two remaining cases that researchers did not completely comprehend.

One can compute a Gröbner basis to show that quadrics generate the relevant ideal I. Yet I is given indirectly as the radical of another ideal J, which has 4,220 quadric generators in 129 variables. Since this problem is far too large for a direct computation with current methods, we seek to study the Cox ring as a subalgebra that is spanned by 129 generators in a polynomial ring with only 14 variables. Our proof computes a Khovanskii basis of the Cox ring, which is an analog of a Gröbner basis for a subalgebra (rather than an ideal). Because Khovanskii bases are generally not finite, this task is more subtle. Luckily, `OSCAR` was able to find a finite Khovanskii basis. Our example `Jupyter` notebook[14] illustrates the analogous computation for the blow-up of six points.

Cox Rings of Linear Quotients

A *linear quotient* is the orbit space of a finite group that acts linearly on a finite-dimensional complex vector space. Such objects are the subject of invariant theory — a field of mathematics that dates back at least 150 years and lies at the intersection of group theory, representation theory, and algebraic geometry. Invariant theory in particular pertains to the study of polynomials that remain invariant under the linear action of a group on a polynomial ring; the set of these invariant polynomials forms its own *invariant ring*.

Classical results of David Hilbert and Emmy Noether imply that a linear quotient is an affine algebraic variety. Our example notebook[15] for this project again relates to the Cox ring of this variety. Here, we must compute a certain invariant ring and endow it with a nonstandard grading by a theorem of Ivan Arzhantsev and Sergey Gaĭfullin [2]. Computation of this ring facilitates the study of the birational geometry of a linear quotient [11]. `OSCAR` provides all of the necessary tools for the effective management of matrix groups and their invariant theory.

[13] https://www.juliahomotopycontinuation.org

[14] https://github.com/micjoswig/oscar-notebooks/blob/master/SIAM-News/Cox_rings_of_blow_ups_of_points.ipynb

[15] https://github.com/micjoswig/oscar-notebooks/blob/master/SIAM-News/Cox_rings_of_linear_quotients.ipynb

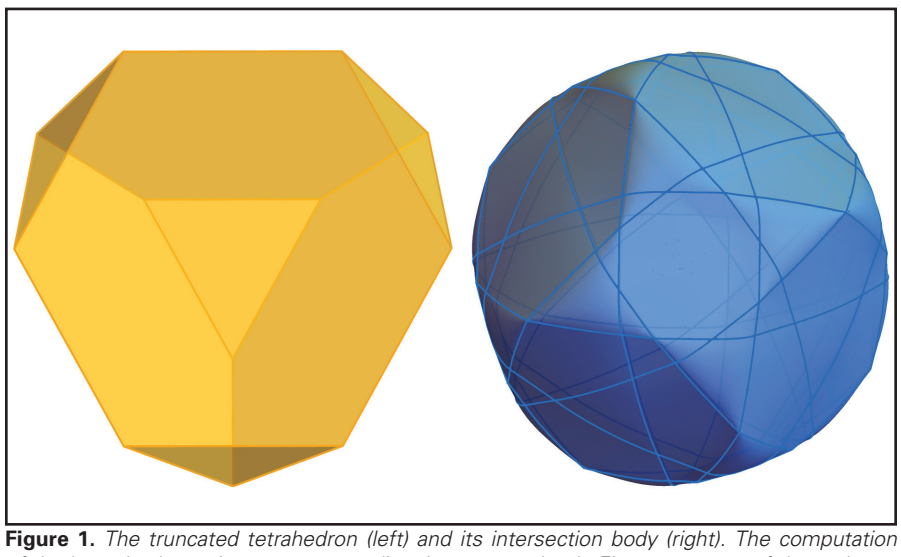


Figure 1. *The truncated tetrahedron (left) and its intersection body (right). The computation of the latter is shown in our corresponding Jupyter notebook. Figure courtesy of the authors.*

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Forward-looking Panel at DS23 Envisions the Future of Conferences

By Jillian Kunze

As research communities emerge from the heavy restrictions of the COVID-19 pandemic and look towards a future impacted by climate change, there is an enlivened interest in rethinking the organizational structure of academic conferences.[1] Virtual conferences, which were a marker of the pandemic, offer unparalleled access but fewer avenues for networking and interpersonal communication. Meanwhile, in-person conferences incur large carbon costs due to the required travel and inhibit the involvement of people who would like to take part in the meeting but are unable to physically attend.

During the 2023 SIAM Conference on Applications of Dynamical Systems[2] (DS23), which took place in Portland, Ore., this May, a forward-looking panel[3] contemplated the future of academic conferences. Chair Vivien Kirk (University of Auckland) led panelists Robbin Bastiaansen (Utrecht University), Kate Meyer (Carleton College), Jonathan Rubin (University of Pittsburgh), and Laurette Tuckerman (CNRS) in a discussion about the merits of different conference models, considerations of various travel options, and essential aspects of forming connections as researchers. "We've rearranged our commitments to be here at this meeting because it's valuable," Kirk said, providing a sentiment that guided the conversation to follow.

All of the panelists noted that their academic institutions either had already implemented or were in the process of developing plans for carbon neutrality and/or other initiatives to address climate change. For instance, Rubin mentioned that the University of Pittsburgh intends to be carbon neutral by 2037 based on multiple pathways,[4] including air travel offsets and alternative travel possibilities. "I appreciate the fact that it doesn't have to be all or none," he said. "We just have to be thoughtful about what we do."

Bastiaansen and Tuckerman both commented on the fortunate fact that their locations within Europe allow them to take trains or other forms of public transportation besides planes to almost any conference within the continent. As such, Tuckerman shared that she has decided not to fly across the ocean to attend a conference without good reason (such as delivering the final invited lecture[5] at DS23). Kirk, however, has a very different experience; since she resides in New Zealand, she must fly everywhere. "The other thing that should be acknowledged is that taking a train can take a lot longer, so it's not always possible," she said. Each person's respective location and situation will determine to what extent they are able to rely on less carbon-intensive forms of transport. Meyer also pointed out that discussions of individual carbon footprints should not remove the blame from industries that have made disproportionate impacts, such as fossil fuel companies.

If someone is attempting to reduce their amount of air travel, they might decide to prioritize visiting family (rather than going to meetings), opt to attend conferences that take place in nearby locations or close to hub airports that don't require inefficient exchanges, and only engage in long-distance travel under special circumstances. Unfortunately, this scenario provides fewer occasions for researchers to directly interact with colleagues from all over the world. "Younger people should have the same opportunities that I did to mix with older people — though it's tough if no older people come," Tuckerman said.

Rubin concurred with this point, adding that he has received job offers based on connections from previous SIAM DS conferences. "I do believe that in-person meetings are important," he said. "It's important in our field that young and less young people are able to get these opportunities."

The discussion then turned to hybrid meetings and the particular merits and drawbacks of online components. A virtual option enhances accessibility and allows more people to participate than would otherwise be able to travel to the conference venue. Online participants can often attend more talks, and recordings enable them to view sessions that they initially missed. However, many people feel drained by the excessive screen time that is inherent to the virtual meeting experience, get distracted by their daily household or work environments, and naturally miss the camaraderie of face-to-face socialization. "Here, you can physically bump into lots of people," Bastiaansen said. "That's the main issue with online."

The hub model—in which several simultaneous gatherings take place at locations across the world, with a mix of in-person events and virtual crossover—offers a

See **Forward-looking Panel** *on page 12*

[1] In an article on page 3 of this issue, James Nagy and Sven Leyffer discuss the changing nature of SIAM conferences over the past few years.

[2] https://www.siam.org/conferences/cm/conference/ds23

[3] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=77817

[4] https://www.sustainable.pitt.edu/commitments-reports/pitt-climate-action-plan

[5] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=77298

2023 SIAM Southeastern Atlantic Section Annual Meeting Attracts Young Researchers

By Traian Iliescu and Honghu Liu

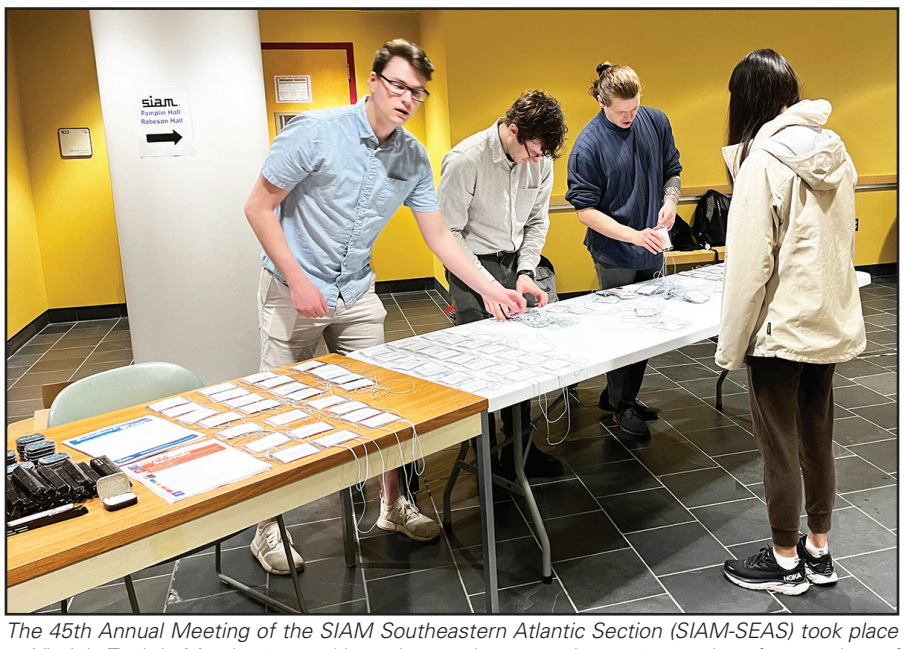
The 45th Annual Meeting[1] of the SIAM Southeastern Atlantic Section[2] (SIAM-SEAS) took place at Virginia Tech (VT) from March 25 to 26, 2023, with generous support from SIAM and VT's Department of Mathematics and College of Science. It was the first fully in-person SIAM-SEAS meeting since the onset of the COVID-19 pandemic, as the previous iteration (at Auburn University in 2021) was hybrid.[3] SIAM provided travel support for the three plenary speakers, as well as 25 travel awards for student attendees.

The 2023 SIAM-SEAS Annual Meeting attracted more than 200 participants, 53 of whom were students. The organizing committee made a special effort to include as many young scientists as possible, and the large number of students and postdoctoral researchers who presented their work reflects the committee's success. All of the student attendees delivered oral presentations during the meeting's 47 minisymposium sessions. A group of 23 minisymposium organizers and 14 faculty members evaluated these presentations and designated the following student award recipients:

- First place: Matt Dallas (University of Florida), Shane McQuarrie (University of Texas at Austin), and Hanwen Yao (Duke University)
- Second place: Mo Zhou (Duke University)
- Third place: McKenzie Black (University of South Carolina), Benjamin Jany (University of Kentucky), Conlain Kelly (Georgia Institute of Technology), and Sarah Strikwerda (North Carolina State University)
- Honorable mention: Linus Balicki (VT), Morgan Jackson (Virginia Commonwealth University), Anthony Krueger (VT), Julia Shapiro (VT), William Snyder (VT), Yixuan Tan (Duke University), and Zezhong Zhang (Florida State University).

Beyond the minisymposium presentations, the three plenary lectures were all very well attended. Sara Pollock (University of Florida) delivered the first plenary talk, which focused on recent innovations in the theory and application of the Anderson acceleration: a powerful, low-cost method that accelerates the convergence of fixed-point iterations. Omer San (Oklahoma State University) gave the second plenary lecture and surveyed exciting state-of-the-art developments in scientific machine learning and classical numerical discretizations, merging fundamentally different ideas to create hybrid computational strategies for the future of science and engineering. In the final plenary address, Lili Ju (University of South Carolina) introduced novel discretization schemes for conservative Allen-Cahn equations that unconditionally preserve the maximum bound principle in the discrete sense.

During the 45th Annual Meeting of the SIAM Southeastern Atlantic Section (SIAM-SEAS), which was held at Virginia Tech in March 2023, Omer San of Oklahoma State University delivers an engaging plenary lecture that surveyed state-of-the-art developments in scientific machine learning and classical numerical discretizations. Photo courtesy of the authors.



The 45th Annual Meeting of the SIAM Southeastern Atlantic Section (SIAM-SEAS) took place at Virginia Tech in March 2023 and brought together more than 200 attendees for two days of presentations and networking. Photo courtesy of the authors.

SIAM-SEAS leadership—president Traian Iliescu (VT), vice president Leo Rebholz (Clemson University), and secretary/treasurer Zhu Wang (University of South Carolina)—worked with SIAM staff to plan the initial components of the 2023 SIAM-SEAS Annual Meeting. The SIAM-SEAS local organizing committee, which made outstanding efforts to ensure the event's success, was chaired by Honghu Liu (VT) and comprised the following members of VT's Department of Mathematics: Nicole Abaid, Paul Cazeaux, Giuseppe Cotardo, Jason LeGrow, Agnieszka Miedlar, Petar Mlinarić, Fazle Rabby, Joseph Wells, Fangchi Yan, and Pengtao Yue. The SIAM Student Chapter at VT[4] (which includes Mike Ackermann, Sam Bender, Jenifer De Jager, Rodrigo Figueroa, Dan Folescu, Wendi Gao, Yichen Guo, Anayse Miller, Ian Moore, Dylan Park, Matt Park, Nicolas Swanson, Tatiane Swap, Cankat Tilki, and Teona Zurabashvili)—along with William Snyder (a student in the Department of Biomedical Engineering and Mechanics)—worked tirelessly to guarantee the conference's seamless execution. The meeting would not have been possible without the help of these volunteers, and we are very grateful for their contributions.

Traian Iliescu is a professor in the Department of Mathematics at Virginia Tech. He holds a Ph.D. from the University of Pittsburgh, received the SIAM Student Paper Prize in 1999, and was the 2000-2001 James Hardy Wilkinson Fellow at Argonne National Laboratory. Iliescu's research focuses on the numerical simulation and analysis of turbulent engineering and geophysical flows, with special emphasis on data-driven Galerkin methods and reduced order models. Honghu Liu is an associate professor in the Department of Mathematics at Virginia Tech. His research utilizes dynamical systems tools for nonlinear partial differential equations, with a focus on bifurcation analysis, phase transition, surrogate systems for optimal control, and stochastic closures for turbulence.

[1] https://conference.math.vt.edu/vt-siam-seas/index.html

[2] https://www.siam.org/membership/sections/detail/siam-southeastern-atlantic-section-siam-seas

[3] https://sinews.siam.org/Details-Page/recapping-the-44th-siam-southeastern-atlantic-section-seas-conference

[4] https://sites.google.com/view/vtsiamsc/home

Forward-looking Panel

Continued from page 11

potential pathway to preserve particularly popular parts of meetings with smaller carbon costs [1]. "When I started learning about the hub model of conferences, I got really excited," Meyer said. "I think that being in person is so helpful for the community aspect. Maybe there could be a North American hub, with things simultaneously happening in Europe, New Zealand, et cetera with some hybridization."

Gathering with a local research community at a hub could help people connect outside of their own programs, establish a sense of belonging in their field, and cross-fertilize scientific ideas with other groups. Traveling to a hub also removes attendees from their regular environments so that they can fully immerse themselves in the conference setting; even if they are watching a recorded talk from another hub, they can do so with the feedback of a live audience. While this modality offers fewer opportunities for participants to directly meet with people from around the world, organizers could potentially arrange virtual socialization events that encourage networking across hubs.

The effective implementation of future hub and hybrid conferences will require creativity and flexibility in order to avoid the loss of essential elements. During the discussion, panelists and audience members shared potential ideas to improve different aspects of these meetings — such as ensuring that online-only sessions do not take place on consecutive days. Conference organizers could also accommodate multiple time zones by scheduling the most important sessions over several-hour blocks that have significant overlap with reasonable hours across the world.

Overall, both panelists and attendees agreed that researchers will likely have to change their future behaviors in some ways and remain open to experimentation with different ideas. "Just among this panel, there are very different experiences," Kirk said. "We're going to have to accommodate these things." Organizations and universities will need to be flexible as well when rethinking the way in which conference participation impacts tenure and other career milestones, as experimentation should not hurt the development of people at critical career stages.

For now, SIAM already offers many opportunities for members to become involved with student chapters[6] or regional sections[7] (both localized hubs). And while the future of conferences remains uncertain, many organizers are working on interesting approaches to maintain the spirit of scientific gatherings while accounting for the reality of climate change. "It's a really hard problem," Kirk said. "We haven't found any solutions, but we have lots of ideas."

[6] https://www.siam.org/students-education/student-chapters

[7] https://www.siam.org/membership/sections

A panel at the 2023 SIAM Conference on Applications of Dynamical Systems, which took place in Portland, Ore., this May, addressed the future of research conferences in light of new hybrid modalities and carbon costs. From left to right: Robbin Bastiaansen (Utrecht University), Laurette Tuckerman (CNRS), Kate Meyer (Carleton College), Jonathan Rubin (University of Pittsburgh), and panel chair Vivien Kirk (University of Auckland). SIAM photo.

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Jillian Kunze is the associate editor of SIAM News.

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What's New at SIAM?

- The first SIAM Conference on the Mathematics of Data Science (MDS22) was held last September, with participants joining remotely from across the globe and in-person in San Diego, California.
- The new SIAM Activity Group on Equity, Diversity, and Inclusion began accepting members.
- SIAM Student Days took place overseas for the first time, at the SIAM Conference on Computational Science and Engineering (CS23) in Amsterdam. With 55+ chapters sending representatives from around the world, chapter leaders networked, attended student-oriented sessions, and got to meet SIAM VIPs!
- 12 new student chapters have been established in 2023. Consider starting or re-starting a chapter at your academic institution!
- The new SIAM NY-NJ-PA Section held its inaugural meeting in October.
- Our career development opportunities are set to include a second career fair (happening virtually on October 11) and industry panels.
- Eight SIAM Activity Groups started or continued hosting webinar series.

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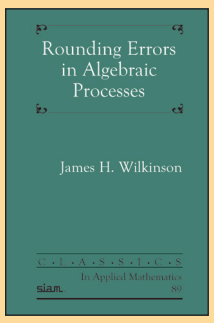
siam | BOOKS

Quality and Value in Mathematical Science Literature

New and Forthcoming

Rounding Errors in Algebraic Processes



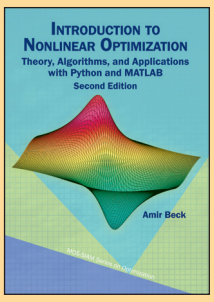
James Hardy Wilkinson

"[This book] combines a rigorous mathematical analysis with a practicality that stems from an obvious first-hand contact with the actual numerical computation. The well-chosen examples alone show vividly both the importance of the study of rounding errors and the perils of its neglect."

— A. A. Grau, *SIAM Review* (1966)

2023 / xiv + 161 pages/ Softcover / 978-1-61197-751-6
List $67.00 / SIAM Member $49.60 / CL89

Introduction to Nonlinear Optimization
Theory, Algorithms, and Applications with Python and MATLAB, Second Edition

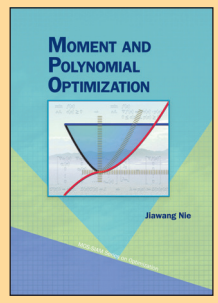


Amir Beck

Built on the framework of the successful first edition, this book serves as a modern introduction to the field of optimization. The author's objective is to provide the foundations of theory and algorithms of nonlinear optimization, as well as to present a variety of applications from diverse areas of applied sciences. Python and MATLAB programs are used to show how the theory can be implemented. The extremely popular CVX toolbox (MATLAB) and CVXPY module (Python) are described and used.

2023 / xii + 354 / Softcover / 978-1-61197-761-5
List $84.00 / SIAM Member $58.80 / MO32

Moment and Polynomial Optimization

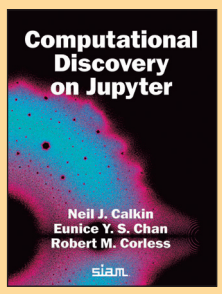


Jiawang Nie

Moment and polynomial optimization is an active research field used to solve difficult questions in many areas, including global optimization, tensor computation, saddle points, Nash equilibrium, and bilevel programs, and it has many applications. Synthesizing current research and applications, this book provides a systematic introduction to theory and methods, a comprehensive approach for extracting optimizers and solving truncated moment problems, and a creative methodology for using optimality conditions to construct tight Moment-SOS relaxations.

2023 / xvi + 467 pages / Hardcover / 978-1-61197-759-2
List $94.00 / SIAM Member $65.80 / MO31

Computational Discovery on Jupyter



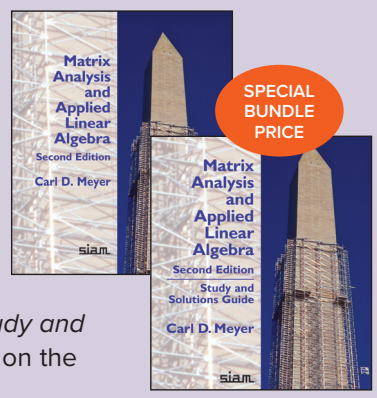
Neil J. Calkin, Eunice Y. S. Chan, and Robert M. Corless

This book uses Python to teach mathematics not found in the standard curriculum, so students learn a popular programming language as well as some interesting mathematics. Videos, images, programs, programming activities, pencil-and-paper activities, and associated Jupyter Notebooks accompany the text, and readers are encouraged to interact with and extend the material as well as contribute their own notebooks.

2023 / xvi + 385 pages / Softcover / 978-1-61197-749-3
List $84.00 / SIAM Member $58.80 / OT190

Recently Published

Matrix Analysis and Applied Linear Algebra, *Second Edition*

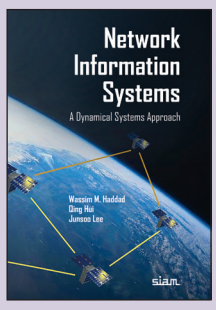


Carl D. Meyer

This second edition has been almost completely rewritten to create a textbook designed to provide flexibility for nearly any desired degree of rigor and depth of coverage. This is achieved with a linear development ensuring that material at any point is not dependent on subsequent developments and by means of graduated levels of sophistication. An accompanying book, *Matrix Analysis and Applied Linear Algebra, Second Edition, Study and Solutions Guide*, contains complete solutions and discussions of each exercise; and historical remarks that focus on the personalities of the individuals who created and contributed to the subject's development.

Textbook: 2023 / x + 999 pages / Hardcover / 978-1-61197-743-1 / List $104.00 / SIAM Member $99.54 / OT188
Solutions and Study Guide: 2023 / vi + 250 pages / Softcover / 978-1-61197-745-5 / List $54.00 / SIAM Member $37.80 / OT189
Bundle: 978-1-61197-770-7 / List $142.20 / SIAM Member $99.54 / MEYERSET

Network Information Systems
A Dynamical Systems Approach

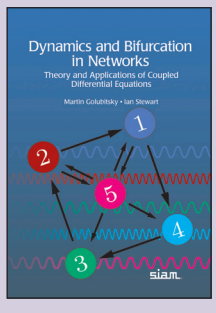


Wassim M. Haddad, Qing Hui, and Junsoo Lee

This text presents a unique treatment of network control systems. Drawing from fundamental principles of dynamical systems theory and dynamical thermodynamics, the authors develop a continuous-time, discrete-time, and hybrid dynamical system and control framework for linear and nonlinear large-scale network systems. The proposed framework extends the concepts of energy, entropy, and temperature to undirected and directed information networks. Continuous-time, discrete-time, and hybrid thermodynamic principles are used to design distributed control protocol algorithms for static and dynamic networked systems in the face of system uncertainty, exogenous disturbances, imperfect system network communication, and time delays.

2023 / xiv + 622 pages / Hardcover / 978-1-61197-753-0 / List $114.00 / SIAM Member $79.00 / OT191

Dynamics and Bifurcation in Networks
Theory and Applications of Coupled Differential Equations



Martin Golubitsky and Ian Stewart

In recent years there has been an explosion of interest in network-based modeling in many branches of science. This book attempts a synthesis of some of the common features of many such models, providing a general framework analogous to the modern theory of nonlinear dynamical systems. How networks lead to behavior not typical in a general dynamical system and how the architecture of the network influences this behavior are the book's main themes.

2023 / xxx + 834 pages / Hardcover / 978-1-61197-732-5 / List $129.00 / SIAM Member $90.30 / OT185

To order, visit the SIAM bookstore at *bookstore.siam.org*
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siam | CONFERENCES

A Place to Network and Exchange Ideas

Upcoming Deadlines

Conference on Uncertainty Quantification (UQ24)

February 27–March 1, 2024 | Trieste, Italy
go.siam.org/uq24 | #SIAMUQ24

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SUBMISSION AND TRAVEL AWARD DEADLINES
September 11, 2023: Minisymposium Proposal Submissions
October 2, 2023: Contributed Lecture, Poster, & Minisymposium Presentation Abstracts
November 27, 2023: Travel Fund Application Deadline

International Conference on Data Mining (SDM24)

April 18–20, 2024 | Houston, Texas, U.S.
go.siam.org/sdm24 | #SIAMSDM24

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SUBMISSION AND TRAVEL AWARD DEADLINES
September 15, 2023: Abstract Submissions
September 22, 2023: Full Paper and Blue Sky Idea Submissions
October 6, 2023: Workshop and Tutorial Proposals
January 18, 2024: Travel Fund Application Deadline

Conference on Applied Linear Algebra (LA24)

May 13–17, 2024 | Paris, France
go.siam.org/la24 | #SIAMLA24

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SUBMISSION AND TRAVEL AWARD DEADLINES
October 16, 2023: Minisymposium Proposal Submissions
November 13, 2023: Contributed Lecture, Poster, & Minisymposium Presentation Abstracts
February 13, 2024: Travel Fund Application Deadline

Conference on Mathematical Aspects of Materials Science (MS24)

May 20–23, 2024 | Pittsburgh, Pennsylvania, U.S.
go.siam.org/ms24 | #SIAMMS24

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Petronela Radu, *University of Nebraska Lincoln, U.S.*

SUBMISSION AND TRAVEL AWARD DEADLINES
October 23, 2023: Submission of Minisymposium Proposals
November 20, 2023: Contributed Lecture, Poster, & Minisymposium Presentation Abstracts
February 20, 2024: Travel Fund Application Deadline

Conference on Imaging Science (IS24)

May 28–31, 2024 | Atlanta, Georgia, U.S.
go.siam.org/is24 | #SIAMIS24

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SUBMISSION AND TRAVEL AWARD DEADLINES
October 30, 2023: Minisymposium Proposal Submissions
November 27, 2023: Contributed Lecture, Poster, & Minisymposium Presentation Abstracts
February 28, 2024: Travel Fund Application Deadline

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Information is current as of August 7, 2023. Visit *siam.org/conferences* for the most up-to-date information.

Upcoming SIAM Events

ACM-SIAM Symposium on Discrete Algorithms
January 7–10, 2024
Alexandria, Virginia, U.S.
Sponsored by the SIAM Activity Group on Discrete Mathematics and the ACM Special Interest Group on Algorithms and Computation Theory

SIAM Symposium on Algorithm Engineering and Experiments
January 7–8, 2024
Alexandria, Virginia, U.S.

SIAM Symposium on Simplicity in Algorithms
January 8–9, 2024
Alexandria, Virginia, U.S.

SIAM Conference on Uncertainty Quantification
February 27–March 1, 2024
Trieste, Italy
Sponsored by the SIAM Activity Group on Uncertainty Quantification

SIAM Conference on Parallel Processing for Scientific Computing
March 5–8, 2024
Baltimore, Maryland, U.S.
Sponsored by the SIAM Activity Group on Supercomputing

SIAM International Meshing Roundtable Workshop
March 5–8, 2024
Baltimore, Maryland, U.S.

SIAM International Conference on Data Mining
April 18–20, 2024
Houston, Texas, U.S.
Sponsored by the SIAM Activity Group on Data Science

SIAM Conference on Applied Linear Algebra
May 13 –17, 2024
Paris, France
Sponsored by the SIAM Activity Group on Linear Algebra

SIAM Conference on Mathematical Aspects of Materials Science
May 20–23, 2024
Pittsburgh, Pennsylvania, U.S.
Sponsored by the SIAM Activity Group on Mathematical Aspects of Materials Science

SIAM Conference on Imaging Science
May 28–31, 2023
Atlanta, Georgia, U.S.
Sponsored by the SIAM Activity Group on Imaging Science

2024 SIAM Annual Meeting
July 8–12, 2024
Spokane, Washington, U.S.

SIAM Conference on Applied Mathematics Education
July 8–9, 2024
Spokane, Washington, U.S.
Sponsored by the SIAM Activity Group on Applied Mathematics Education

SIAM Conference on Discrete Mathematics
July 8–11, 2024
Spokane, Washington, U.S.
Sponsored by the SIAM Activity Group on Discrete Mathematics