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New Mathematical Developments Drive Innovations in Bioartificial Organ Design

By Sunčica Čanić and Yifan Wang

Bioartificial organ design combines biology, engineering, and mathematics to create functional implants that support or replace natural human organs. The practice utilizes an approach called *cell encapsulation*, which embeds therapeutic cells in a poroelastic scaffold and encloses them in a semi-permeable membrane (see Figure 1). This process protects cells from immune rejection while allowing for nutrient and oxygen exchange, ultimately enabling long-term function without immunosuppression (e.g., in a bioartificial pancreas for the treatment of diabetes).

Ensuring cell survival over time is a major challenge, especially given the limited availability of oxygen — the key factor that affects viability. Scaffold elasticity, porosity, and architecture strongly impact oxygen and nutrient transport; to account for this influence, recent designs use vertically drilled ultrafiltrate channels to improve oxygen delivery to cells in the poroelastic scaffold. Unfortunately, hypoxic regions persist [3].

This limitation highlights the need for advanced mathematical approaches that optimize scaffold design to enhance oxygen delivery. A robust model that properly addresses this requirement must capture the following three elements: (i) the flow of blood plasma and oxygen transport within the poroelastic scaffold, (ii) the scaffold's encapsulation within semi-permeable poroelastic membranes or plates, and (iii) the encapsulated scaffold's integration with a vascular graft that delivers oxygen-rich blood to the transplanted cells while removing insulin and metabolic waste.

Figure 1a depicts a bioartificial pancreas implant in a patient's arm. An anastomotic graft connects the encapsulated scaffold—which houses insulin-producing β cells—to the patient's vasculature. Accurate modeling of fluid-structure interaction (FSI) between blood flow in the graft and blood plasma filtration through the poroelastic encapsulating membrane and scaffold helps predict oxygen delivery and capture the bioartificial pancreas's mechanistic function.

The Mathematical Approach

To study cell encapsulation, we are developing a comprehensive multiscale and multiphysics framework that incorporates state-of-the-art mathematical and computational methods. The framework utilizes the following four modules:

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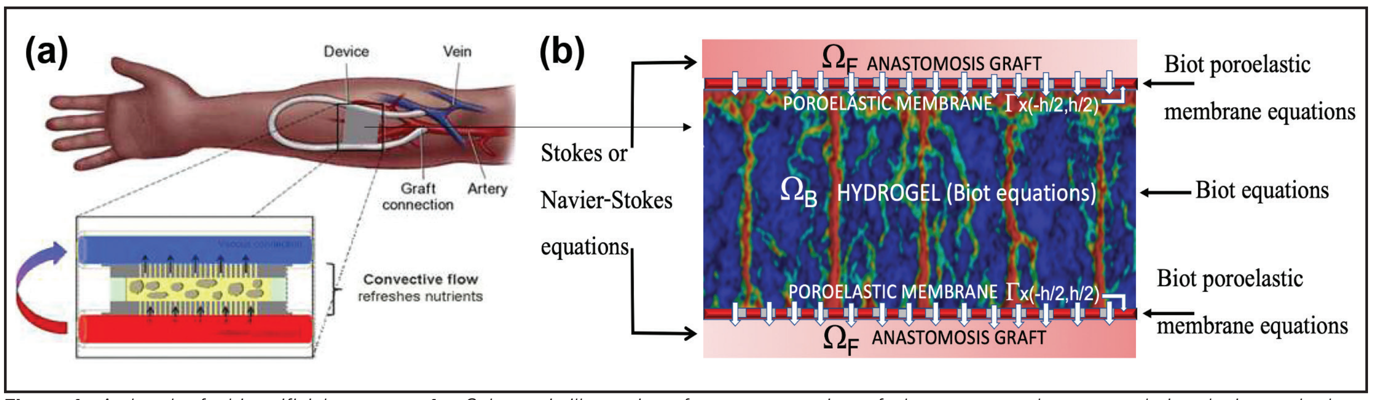

Figure 1. *A sketch of a bioartificial pancreas.* **1a**. *Schematic illustration of an anastomosis graft that connects the encapsulation device to the host vasculature.* **1b.** *Encapsulation device that depicts the poroelastic hydrogel scaffold, encapsulating membranes, and part of the anastomosis graft. Figure 1a courtesy of Shuvo Roy and 1b courtesy of Sunčica Čanić.*

Mixed-precision Computing: High Accuracy With Low Precision

By Erin Carson and Theo Mary

Mixed-precision algorithms have launched an era in which efficiency and accuracy are no longer mutually exclusive. *Mixed-precision arithmetic* refers to the use of numbers of varying bit widths within a single computation or across different stages of an algorithm. Rather than rely entirely on high-precision formats like double (64-bit) precision, mixed-precision algorithms apply lower precisions—such as single (32-bit) or half (16-bit) precision—whenever possible, reserving higher precision only for critical steps. Doing so can drastically reduce memory requirements, improve performance, and lessen energy consumption on modern computer hardware without sacrificing accuracy or stability.

Computers have a finite number of bits for storage and computation. The industry standard—established in the 1980s by the Institute of Electrical and Electronics Engineers (IEEE)—is IEEE floating-point numbers. We can represent a base-2 floating-point number as $(-1)^{\text{sign}} \times 2^{\text{exponent-offset}} \times 1.\text{fraction}$, with 1 bit for the sign field and some number of bits for the exponent and fraction fields (see Figure 1). The number of exponent bits determines the range $\pm[f_{\min}, f_{\max}]$ of representable numbers, and the number of fraction bits determines the unit roundoff u: the relative precision with which numbers are stored. Virtually all current computers utilize this system.

Motivated by machine learning applications, modern graphics processing units (GPUs) now support multiple types of precisions—e.g., double, single, and half precision—as well as non-IEEE standard formats such as bfloat16, TensorFloat-32 (tf32), and variants of quarter (8-bit) precision. In fact, artificial intelligence (AI) applications have resulted in more devoted chip space for low-precision computations, which means that the potential speedups are superlinear in terms of the number of bits.

Mixed-precision hardware in supercomputers is a growing trend, with a steady increase in the TOP500 rankings[1] of systems that use mixed-precision accelerators. Therefore, ignoring the availability of low-precision hardware during algorithm development is akin to leaving potential performance on the table. In today's world, we must rethink our algorithms to determine when and where different precision formats can improve performance while still maintaining accuracy and stability. Of course, doing this in an effective, rigorous way involves numerous challenges.

[1] https://top500.org/lists/top500

	Signif. bits	Exp. bits	Range ($f_{\max}/f_{\min}$)	Unit roundoff u
fp128	113	15	$2^{32766} \approx 10^{9863}$	$2^{-114} \approx 1 \times 10^{-34}$
fp64	52	11	$2^{2046} \approx 10^{616}$	$2^{-53} \approx 1 \times 10^{-16}$
fp32	23	8	$2^{254} \approx 10^{76}$	$2^{-24} \approx 6 \times 10^{-8}$
tf32	10	8	$2^{254} \approx 10^{76}$	$2^{-11} \approx 5 \times 10^{-4}$
fp16	10	5	$2^{30} \approx 10^{9}$	$2^{-11} \approx 5 \times 10^{-4}$
bfloat16	7	8	$2^{254} \approx 10^{76}$	$2^{-8} \approx 4 \times 10^{-3}$
fp8 (E4M3)	3	4	$2^{15} \approx 3 \times 10^{4}$	$2^{-4} \approx 6 \times 10^{-2}$
fp8 (E5M2)	2	5	$2^{30} \approx 10^{9}$	$2^{-3} \approx 1 \times 10^{-1}$
fp6 (E2M3)	3	2	$2^{3} \approx 8$	$2^{-4} \approx 6 \times 10^{-2}$
fp6 (E3M2)	2	3	$2^{7} \approx 128$	$2^{-3} \approx 0.125$
fp4 (E2M1)	1	2	$2^{3} \approx 8$	$2^{-2} \approx 0.25$

Figure 1. *Floating-point number formats. Figure courtesy of the authors.*

Challenges of Low/Mixed Precision

The need for tight descriptive error bounds and adaptive approaches: When utilizing low and mixed precision, we need to ensure that computational errors remain controlled and predictable. Doing so necessitates the use of (mixed) finite-precision rounding error analysis to develop error bounds that provide guidance on precision configuration in different parts of the computation. For many relatively simple algorithms, such as direct solvers for dense linear systems, we can extend established techniques to accomplish this goal. But when dealing with complex, real-world applications, it is much harder to track the accumulation of rounding errors and their amplification of other errors throughout a large code base.

In any case, the obtained error bounds are data dependent according to problem dimension, conditioning, the norms of various involved quantities, and so forth. Since we often do not know these properties until runtime (and maybe not even then), it is frequently impossible to choose the correct precisions *a priori*. This limitation requires *adaptive* approaches that dynamically adjust precisions based on input and/or monitoring throughout the computation.

The (in)validity of error bounds for large-scale applications: Bounds on backward and forward errors typically only hold under certain constraints and often take forms like $nu < 1$. In the context of low precision for large-scale computations, such constraints can be problematic. Here, the potentially large size of both n and u means that these constraints may not hold and error bounds that are derived in the traditional way might not be valid.

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A Peek Into the EDGE Experience: Reflections From the 2025 SIAM EDGE Fellow

By Cheyene Henry

My journey towards a career in mathematics is truly something that I never could have imagined. During my junior year at Howard University, I switched my major from chemistry to mathematics and immersed myself in the mathematical community. My current reality as a recent graduate with a B.S. in mathematics is far from how I had originally envisioned my postgraduate life as a chemist, but in the best way. This auspicious change is due in part to all of the wonderful people that I've met along the way, my willingness to embrace unexpected challenges, and my perpetual stubbornness and resilience in the face of adversity.

I must admit that my confidence during the graduate school application process was initially low. I was riddled with self-doubt and missed a lot of wonderful opportunities by preemptively counting myself out. Because I didn't focus on mathematics until well into my undergraduate years, I believed that my mathematical maturity wasn't developed enough for graduate school; I even considered taking a gap year and gaining additional experience to make myself a stronger candidate. Yet despite my insecurities, I applied to several graduate programs in applied mathematics, committed to pursuing my Ph.D. at Howard, and tried to conceptualize a rough idea of what my future might look like.

One piece of advice that I've always held close is courtesy of Rebecca Betensky and Vardia Duterville of New York University's Pathways to Quantitative Aging Research Summer Program.[1] When I participated in the 2024 program, they urged me to go to as many conferences as possible and build meaningful connections. So when I was fretting about my career decisions, I took their advice. In January 2025, I attended the Joint Mathematics Meetings[2] (JMM) in Seattle, Wash., where I met a few women who had completed the Enhancing Diversity in Graduate Education[3] (EDGE) Summer Program.[4] They spoke about how EDGE had become a beacon in their career endeavors and encouraged me to apply. On January 15 (coincidentally, my birthday), I had my first direct interaction with the EDGE community when I was invited to an EDGE webinar[5] by Shakuan Frankson of the U.S. Census Bureau (and participant of the 2020 EDGE Summer Program) titled "The Power of Community: Learning From EDGE Alumni." This webinar introduced me to all of the "Women Math Warriors" who have flourished professionally since their involvement with EDGE. They talked about their respective journeys and detailed the ways in which EDGE helped them advance. This praise from the webinar—along with the positive remarks from JMM attendees and the encouragement of Dennis Davenport, my advisor at Howard—convinced me to apply to the 2025 EDGE Summer Program.[6]

Student participants and mentors of the 2025 Enhancing Diversity in Graduate Education Summer Program—which was held in June at the University of Tennessee, Knoxville—explore campus during a daily walk and gather for a group photo with Smokey, the official mascot of the university. Author Cheyene Henry is second from left in the bottom row. Photo courtesy of the author.

Cheyene Henry, a first-year Ph.D. student in mathematics at Howard University, is the 2025 SIAM Enhancing Diversity in Graduate Education (EDGE) Fellow. She attended the 2025 EDGE Summer Program, which took place in June at the University of Tennessee, Knoxville. Photo © Steve Myaskovsky and courtesy of the NYU Photo Bureau.

I still remember the day that I got the email about my acceptance to EDGE. I was in the checkout line at the grocery store and was immediately overcome with excitement and validation that I'd made the right career decision in pursuing mathematics.

On June 1, I made my way to the University of Tennessee, Knoxville, for my monthlong stint as an EDGE scholar. On the first day, I was full of nervous jitters as I looked around at my fellow cohort members, mentors, instructors, and local hosts. A defining tenet of EDGE is learning to vocalize your identity in the mathematical world. As such, we were immediately asked to each pick an animal—lion, squirrel, whale, or eagle—that we felt represented us as mathematicians. I selected an eagle, since they soar high in the sky and explore a lot of ground from a bird's-eye view but can swoop down and become nestled in reality when something catches their attention.

The first two weeks of the program were the most intimidating. I like to joke that EDGE is similar to graduate school, but with 100 times the intensity. Our lives were full of proofs for real analysis and "linear a-bstract-lgebra," as our instructor Catherine Buell of Fitchburg State University would say. We spent our nights working through homework assignments, leaving us with just enough sleep to make it to lectures the next morning. Although the rigorous schedule was an adjustment for all of us, we quickly learned how to prioritize difficult tasks and lean on each other for help.

At first, I thought that constantly asking questions and seeking clarification at study sessions was a sign of weakness. I was worried about being judged or seeming like I didn't belong. But I soon realized that this insecurity was all in my head — my curiosity and willingness to step outside of my comfort zone made me a better mathematician. As we transitioned to more advanced courses in MATLAB, numerical analysis, and measure theory, we found a balance and encouraged each other to learn to the best of our abilities during our short time at Knoxville. We closed out the program with final presentations, and it was amazing to witness and reflect on all of our achievements as both individuals and a collective. Personally, I chose to apply a numerical analysis concept to a classic game in game

See **SIAM EDGE Fellow** *on page 5*

1 https://publichealth.nyu.edu/department/biostatistics/pathways-quantitative-aging-research-summer-program
2 https://jointmathematicsmeetings.org/meetings/national/jmm2025/2314_intro
3 https://www.edgeforwomen.org
4 https://www.edgeforwomen.org/summer-session
5 https://www.edgeforwomen.org/edge-webinar
6 https://www.edgeforwomen.org/summer-session/edge-2025-participants

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Bioartificial Organ Design

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(I) A *macroscale FSI module* models the interaction between blood flow through the anastomosis graft—via the Stokes or Navier-Stokes equations—and the encapsulated poroelastic scaffold (see Figure 1b, on page 1). We represent the encapsulated organ as a multilayered poroelastic medium that comprises a thin membrane (modeled via reduced Biot membrane/plate equations [8]) and a thick poroelastic hydrogel scaffold (modeled via nonlinear Biot equations [10]). Both Biot components track pore pressure, Darcy velocity, and structural displacement. Permeability coefficients depend on microstructure [1, 4, 10]; two-way coupling conditions link the fluid and poroelastic subproblems [1, 7].

Our mathematical analysis establishes the existence and stability of weak finite-energy solutions for this new FSI model, advancing the theory of FSI with poroelastic media [1, 6]. These weak solutions serve as the backbone for finite element method (FEM)-based computational solvers. To simulate the model, we developed both monolithic and partitioned schemes [9, 10] that produce fluid velocity and poroelastic structure displacement, which feed into oxygen transport modeling.

(II) A *macroscale advection-reaction-diffusion module* uses advection-reaction-diffusion equations to characterize oxygen- and glucose-dependent insulin release within the encapsulated poroelastic hydrogel. It links microscale processes like oxygen consumption and insulin secretion to macroscale transport; the fluid velocities from the previous module drive advection. We define the equations on moving domains; incorporate hydrogel poroelasticity, which significantly affects transport; and generate a novel FEM-based solver to efficiently simulate the fully coupled system [10].

(III) A *micro/nanoscale module* employs smoothed-particle hydrodynamics (SPH) to model local hydrogel structure/architecture and plasma filtration at the micro/nanoscale. These simulations allow us to recover the spatially varying macroscale permeability tensor for use in the aforementioned FSI model [10].

(IV) An *artificial intelligence module* utilizes an encoder-decoder convolution neural network (CNN) to efficiently estimate macroscale properties—such as the spatially varying permeability tensor—from micro/nanoscale hydrogel simulations. Instead of running costly SPH simulations online, we train the CNN on synthetic data *offline* to rapidly predict permeability for new architectures — including those from fabricated hydrogels. The predicted permeability tensor parameters feed into the FSI model, influencing oxygen transport results.

Results

Using the four modules, we developed FEM-based solvers [2, 9, 10] to simulate blood flow and oxygen transport in an implantable bioartificial pancreas (iBAP) prototype manufactured in the Biodesign Laboratory at the University of California, San Francisco. Figure 2a depicts the iBAP prototype during implantation in a porcine model. The device connects to an artery for blood inlet and to a vein at the outlet; pressure difference drives flow through the channel. Semipermeable silicon membranes connect the channel to poroelastic scaffolds (i.e., islet chambers) and filter plasma into the hydrogel scaffold, where transplanted islets absorb nutrients and release insulin.

Figure 2b illustrates simulated flow through one chamber. The results of our FSI solver and scaffold microarchitecture data reveal strong filtration flow near the membranes/inlet and drilled channels, suggesting that oxygen levels are highest in these regions. Indeed, simulations with the advection-reaction-diffusion solver indicate a high oxygen concentration near the inlet and vertical channels, with hypoxic regions near the outlet where oxygen falls below the survival threshold (see Figures 2c and 2d).

To improve oxygen concentration in the cell chamber, we investigated different hydrogel scaffold architectures and produced an architecture with ultrafiltrate channels that provides oxygen concentration that is (i) as uniform as possible throughout the scaffold and (ii) above the minimum concentration at which hypoxia occurs. For this purpose, we developed a computational algorithm that employs a diffuse interface approach to solve the corresponding multiphysics problem that couples the time-dependent Stokes equations—which govern blood plasma flow through the channel network—with the time-dependent Biot equations, which characterize the Darcy velocity of blood plasma, pressure, and displacement within the poroelastic hydrogel scaffold. We subsequently utilized the calculated plasma velocity to determine oxygen concentration within the scaffold via a diffuse interface advection-reaction-diffusion model [2].

Next, we considered three scaffold architectures that are inspired by biological flow-nutrient scenarios: (i) vertical ultrafiltrate channels, the standard in bioartificial pancreas design; (ii) bifurcating channels that are modeled after vascular branching; and (iii) hexagonal channels that mimic interstitial flow in epithelial tissues. For the sake of comparison, we generated all geometries with the same total channel volume. Figure 3 shows velocity and oxygen concentration for the three cases. Most flow in vertical channels occurs within the channels, leaving hypoxic regions in between. In bifurcating networks, higher velocities appear in the first two generations of branches, leading to improved but still incomplete oxygenation between vessels. Channels in the *hexagonal geometry* (see Figure 3) have the smallest radius, the highest fluid velocity, and are uniformly distributed throughout the scaffold. The resulting Darcy velocity is consequently significant across the entire poroelastic hydrogel, yielding a nearly uniform oxygen distribution that is well above the critical threshold. This outcome ensures adequate oxygen delivery throughout the hydrogel and sustains normal insulin production.

Ultimately, our findings indicate that hydrogel scaffolds with hexagonal geometry (extruded in the third dimension) are more effective than the conventional vertical channel designs in current hydrogel architectures. These results are particularly significant given recent advances in hydrogel fabrication, which now permit the fine-tuned modulation of hydrogel rheological properties [5] and enable the translation of computational predictions into physically optimized scaffold designs.

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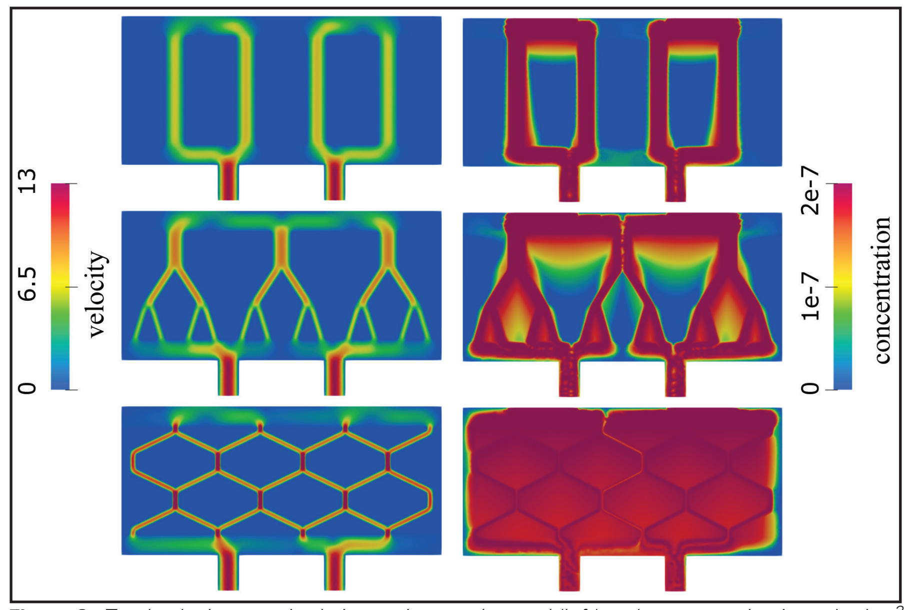

Figure 3. *Total velocity magnitude in centimeters/second (left) and concentration in moles/cm^3 (right) within a network that consists of straight channels (top), bifurcating channels (middle), and a hexagonal geometry (bottom). Figure courtesy of the authors.*

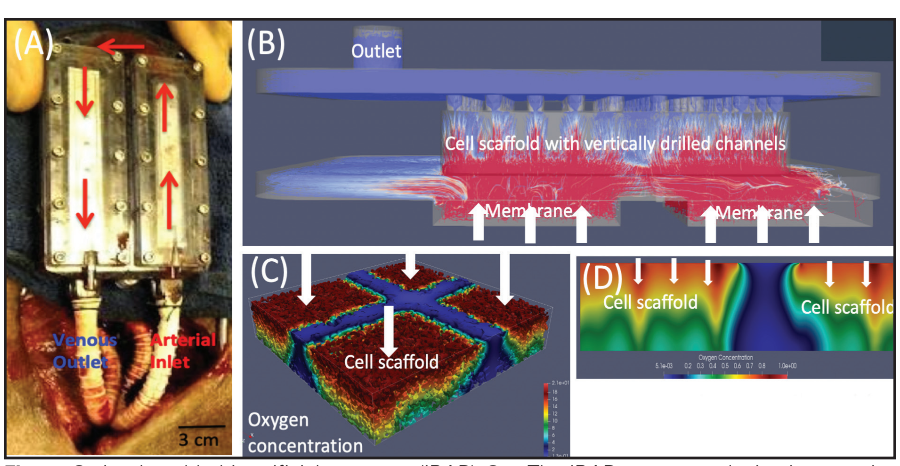

Figure 2. *Implantable bioartificial pancreas (iBAP).* **2a.** *The iBAP prototype device in a porcine model.* **2b.** *Streamlines that depict flow direction and magnitude. Red indicates a high level of flow, and white and blue indicate low levels.* **2c.** *A three-dimensional (3D) simulation of oxygen concentration in the scaffold. Red signifies a high level of oxygen, and cyan and blue signify low levels.* **2d.** *A two-dimensional slice of the 3D simulation in 2c. White arrows denote flow direction. Figure 2a courtesy of Shuvo Roy and 2b-2d courtesy of Sunčica Čanić.*

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Mixed-precision Computing

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Interestingly, rounding error bounds are typically quite loose. As such, the algorithm output regularly satisfies the error bounds despite violation of the theorem constraints. This reality has motivated many researchers to rely on methods that derive tighter error bounds, e.g., via probabilistic rounding error analysis [3].

Working with a limited range: Most analyses of algorithm accuracy and stability assume that no overflow or underflow occurs. In the IEEE 754 standard, overflow and underflow mean that numerical values respectively become $\pm\infty$ or 0. While this assumption might be reasonable for double precision, overflow and underflow happen much more frequently in lower precisions.

We can address this challenge by developing procedures that avoid errors in the first place, such as a sophisticated scaling and/or shifting technique to "squeeze" matrix entries within a given range. The right scaling factors may not be obvious; in Gaussian elimination, for example, we should scale according to the pivot growth factor, which is often not immediately evident.

Another difficulty stems from the software engineering aspect. Users must carefully implement code to detect and resolve errors as they occur. While the detection of overflow is usually straightforward, recognizing underflow may be more difficult because it is not always clear whether a number should *actually* be 0. In some cases, underflow is benign; in others, it can cause algorithms to fail due to loss of matrix properties like nonsingularity or positive definiteness.

When Mixed Precision Makes Sense

The use of mixed precision is natural in a number of common cases.

When a self-correction mechanism is available: The prototypical example of algorithms that have a natural self-correction mechanism is iterative refinement for the solution of linear systems. Given an initial approximate solution x_i to $Ax=b$, iterative refinement repeatedly evaluates the residual $r_i=b-Ax_i$, solves $Ad_i=r_i$, and constructs the next approximate solution $x_{i+1}=x_i+d_i$. A key point is that the solve for d_i need not be especially accurate; to guarantee convergence, it only has to make *some* forward progress. Therefore, we can often utilize lower precision in this part of the computation. Many other algorithms also have self-correction mechanisms, which are often characterized by inner-outer solve schemes [4, sections 5-8].

When finite-precision error is small compared to other sources of error: Real-world applications involve a variety of errors: (i) errors from modeling, discretization, and measurement; (ii) approximation errors from low-rank approximation, sparsification, and randomization; and (iii) truncation errors due to the use of stopping criteria in iterative methods. With all of these errors, we may wonder whether it is truly necessary to solve problems to such a high level of accuracy — we might be solving the wrong problem anyway.

To fully understand the lowest feasible level of precision, we must recognize the magnitude of the other errors at play; increasingly large errors mean that an increasingly low precision may be suitable. For example, consider the computation of a rank-k approximation of a matrix A. If we only want a very rough approximation where k is relatively small, then we can often perform the entire computation in lower precision. The difference between A and its low-rank approximation A_k could be the same order of magnitude regardless of precision type, since the error due to low-rank approximation will dominate.

When the computation naturally contains less sensitive subparts: Mixed precision is natural in computations that comprise subparts with intrinsically different sensitivity. In this case, a subpart's sensitivity depends on the way in which a local error in the subpart affects the accuracy of the global computation. Such sensitivity may take different forms based on the application; a few concrete examples of things that can be stored in lower precision include elements of a matrix if their magnitudes are sufficiently small, singular vectors if their associated singular values are sufficiently small, and diagonal blocks if their condition numbers are sufficiently small. For all of these examples, the potential use of lower precision completely depends on the data. To leverage this potential, we must hence develop adaptive precision algorithms that dynamically select each subpart's precision at runtime. And since the variations in sensitivity are often continuous, we can better adapt to the problem if more precision formats are available [4, section 14].

When low-precision hardware can efficiently emulate high precision: Motivated by deep learning applications, the computational power of current supercomputers comes almost entirely from GPU accelerators with specialized computing units—such as NVIDIA tensor cores—that are tailored for matrix multiplication in extremely low precision (e.g., 16- or even 8-, 6-, or 4-bit).

While these precisions are very low, they are also very fast; for instance, 8-bit arithmetic is more than 100 times faster than 64-bit arithmetic on NVIDIA Blackwell GPUs. This speed has motivated a new class of mixed-precision algorithms that *emulate* high-precision matrix multiplication based on low-precision units. The main idea is to split the matrices into multiple "words" that are stored in lower precision. For example, we can represent an fp32 matrix (24 fraction bits) as the sum of three bfloat16 matrices (8 fraction bits each). We then reconstruct the result from the individual word products. The number of required products can span three to several dozen depending on the precisions in question, the emulation algorithm, and the dynamical range of the matrix elements [4, section 13].

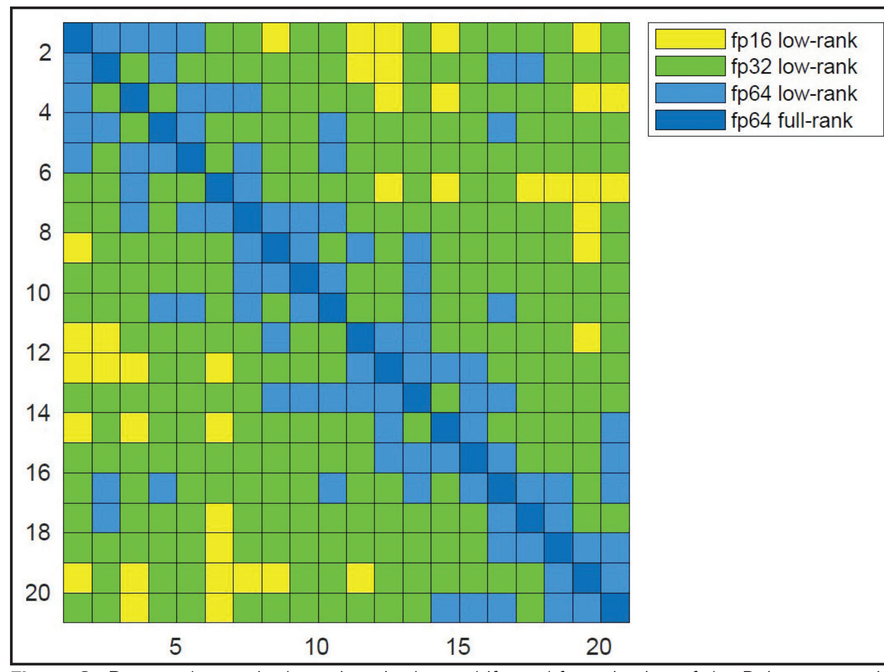

Figure 2. *Root node matrix that arises in the multifrontal factorization of the Poisson equation on a* 70^3 *domain. The resulting* 20×20 *block matrix has a mixed-precision block low-rank property, in that many of its off-diagonal, low-rank blocks can be stored in lower precisions without affecting the overall error (bounded by* $\varepsilon=10^{-10}$*). Figure courtesy of the authors.*

When data transfers are the bottleneck: The volume of data transfers between processors or levels of the memory hierarchy strongly influences performance in many applications. Thus, a natural strategy to accelerate these memory-bound applications is to store the transferred data in lower precision. It is sometimes meaningful to decouple this lower storage precision from the compute precision, which remains high to preserve accuracy. In particular, the storage precision has no effect on rounding error accumulation. Decoupling the storage and compute precisions necessitates the development of *memory accessors*, which access the stored data in low precision and convert it to high precision for the purpose of computation. Besides reducing error accumulation, this type of approach does not require the storage precision to be a standard, hardware-supported arithmetic because it is not used in computations. We can therefore employ custom data formats—such as floating point with truncated fraction and/or exponent—that provide more flexibility when tuning the storage-accuracy tradeoff [1, section 4.3].

Impact on Applications

Figure 2 illustrates the mixed-precision opportunities that arise in the block low-rank approximation of a dense matrix. Specifically, off-diagonal blocks exhibit rapidly decaying singular values and are thus amenable to both low-rank truncation and reduced precision, all while preserving high accuracy relative to the entire matrix. Researchers have used this mixed-precision method in both dense and sparse direct solvers, resulting in significant storage and performance gains in climate and geoscience applications [2, 5]. For instance, the method led to a 3× reduction in storage requirements, allowing for the solution of a system with nearly 500 million unknowns — one of the largest real-world problems ever solved by a direct solver [5]. This is merely one example of the potential of mixed-precision algorithms, which users have successfully employed in many other application fields.

Ultimately, we believe that a significant opportunity exists for a broad set of algorithms and scientific applications to benefit from the use of mixed precision. We end by asking readers to consider where they can potentially use less than the standard double precision to improve performance in their own computations.

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SIAM EDGE Fellow

Continued from page 2

theory; this project allowed me to improve my proficiency in MATLAB and create my first Beamer presentation, both goals that I had hoped to achieve during the summer.

In addition to the skills that I gained, the bonds I formed with other members of my cohort are truly invaluable, and I will cherish them long into my career. I genuinely could not have picked a better set of people with whom to experience EDGE. While there were so many wonderful moments, one memory that stands out is our first group huddle as a cohort — courtesy of fellow participant Amira Claxton of the University of Texas at Arlington (who, incidentally, participated in the inaugural SIAM-Simons Undergraduate Summer Research Program[7] in 2023). Before that point, most of us were struggling in silence and just trying to make it through; being vulnerable with each other brought us closer together and changed the trajectory of the following weeks. On our last day, we parted with a group hug and a much-needed reflective chat. This moment solidified our connection outside of mathematics and makes me especially excited for Reunion Weekend! The thought of once again doing the "Women Math Warrior dance"—created by EDGE President Ami Radunskaya of Pomona College—keeps me motivated.

As a cohort, many things defined our bond: Jason's Deli ice cream, personality tests, the card game Exploding Kittens, and binge-watching Love Island. Our genuine friendships augmented our approach to learning, which evolved into a group endeavor with mutual gain. Being able to rely on each other became second nature, and the imagined guilt of burdening the rest of the cohort faded away. We all wanted each other to not only succeed, but truly understand. This dynamic was so beneficial, and I really hope to recreate it in graduate school.

EDGE has both reshaped me as a student and exposed me to a variety of teaching styles that I intend to emulate one day. The lecturers went above and beyond, and each instructor embodied certain traits that I have since implemented as a teaching assistant at Howard. For example, Noelle Sawyer of Southwestern University was an absolute comedian and continuously started her sessions in high spirits, posing a new question every day. Catherine Buell was so patient during office hours and always offered a useful example to further my understanding of a concept. Erica Graham of Bryn Mawr College lectured with engagement, approached questions with compassion, and offered great advice. And Jenna Zomback of the University of Maryland has one of the best board workups that I've ever seen, which is a total inspiration. Each of the four faculty members left a sizeable impression on me; it was a privilege to learn from women in mathematics, especially since that has been such a rarity throughout my schooling.

In addition to the spectacular instructors, we also had amazing directors. Candice Price of Smith College and Alison Marr of Southwestern University, co-directors of the EDGE Summer Program, were lovely to be around; our lunches with them were simply the best. They made genuine efforts to understand and uplift each of us, and I honestly could not have asked for more from either of them. At the end of the program, I was honored to learn that the directors and faculty had selected me as the 2025 SIAM Edge Fellow.

As I embark upon my first year as a Ph.D. student at Howard, it has been challenging to develop a routine and manage the many responsibilities of graduate school. But I can confidently say that without EDGE, this adjustment process would have been much harder. During the EDGE Summer Program, I demonstrated a level of resilience that I didn't even know I had. EDGE helped me realize that I can dedicate myself to my studies, produce great work, and facilitate a sense of community among my peers. I learned that even when assignments are difficult, my drive and support network will push me towards the finish line. EDGE has equipped me with the necessary tools to succeed as both an aspiring mathematician and a young professional in control of my future.

I am beyond thankful to have had the privilege of experiencing EDGE this past summer. Being recognized as the SIAM EDGE Fellow is certainly a high honor, and it's a pleasure to know that my effort, intellect, and personality shone though. It was even sweeter to receive this acknowledgment the same year that I reinstated the Howard University SIAM Student Chapter[8] as the former undergraduate president. I look forward to continuing my involvement with the SIAM community—perhaps by attending a future SIAM conference—and want my story to inspire other students to not count themselves out and always accept new adventures that offer the chance for learning and growth. If you're a young woman who is working towards a Ph.D. in mathematics, then EDGE is the place to be. I can't wait to see what my future career will look like; I know it will be fruitful due to the wonderful mathematical family that I'm building today. I'm so grateful that EDGE has become an integral part of my journey.

Cheyene Henry is a first-year Ph.D. student in mathematics at Howard University. She earned her B.S. in mathematics with a minor in chemistry from Howard in 2025. Henry's research explores the interdisciplinary application of mathematical principles to problems in biostatistics, game theory, and theoretical fusion. She is also dedicated to fostering diversity and mentorship within the mathematical sciences.

[7] https://www.siam.org/programs-initiatives/programs/siam-simons-undergraduate-summer-research-program

[8] https://mathematics.howard.edu/articles/howard-university-siam-student-chapter

During the 2025 Enhancing Diversity in Graduate Education (EDGE) Summer Program—which took place in June at the University of Tennessee, Knoxville—student participants, hosts, speakers, EDGE faculty and staff, and EDGE alumnae pose for a photo after the annual Reunion Weekend banquet. The group embarked on a dinner cruise along the Tennessee River to spend time together outside of the classroom and celebrate their achievements. Photo courtesy of Lily Farabaugh.

Navigating Challenges, Opportunities, and Uncertainties as Women in Data Science

By Jillian Kunze

Data science is an exciting area of study that presents opportunities for researchers to apply computational, mathematical, and domain-specific knowledge to a diverse array of problems. Yet despite the field's continued growth and broad applications, the gender distribution among data scientists remains imbalanced; according to Women in Data Science Worldwide,[1] females comprise less than 20 percent of data science students and under 10 percent of decision-makers in the field. As such, women who pursue careers in data science may encounter gender biases or roadblocks that pertain to professional development; mentorship; and the balance between work, life, and family.

During the Third Joint SIAM/CAIMS Annual Meetings[2] (AN25)—which took place in Montréal, Québec, Canada, this past summer—the Association for Women in Mathematics[3] hosted an engaging panel session[4] that focused on the experiences of women in data science professions. The event was co-organized by Jamie Haddock of Harvey Mudd College and Anna Little of the University of Utah. Little chaired the discussion between panelists Tammy Kolda of MathSci.ai,[5] Anna Konstorum of the Institute for Defense Analyses,[6] and Yifei Lou and Caroline Moosmueller of the University of North Carolina at Chapel Hill, all of whom shared insights into the realities of data science careers.

The panelists opened the conversation by outlining their processes for beginning new data science projects and identifying worthwhile research problems. "My advice for choosing problems, especially in the early stages of your career, is to read deeply and broadly," Kolda said, recommending survey papers and foundational book series as good sources of information. She explained that early-career researchers who develop a formative knowledge base can better understand the field and start to formalize their own questions. "Aim for something that doesn't just make [a problem] a little bit better, but takes it from unsolvable to solvable," Kolda continued. "Don't just aim for papers; aim for solving problems that are interesting to you."

Working with collaborators in interdisciplinary fields can introduce junior scientists to a wide range of open problems. For example, Konstorum has stumbled upon interesting research questions by helping colleagues with a nonfunctioning algorithm, then digging deeply into the issue's underlying cause. "If you're hitting a wall, be open to going 'if I can find a way to get through that, that's *research*,'" she said. However, it is equally necessary to prepare for the inevitable reality that some research endeavors may not be successful. "It's just something that you have to get used to," Moosmueller said. "Not every idea and great collaboration will lead to a paper."

The panelists next discussed their respective experiences with mentorship, which can play a major role in data science career trajectories. Lou reported that she has especially benefited from the mentorship of senior coworkers who divulged useful tips and tricks for working within specific academic settings. Kolda then elaborated on the idea of *sponsorship*, wherein a mentor works diligently behind the scenes to support a junior colleague's progression. By attending scientific gatherings early in her career and being bold and strategic in her interactions, Kolda was able to establish connections with potential sponsors. On the other hand, Moosmueller admitted that she has not had many mentors and reassured listeners that success is still possible even without effectual mentorship. Instead, she has benefited from a robust network of both veteran researchers and peers whose experience levels mirror her own.

As in many scientific careers, data scientists may face time management challenges and competing demands from work, research, teaching, travel, and service. Although Lou emphasized that it is okay to say "no" to certain appeals, particular strategies for tactfully saying "no" can help avoid negative consequences. For internal requests, one can politely list current responsibilities and inquire how to best adjust them to accommodate a new task. However, external requests may require more delicate handling and additional flattery; and when feasible, saying "yes" to these asks can lead to important visibility and connections.

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Konstorum advised female listeners to confirm that the demands on their time are indeed appropriate, especially in terms of nonscientific departmental services. "Be your own advocate," she said, urging attendees to assess whether their male counterparts are fielding the same types of requests. "Be aware of what's going on and talk to your colleagues."

When the workload does require multitasking, the panelists offered several suggestions to tackle competing demands. "Make a list and cross it off," Lou said. "Sometimes, add a deadline." Effective tactics can involve comparing notes with colleagues who have similar workloads, occasionally switching the subject of focus to keep things fresh, and actively defining a set schedule. "As time goes on, you learn how to do it," Moosmueller said. "Somehow you adapt; sometimes it's easier and sometimes it's harder."

At the Third Joint SIAM/CAIMS Annual Meetings—which took place this summer in Montréal, Québec, Canada—the Association for Women in Mathematics hosted a panel session that focused on the challenges and opportunities of careers in data science. From left to right: panelists Tammy Kolda of MathSci.ai, Yifei Lou and Caroline Moosmueller of the University of North Carolina at Chapel Hill, and Anna Konstorum of the Institute for Defense Analyses. SIAM photo.

Data scientists—especially those in the early stages of their careers—may experience burnout for several reasons, including high workloads or psychological barriers like lack of advisor support, research obstacles, or concerns about future employability. "The first step is to identify the sources," Konstorum said. "If you're not feeling motivated and you don't have a ton of work, sit down with yourself and figure out what's going on." Select strategies can help individuals push through the loss of motivation and avoid diminishing returns when they are overloaded or uninspired. For instance, maintaining hobbies and passions outside of research can prevent overwork and provide a creative or physical outlet. It can also be helpful to recognize the cyclical nature of academic work in particular, with varying time requirements for teaching, writing grants, and conducting research throughout the year.

In addition to burnout, data scientists at all career levels might experience the isolating effects of imposter syndrome, where an individual feels as though they do not belong in a certain environment or were not "built for research." The panelists disclosed that even they still encounter these feelings on occasion. Kolda is a proponent of "faking it until you make it;" she noted that she likes to imagine herself in the mindset of a different, more outspoken person. Konstorum, who majored in biology as an undergraduate, then recalled that she felt like an imposter when starting her Ph.D. studies in mathematics. But as she began to find success in her research, she realized that she possessed a unique skillset and viewpoint that others in her cohort did not. "If you feel like an imposter, that means you have something different than the people there and something unique to add," Konstorum said.

The panelists agreed that it is best to avoid comparing oneself with other scientists who may have a greater number of citations or a more developed research profile. Mental health resources can help researchers cultivate the focus and self-control that is required to avoid unhealthy behaviors, such as overly checking Google Scholar. It is also important to remember that everyone has different professional and personal responsibilities and priorities; routine self-reflection about one's own motivations, previous achievements, and future goals is almost always beneficial. "If I was young me, I'd really want to be [current] me," Kolda said. "You'll have your own way of being successful."

Job seekers who also wish to prioritize their families should thoroughly research open positions to determine a department's level of support for working parents, which may vary between organizations both within and outside of academia. Throughout her career, Lou—who has two children—has found her colleagues to be understanding about any necessary adjustments to her schedule. "Most people try to accommodate my requests," she said.

For those in the U.S., the political climate imposes additional stress and uncertainty surrounding the stability of research projects, job opportunities, and accessible funding. The panelists stated that they have been leaning on their general life skills—connecting with colleagues, fortifying their networks, thinking creatively to overcome setbacks, and taking opportunities to learn—to offset some of the strain. In the present environment, the job search may also require some extra patience. "You have really good skills, so give yourself some breathing room as things may take a little time," Kolda said.

When advising students amidst the ongoing uncertainty, Moosmueller acknowledges the reality behind their worries and talks to them about alternative career paths outside of academia. Taking pragmatic action can help students and researchers maintain their forward momentum and confidence during

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[1] https://www.widsworldwide.org/about/our-mission
[2] https://www.siam.org/conferences-events/past-event-archive/an25
[3] https://awm-math.org
[4] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=84776
[5] https://mathsci.ai
[6] https://www.ida.org


During a data science panel that was hosted by the Association for Women in Mathematics at the Third Joint SIAM/CAIMS Annual Meetings—which were held in Montréal, Québec, Canada, this past summer—moderator Anna Little of the University of Utah (left) leads the career-focused discussion while panelist Tammy Kolda of MathSci.ai looks on. SIAM photo.

AN25 Film Screening and Panel Discussion Continue Conversation About the Journeys of Black Mathematicians

By Lina Sorg

Last year's 2024 SIAM Annual Meeting,[1] which took place in Spokane, Wash., featured a film screening and discussion[2] of *Journeys of Black Mathematicians: Forging Resilience*[3] [1]. The documentary, which was created by George Csicsery and jointly commissioned by ZALA Films[4] and the Simons Laufer Mathematical Sciences Institute,[5] explores the personal stories of Black mathematicians. Following that successful screening, the Third Joint SIAM/CAIMS Annual Meetings[6] (AN25)—which were held this past summer in Montréal, Québec, Canada—included a consequent session[7] that was sponsored by the Workshop Celebrating Diversity; SIAM Activity Group on Equity, Diversity, and Inclusion[8] (EDI); and Canadian Applied and Industrial Mathematics Society's (CAIMS) Equity, Diversity, Inclusiveness and Membership Committee.[9]

This special event opened with a showing of the second installment in Csicsery's film series, titled *Journeys of Black Mathematicians: Creating Pathways.*[10] Released in 2025, the new documentary spotlights additional present-day researchers, celebrates the lives of pioneering Black mathematicians from the 20th century, and addresses the impacts of segregation and discrimination. After the screening, Ron Buckmire of Marist College—former SIAM Vice President for EDI—moderated an insightful conversation between Lucy Campbell of Carleton University in Canada, Jude Kong of the University of Toronto, and Zerotti Woods of Johns Hopkins University. Throughout the hourlong discussion, panelists shared their personal experiences and affirmed the importance of EDI in the mathematical sciences.

The speakers introduced themselves by overviewing their individual pathways into mathematics. Campbell, an associate professor at Carleton, discovered her passion for the subject at just three years old. "Early on, I started to show an interest in and aptitude for math," she said. "I was always talking about numbers. Fortunately for me, I come from a family of teachers." Campbell's mother, who was born in Ghana, was a teacher and herself descended from a line of teachers; her father was a group theorist and mathematics professor from Barbados.

As an educator, Campbell's mother observed and nourished her daughter's penchant for mathematics. "She saw right away that I was interested in math," Campbell continued. "It seemed like a natural choice because my father was a mathematician. For all my life, I saw myself as someone who would be doing math." As she progressed in her studies, Campbell was excited by the realization that she could pursue a career that allowed her to both teach *and* conduct research.

Kong, an assistant professor at Toronto, spoke about his upbringing with four siblings in a remote area of Cameroon — where *community* was the focal point of all endeavors. As a student in primary school, his thoughts centered on how he could best support his family and especially his mother, who worked on a farm. "There was no time when I thought I would be a mathematician," he said, noting that many people in his hometown did not attend secondary school. However, Kong's attention to community was the driving factor that ultimately ensured his academic success; he sought to perform well academically to earn the respect of his friends and peers.

Kong explained that he felt a particular sense of pride when solving math problems. "That excited me and kept me doing the same thing over and over," he said, adding that he regularly shared his knowledge with friends to help them learn and keep them out of trouble. "That *resilience* is because of community." Yet despite his talent, Kong did not immediately recognize his own propensity for math; he simply saw his actions as a service to the collective whole.

Like Kong, Woods—a chief scientist in Johns Hopkins' Applied Physics Laboratory—also recalled helping his classmates with math assignments as a child. After earning a B.S. in mathematics from Morehouse College, he enrolled in a rigorous graduate program at the University of Georgia. The first year, he did not pass his qualifying exams; his graduate advisor told him that he would likely fail out of the program entirely and would need to finish his degree elsewhere. Rather than surrender to this lack of encouragement, Woods turned the expectation for failure into a sense of determination and set out to complete the curriculum and prove his capability.

Kong remarked that the traditional higher education system is not designed to accommodate individuals from underrepresented backgrounds, who often receive less support from instructors, advisors, and peers. He therefore seeks to cultivate a sense of community and togetherness within his classroom whenever possible. "The first thing I always talk about is that community piece and family-oriented way of teaching," he said. "I try to get people to feel like they're part of this, like someone will take what they say into account."

To prevent the disengagement of students from marginalized backgrounds via the so-called "leaky pipeline," Kong urged academics to develop *microcommunities* where women, people of color, first-generation college students, and other minoritized groups can find a safe landing space in the face of challenges. "No matter how a single person makes them feel due to conscious or unconscious bias, they'll know that they have a microcommunity," he said. "They'll feel like they're not alone in what they're going through." For example, Kong specifically reached out to all of his Black students during the COVID-19 pandemic—a particularly difficult time for many people—to schedule regular group check-ins and offer support.

As a Black woman with a higher degree in applied mathematics, Campbell is personally familiar with the leaky pipeline phenomenon. From a young age, she was acutely aware that she was different. "I was always the only girl in the science class, the only girl in the advanced math class," she said. This sense of isolation became even more pronounced throughout her graduate studies in the U.K. and Canada, as Campbell was frequently the sole Black person and sole female in the room. "What kept me going through all of this was coming from a family of very powerful, strong women," she continued, explaining that her family's educational values protected her from the full effects of imposter syndrome. "I didn't feel like much of an imposter because I'd had this interest forever." In a way, Campbell's family served as her own microcommunity — a counternarrative to any negativity.

The Third Joint SIAM/CAIMS Annual Meetings, which took place this summer in Montréal, Québec, Canada, featured a panel discussion and film screening of a 2025 documentary titled Journeys of Black Mathematicians: Creating Pathways. From left to right: panelists Zerotti Woods of Johns Hopkins University, Jude Kong of the University of Toronto, Lucy Campbell of Carleton University, and moderator Ron Buckmire of Marist College. SIAM photo.

Conversation next turned to the importance of EDI in the workforce, with the panelists collectively agreeing that the very concept of diversity inherently encompasses all people, not just certain groups. Kong surmised that critics of EDI-focused programs perhaps misunderstand the all-inclusive definition of EDI. "Politicians can act on emotions and not facts," he said, noting that opponents of EDI often erroneously believe that it only serves the interests of women, people of color, or other marginalized communities. He thus advocated for more transparent messaging about the intent of EDI initiatives. "What communication piece is missing that has led to that misinformation spreading?" Kong asked. "EDI is not to give handouts to people; it's to advance science and get different feedback. But that communication is lacking, so how can we advance it?"

Campbell seconded Kong's comments on misinformation and acknowledged the additional dangers of *disinformation*: the intentional spread of falsehoods to advance a particular agenda. "It's more than just a misunderstanding," she said. "It's deliberately giving false information and knowing that people will listen and take what is said."

Woods touted the value of open dialogue between people of all backgrounds, revealing that he has had interesting, nuanced conversations with individuals who did not face the same roadblocks or biases in their educational or career journeys. These sorts of honest discussions expose everyone to a broader range of viewpoints and can validate the experiences of individuals from underrepresented groups. "The people who had to start efforts in EDI did not want to start efforts in EDI," Woods said. "The point of EDI is for us not to have to say it anymore, but we're not there yet. If we don't need it, we won't have it."

Woods further expounded that the inclusion of diverse populations in decision-making processes, research projects, and other professional endeavors does not lower the standard of excellence, but rather yields a more robust understanding of the problems at hand. However, minority personnel may feel that they are held to a stricter performance standard than their counterparts, potentially leading to higher rates of mental health concerns [2]. "EDI won't be needed anymore when people from underrepresented communities can be average," Woods said. "People need to stop thinking about this emotionally, and more like a science problem."

As the panel concluded, the speakers underscored the significance of continued conversation and storytelling—as in Csicsery's *Creating Pathways* documentary—to normalize EDI in both academia and industry. "We need to tell the stories of how solutions that are saving lives are brought forward," Kong said. "Let's show how the diverse knowledge that was brought to the table brought about the solution."

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Lina Sorg is the managing editor of SIAM News.

[1] https://www.siam.org/conferences-events/past-event-archive/an24

[2] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=80823

[3] https://www.zalafilms.com/jbm/forging.html

[4] https://www.zalafilms.com

[5] https://www.slmath.org

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

[7] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=84513

[8] https://www.siam.org/get-involved/connect-with-a-community/activity-groups/equity-diversity-and-inclusion-siag

[9] https://caims.ca/committee/edi-and-membership

[10] https://www.zalafilms.com/jbm/creating.html

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unsteady circumstances. "What you can control is getting up in the morning and doing good research," Moosmueller said. "This is what we should focus on at the moment."

Researchers should also find genuine opportunities to affect the culture within their own communities. Institutionally, sitting on hiring committees and encouraging student leadership can shape the culture of a department. "Pass down this goodwill to the next generation," Lou said. "That's a big way to make an impact." On a larger scale, volunteering and accepting leadership roles at organizations like SIAM can influence the direction of an entire field. It is never too early to start building this network and advocating for long-term impacts.

The panelists concluded the AN25 session with some final thoughts for early-career data scientists. Moosmueller and Konstorum urged attendees to remain aware of other people's points of view when heeding their advice; advisors may not always know the best course of action for a specific situation or goal, so it is important to consult a variety of viewpoints while ultimately forging one's own path. "Seek out people who will not just tell you what to do, but will listen and help you articulate what you *want* to do," Konstorum said.

Kolda emphasized the significance of networking for career progression. Setting goals for conference interactions, perfecting a personal introduction, and following up via email are reliable ways to establish a wide network of people who can assist with various problems and goals. Ultimately, the panelists affirmed that every connection is worthwhile; soon enough, fellow students and early-career researchers will be making a large impact on the field.

Jillian Kunze is the former associate editor of SIAM News. She is currently a master's student in data science at Drexel University.

Coffee and Qubits: A Student Perspective on the 2025 SIAM-Simons Undergraduate Summer Research Program

By Mia Escobar

This past summer, I was honored to participate in the third cohort of the SIAM-Simons Undergraduate Summer Research Program.[1] This program provides funding for 10 undergraduate students to actively partake in applied mathematics and computational science research at various sites throughout the U.S. My research partner, Valentin Garcia, and I spent eight weeks at the University of Hartford; other locations included Duke University, Adelphi University, and Texas State University. In addition to learning about the scientific research process, we honed our communication skills and gained a better understanding of career prospects in applied mathematics, computational science, and data science.

Now that I've returned to the University of Washington Tacoma for my senior year of undergraduate education, I continue to notice the program's many positive impacts on both my research skills and academic confidence. I will be graduating in the spring of 2026 with a B.S. in mathematics, and I feel both excited and prepared for a future career in the mathematical sciences. I wholeheartedly believe that the SIAM-Simons program is a great experience for any undergraduate student who is interested in a career in applied math or a related field, whether it be in academia, industry, or government.

A major benefit of the program is that it covers all costs—including travel, lodging, and meals—and provides participating students with a weekly stipend for other miscellaneous expenses. This generosity helps to eliminate financial barriers that may otherwise prevent undergraduate students from conducting research, making the opportunity accessible to a diverse array of applicants. I was able to devote all of my energy to research instead of worrying about finances, which was invaluable.

Students in the 2025 cohort focused on different topics depending on their assigned location. Research themes ranged from mRNA transport in neuronal cells to deforestation prevention and clustering methods. At our site, Valentin (an undergraduate student at Brown University) and I studied perfect state transfer (PST) and early state exclusion (ESE) in quantum spin chains under the mentorship of Anastasiia Minenkova, an assistant professor of mathematics at Hartford. For the majority of the program, we worked directly with Dr. Minenkova, learning about both the project at hand and the various possible career trajectories for applied mathematicians. Throughout the eight weeks, we also connected virtually with the other 2025 SIAM-Simons participants and attended sessions with guest speakers from academia and industry.

Each day, Valentin and I met with Dr. Minenkova in both the morning and afternoon. These standing meetings enabled us to set a goal for the day, review and work through any assigned articles as background reading, make note of ideas and questions, and reconvene. The flexible structure of the SIAM-Simons Undergraduate Summer Research Program meant that each mentor-mentee group could organize their time as they saw fit, which allowed us to determine how to best collaborate and adapt to the various steps of the research process.

Our particular project involved quantum spin chains, which essentially comprise a one-dimensional row of quantum bits (qubits). We specifically focused on qubits that were experiencing nearest-neighbor interactions. While the interaction process itself is fairly complex, we can think of it as the transfer of the state of one qubit to another. If at some time T, the state of the first qubit in the chain equals 0 and the state of the last qubit equals exactly 1, then we say that the quantum spin chain has PST (see Figure 1a). In contrast, if there is a time τ *before* the first instance of PST where the state of the first qubit equals 0 and the last is *not* exactly 1, then the chain is demonstrating ESE (see Figure 1b).

We can represent these systems' Hamiltonians with a tridiagonal persymmetric matrix called a *Jacobi matrix*. Given the eigenvalues of a system, the corresponding Jacobi matrix is always unique. This useful feature permitted us to reconstruct the matrices from their eigenvalues alone (for context, other matrices may have the same eigenvalues but look completely different).

At the onset of the program, Valentin and I studied the fundamentals of Jacobi matrices and inverse eigenvalue problems. We then generated the matrices by writing code in MATLAB, which was a completely new undertaking for me. I personally found this part of the project to be extremely valuable because I gained firsthand experience with a new coding language that I will undoubtedly utilize in the future. We used the resulting matrices and graphs to note the specific eigenvalues that generated Hamiltonians with and without ESEs.

By the end of the summer, we had proved two theorems about order 7 quantum spin chains. First, a Jacobi matrix with positive and negative eigenvalues 0, 1, $2m$, and $2m+1$—where m is an integer that is greater than or equal to 1—never has ESE. Second, a Jacobi matrix with positive and negative eigenvalues 0, $2m+1$, $2m+2$, and $2m+3$ has ESE $2m$ times. When not working on these theorems, we drank copious amounts of Dunkin' iced coffee and explored neat spots around campus and the surrounding area.

In late June, the students from all four locations met up in New York City to visit the Simons Foundation's Flatiron Institute,[2] where we presented our findings up to that point. This trip to the Flatiron Institute was a key highlight of the program. In addition to networking with each other, we toured the institute and met researchers who are currently working at the cutting edge of applied mathematics right in New York. Each floor of the building was dedicated to a different concentration of applied math, ranging from biology to quantum physics. I left feeling invigorated and knowing that the work I was doing actually has direct implications for many disciplines. Ultimately, however, the most impactful part of the visit was getting to interact with all of the participants in person. It isn't often that I meet nine other people with the same shared interest as me in one space. Everyone was so passionate and knowledgeable about their topics, and I felt honored to stand next to them and learn from their presentations.

Later in the summer, Valentin and I also presented our results at Mount Holyoke College and spoke with students and professors about their own research endeavors. Mount Holyoke is a private women's liberal arts college, so it was amazing to meet so many other women who are equally passionate about mathematics.

Overall, I hope that my reflections help other undergraduate students seize similar opportunities to advance their intellectual prowess, even if such opportunities are out of their comfort zones. The SIAM-Simons program marked many firsts for me: I had never been to Connecticut, never coded in MATLAB, and never been so directly immersed in the field of quantum computing. But I recognized the value of the program and knew that it could positively impact my future, so I applied. In the mere eight weeks that I was in Hartford, my team achieved things that might have otherwise taken multiple semesters; we even published a preprint about our results [1] that has been accepted to *SIAM Undergraduate Research Online*.[3] I gained invaluable experience, forged lifelong friendships, and connected with colleagues with whom I hope to collaborate in the future. I'm also looking forward to presenting our work at the 2026 SIAM Annual Meeting[4] in Cleveland, Ohio, next July.

I would like to thank both SIAM and the Simons Foundation for facilitating such an amazing experience and striving to make the field of applied mathematics a more accessible and welcoming space for students like myself.

References

[1] Escobar, M.G., & Garcia, V. (2025). Early state exclusion in 7-qubit spin chains. Preprint, *arXiv:2507.18767*.

Mia Escobar is a senior at the University of Washington Tacoma, where she is working towards a B.S. in mathematics and a minor in global engagement. She is president of the University of Washington Tacoma Math Club and is specifically interested in applied mathematics, with a focus in partial differential equations and numerical analysis.

[1] https://www.siam.org/programs-initiatives/programs/siam-simons-undergraduate-summer-research-program

[2] https://www.simonsfoundation.org/flatiron

[3] https://www.siam.org/publications/siam-journals/siam-undergraduate-research-online-siuro

[4] https://www.siam.org/conferences-events/siam-conferences/an26

Mia Escobar of the University of Washington Tacoma and her research partner, Valentin Garcia of Brown University (rear), studied perfect state transfer and early state exclusion in quantum spin chains at the University of Hartford this past summer. The two took part in the 2025 SIAM-Simons Undergraduate Summer Research Program, which provides funding for undergraduate students to conduct eight weeks of research at various institutions across the U.S. Photo courtesy of the author.

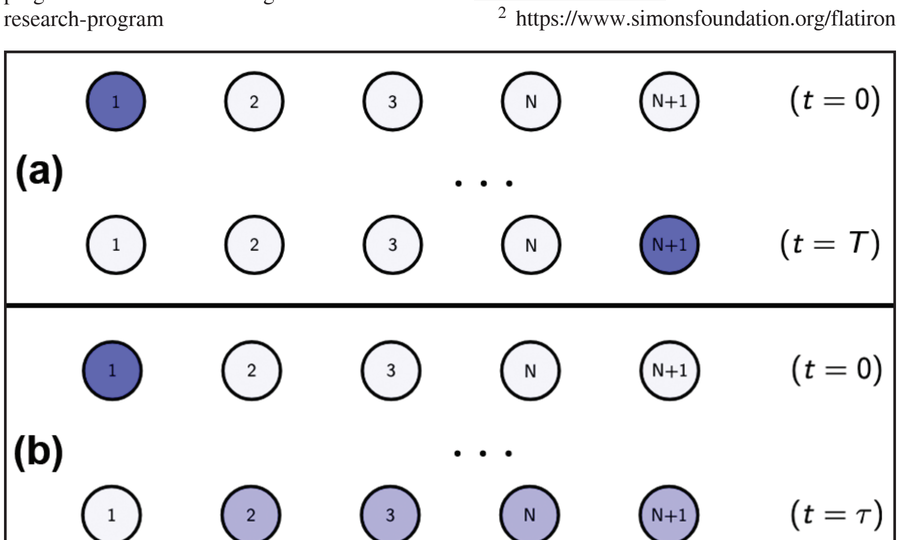

Figure 1. *Possible states of a quantum chain.* **1a.** *Perfect state transfer.* **1b.** *Early state exclusion. Figure courtesy of the author.*

Student participants of the 2025 SIAM-Simons Undergraduate Summer Research Program visit the Simons Foundation's Flatiron Institute in New York City, where they presented the results of their ongoing projects. Author Mia Escobar of the University of Washington Tacoma is fourth from left in the back row, and Valentin Garcia of Brown University is second from left in the front row. Photo courtesy of SIAM.

InsideSIAM

Conferences, books, journals, and activities of Society for Industrial and Applied Mathematics

SIAM | CONFERENCES

A Place to Network and Exchange Ideas

Upcoming Deadlines

siam 2026

SIAM Conference on Discrete Mathematics (DM26)

June 22–25, 2026 | San Diego, California, U.S.
siam.org/dm26 | #SIAMDM26

ORGANIZING COMMITTEE CO-CHAIRS
Vida Dujmovic, *University of Ottawa, Canada*
Jacques Verstraete, *University of California, San Diego, U.S.*

SUBMISSION AND TRAVEL SUPPORT DEADLINES
November 24, 2025: Minisymposium Proposal Submission
December 22, 2025: Contributed Lecture and Minisymposium Presentation Abstract Submissions
March 23, 2026: Travel Support Application

The following conferences are co-located. The application deadline for travel support is April 6, 2026:

SIAM Annual Meeting (AN26)

July 6–10, 2026 | Cleveland, Ohio, U.S.
siam.org/an26 | #SIAMAN26

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Charles Wampler, *University of Notre Dame, U.S.*

SUBMISSION DEADLINES
January 26, 2026: Minisymposium Proposal Submission
February 16, 2026: Contributed Lecture, Poster, Miniposterium, and Minisymposium Presentation Abstract Submissions

SIAM Conference on Mathematics of Planet Earth (MPE26)

July 6–8, 2026 | Cleveland, Ohio, U.S.
siam.org/mpe26 | #SIAMMPE26

ORGANIZING COMMITTEE CO-CHAIRS
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Kara Peterson, *Sandia National Laboratories, U.S.*

SUBMISSION DEADLINES
January 12, 2026: Minisymposium Proposal Submission
February 2, 2026: Contributed Lecture, Poster, and Minisymposium Presentation Abstract Submissions

SIAM Conference on The Life Sciences (LS26)

July 6–9, 2026 | Cleveland, Ohio, U.S.
siam.org/ls26 | #SIAMLS26

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Nessy Tania, *Pfizer Research and Development, U.S.*

SUBMISSION DEADLINES
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February 2, 2026: Contributed Lecture, Poster (including Miniposterium), and Minisymposium Presentation Abstract Submissions

SIAM Conference on Applied Mathematics Education (ED26)

July 9–10, 2026 | Cleveland, Ohio, U.S.
siam.org/ed26 | #SIAMED26

ORGANIZING COMMITTEE CO-CHAIRS
Ariel Cintron-Arias, *Catawba College, U.S.*
Maeve McCarthy, *Murray State University, U.S.*

SUBMISSION DEADLINES
January 26, 2026: Minisymposium Proposal Submission Deadline
February 16, 2026: Contributed Lecture and Minisymposium Presentation Abstract Submissions

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Upcoming SIAM Events

SIAM Conference on Analysis of Partial Differential Equations
November 17–20, 2025
Pittsburgh, Pennsylvania, U.S.
Sponsored by the SIAM Activity Group on Analysis of Partial Differential Equations

ACM-SIAM Symposium on Discrete Algorithms
January 11–14, 2026 | Vancouver, Canada
Sponsored by the SIAM Activity Group on Discrete Mathematics and the ACM Special Interest Group on Algorithms and Computational Theory

SIAM Symposium on Algorithm Engineering and Experiments
January 11–12, 2026 | Vancouver, Canada

SIAM Symposium on Simplicity in Algorithms
January 12–14, 2026 | Vancouver, Canada

SIAM Conference on Parallel Processing for Scientific Computing
March 3–6, 2026 | Berlin, Germany
Sponsored by the SIAM Activity Group on Supercomputing

SIAM International Meshing Roundtable Workshop 2026
March 3–6, 2026 | Berlin, Germany

SIAM Conference on Uncertainty Quantification
March 22–25, 2026
Minneapolis, Minnesota, U.S.
Sponsored by the SIAM Activity Group on Uncertainty Quantification

SIAM Conference on Nonlinear Waves and Coherent Structures
May 26–29, 2026
Montréal, Québec, Canada
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SIAM Conference on Optimization
June 2–5, 2026
Edinburgh, United Kingdom
Sponsored by the SIAM Activity Group on Optimization

SIAM Conference on Discrete Mathematics
June 22–25, 2026
San Diego, California, U.S.
Sponsored by the SIAM Activity Group on Discrete Mathematics

SIAM Conference on Mathematics of Planet Earth
July 6–8, 2026
Cleveland, Ohio, U.S.
Sponsored by the SIAM Activity Group on Mathematics of Planet Earth

SIAM Conference on the Life Sciences
July 6–9, 2026
Cleveland, Ohio, U.S.
Sponsored by the SIAM Activity Group on Life Sciences

2026 SIAM Annual Meeting
July 6–10, 2026
Cleveland, Ohio, U.S.

SIAM Conference on Applied Mathematics Education
July 9–10, 2026
Cleveland, Ohio, U.S.
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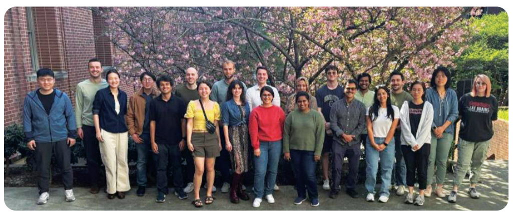
SIAM Student Chapter Activities and Updates

Colorado Student Chapter Conference
SIAM student chapters of Colorado—including Colorado University (CU) Denver, CU Boulder, CU Colorado Springs, Colorado College, and many others—planned, organized, and hosted the 21st Annual Regional Student Conference on Applied Mathematics for all schools along the Front Range. Hosted at the University of Colorado Denver, this event allowed undergraduate and graduate students from different universities in the area to see what is being done in the applied mathematics field. The conference consisted of a keynote speech, an industry panel, and 18 student presentations.

Graduate Seminar Sessions
Columbia University SIAM Student Chapter hosted weekly, hour-long seminars where graduate students shared their ongoing research or a recent paper/topic of interest. Each talk was followed by an open Q&A session, giving presenters a low-stakes forum to practice communicating complex ideas and allowing attendees to explore topics outside their specialties.



Georgia SIAM Student Conference
*Alongside SIAM student members from **Georgia Tech** and **Emory University, Georgia State University SIAM Student Chapter** hosted their first SIAM student chapter conference fully organized by their dedicated student members.*

Integration Bee
***University of California at Merced SIAM Student Chapter** held its annual integration bee with over 95 students in attendance. The event included students from different math backgrounds who worked to solve increasingly difficult integration problems across multiple rounds. The students that participated in the event received ribbons, stuffed bees, and slices of pie!*

Panel Discussion
***Louisiana State University SIAM Student Chapter** hosted a panel discussion titled "Navigating Life after a Ph.D.: Focusing on the Challenges and Opportunities of Job Searching Post-graduation." Their chapter's alumni, alongside postdoctoral researchers and university professors, shared their insights and experiences on transitioning from academia to industry and other professional paths.*

Industry Field Trip
***Trier University SIAM Student Chapter** took a one-day field trip to the pump manufacturer KSB in Frankenthal, Germany. During their trip, they visited the production areas, saw presentations on research and development at KSB, and heard from speakers who shared their personal impressions and experiences on the transition from academia to industry.*

Math Competition
Along with **Duke University, University of North Carolina, North Carolina State University**, and **Ohio State University, Brown University SIAM Student Chapter** hosted a math competition where undergraduates solved two problems related to mathematical modeling. Top scoring teams were given a monetary prize and the top team received funding to enter the International Math Competition for Modeling.

Field Trip to Argonne National Laboratory
Loyola University of Chicago SIAM Student Chapter took a field trip to Argonne National Laboratory where they visited the Advanced Photon Source (APS), the Aurora exascale supercomputer, and Argonne's nuclear history exhibit. The chapter was hosted by former SIAM President, Sven Leyffer and over 40 students and faculty members were able to attend, marking a greatly successful tour.

Medical Center Field Trip
The National Central University SIAM Student Chapter recently visited IH Medical Center for a field trip. During the visit, the center's professional team introduced students to its advanced medical image analysis systems. Through hands-on activities, the team guided students in exploring how artificial intelligence and image recognition technologies assist doctors in disease diagnosis and treatment planning.

2024 SIAM Student Minisymposium in Applied Mathematics
Hosted by the **University of Michigan SIAM Student Chapter**, this event gave students from different disciplines across the region the opportunity to see current research in the field and promoted interest in the general field of applied mathematics. It was open to all undergraduate and graduate students at the University of Michigan.

Visit to the Meadows Museum in Dallas
University of Texas at Dallas and Southern Methodist University SIAM Student Chapters organized a field trip to the Meadows Museum to explore the intersection of art and mathematics. Student members enjoyed viewing the museum's geometric exhibits, which provided a unique backdrop for them to discuss the appearance of mathematic concepts in visual art, design, and curation.

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SIAM members (excluding student members) can nominate up to two students per year for free membership. Go to ***my.siam.org/forms/nominate.htm*** to make your nominations.

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SIAM offers its student chapters the opportunity to hear talks from a unique roster of experienced and inspirational applied mathematicians and computational scientists in industry, government, and academia. Student chapters can invite lecturers to give on-campus and remote talks or meet with students and faculty directly to speak on a variety of topics, career opportunities, professional development, and more. To learn more about the program and contact a lecturer go to ***siam.org/programs-initiatives/programs/visiting-lecturer-program***.

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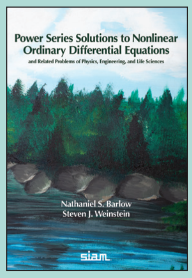

Nathaniel S. Barlow and Steven J. Weinstein

This book introduces a systematic approach to solving nonlinear ODEs using power series, with a focus on problems in mathematical physics. It equips readers with tools to streamline recursive computations and tackle convergence challenges, making power series methods both practical and accessible. Grounded in a hands-on teaching philosophy, the text features idea-driven examples and research-based problems, with minimal proofs. Ideal for applied mathematicians, scientists, and engineers, the book demonstrates how power series techniques can complement numerical methods as a versatile problem-solving tool.

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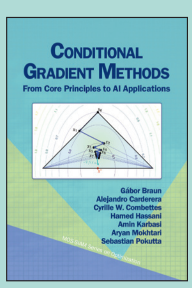
From Core Principles to AI Applications



Gábor Braun, Alejandro Carderera, Cyrille W. Combettes, Hamed Hassani, Amin Karbasi, Aryan Mokhtari, and Sebastian Pokutta

This comprehensive monograph offers a definitive and modern treatment of one of the most elegant and versatile algorithmic families in optimization: the Frank–Wolfe method and its many variants, which now play a central role in machine learning, signal processing, and large-scale data science. It unites deep theoretical insights with practical considerations, guiding readers through the foundations of constrained optimization and into cutting-edge territory. With a clear narrative, rigorous proofs, and illuminating illustrations, the book demystifies adaptive variants, away-steps, and the nuances of dealing with structured convex sets.

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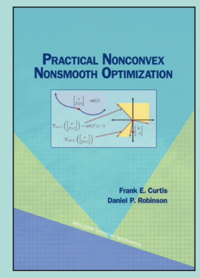

Frank E. Curtis and Daniel P. Robinson

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

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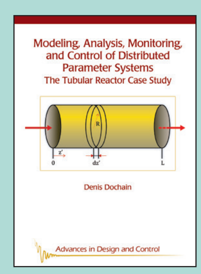

Denis Dochain

This book compiles key findings on the modeling, analysis, estimation, and control design of various tubular reactor configurations. It explores both linear and nonlinear hyperbolic and parabolic partial differential equations, bridging the gap between theory and application in distributed parameter systems. The tubular reactor offers several important advantages when teaching and studying distributed parameter systems: it covers multiple classes of partial differential equations, providing a broad mathematical foundation; it bridges finite- and infinite-dimensional models; it demonstrates diverse behaviors; and it links theoretical concepts to practical applications. Furthermore, the tubular reactor has a broad scope of application in biological, environmental, and chemical systems.

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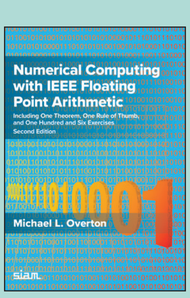

Michael L. Overton

This book provides an easily accessible, yet detailed, discussion of computer arithmetic as mandated by the IEEE 754 floating point standard, arguably the most important standard in the computer industry. Although the basic principles of IEEE floating point arithmetic have remained largely unchanged since the first edition of this book was published in 2001, the technology that supports it has changed enormously. Every chapter has been extensively rewritten, and two new chapters have been added: one on computations with higher precision than that mandated by the standard and one on computations with lower precision than was ever contemplated by those who wrote the standard, driven by the massive computational demands of machine learning. It includes many technical details not readily available elsewhere, along with many new exercises.

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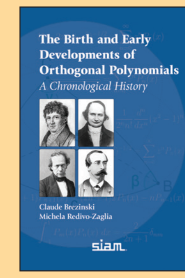

Claude Brezinski and Michela Redivo-Zaglia

The shape of the Earth was a significant scientific question in the eighteenth century. When it was discovered that the Earth was flattened at the poles, scientists sought to understand the cause, leading to the discovery of orthogonal polynomials. Over time, as interest in the gravitational problem of spheroids waned, the intrinsic mathematical interest in orthogonal polynomials took precedence. This is the first book to describe the history of orthogonal polynomials, covering their birth and early developments from the end of the 18th century to the middle of the 20th century. It includes biographies of principal and lesser-known figures, anecdotes, and accounts of the countries and institutions involved. The book will appeal to researchers, students, and those interested in the history of mathematics.

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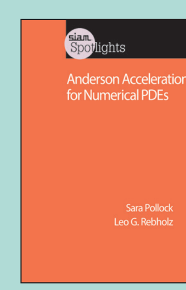
Anderson Acceleration for Numerical PDEs



Sara Pollock and Leo G. Rebholz

Research on Anderson acceleration (AA) has surged over the last 15 years. This book compiles recent fundamental advancements in AA and its application to nonlinear solvers for partial differential equations. These solvers play an important role across mathematics, science, engineering, and economics, serving as a critical technology for determining solutions to predictive models for a wide range of important phenomena. This book covers AA convergence theory for both contractive and noncontractive operators, as well as filtering techniques for AA. It includes examples of how convergence theory can be adapted to various application problems. It also includes AA's impact on sublinear convergence and integration of AA with Newton's method.

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