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

siam news

Volume 58/ Issue 7
September 2025

Taming the Chaos of Computational Experiments

By Tamara G. Kolda

Today's computational experiments form the basis of scientific simulations and data analysis methods that will fuel future scientific advancements, engineering-based designs and evaluations, government policy decisions, and much more. For this reason, it is crucial that we—as computational scientists—discuss the importance of best practices in experimentation.

The ease with which we can repeat experiments is both a blessing and a curse. We can change our codes with just a few keystrokes and run them repeatedly with different random initializations and conditions. However, the flexibility of rapid iteration often leads to disorganized workflows, undocumented changes, and unreproducible results. What advice should we follow? What type of training should we provide for our students? How can we ensure that computational science maintains the necessary rigor?

As part of this discussion, I hope that we also consider the importance of involving *all* authors in computational experiments. While each author need not necessarily write their own code and run it independently, everyone should *understand* the experiments — the inputs, codes, individual outputs, and summary results. Although this strategy will not guarantee infallibility, it exponentially lowers the probability of issues going unnoticed. Scientists frequently feel pressure to publish and produce "results" and may rely on shortcuts, such as the use of artificial intelligence, to "help" with certain aspects of coding or analysis. Together, coauthors can support one another to ensure that their experiments are rigorous and scientifically valid. These principles are important for the intellectual standing of our field, not to mention individual reputations [2].

In this article, I will share seven pragmatic practices for improving the replicability, validation, reproducibility, and usability of computational experiments. I present these suggestions—which are designed to be adaptable for situations that range from Python code on a laptop to high-performance C++ code on a supercomputer—in rough order of implementation difficulty.

I recognize that religiously following these practices is not necessarily easy. As I was preparing this text, I was humbled to discover that I had failed to heed my own advice and was having trouble reproducing some recent experiments! Moreover, I hope that you won't agree with everything I have to say; I would be delighted to inspire collective discussion and debate on how to increase the utility of computational science research for ourselves and the world at large.

With that in mind, here are my recommendations.

Use Version Control (Preferably Git)

Version control is essential. It allows you to track changes in your code and reference any past versions that have been "checked in" to the version-controlled repository. This is generally done via hashes or named tags, and Git[1] is the recommended tool.

Online versions of Git—such as GitHub,[2] GitLab,[3] Bitbucket,[4] and Codeberg[5]—enable collaboration and sharing. GitHub stands out due to its integration with Overleaf[6] for paper writing, while Codeberg is unique because it is run by a nonprofit.[7] I strongly discourage Google Drive or Dropbox for versioning code, as they lack the granularity and traceability of Git. If

See **Computational Experiments** *on page 4*

1 https://git-scm.com
2 https://github.com
3 https://about.gitlab.com
4 https://bitbucket.org
5 https://codeberg.org
6 https://www.overleaf.com
7 Many thanks to Gautam Iyer of Carnegie Mellon University for introducing me to Codeberg.

Figure 1. *Separate experimental output from figure generation, saving the data into a comma-separated value (CSV) format or other data file representation so that the figures can be reproduced without rerunning the experiments. Figure courtesy of SIAM.*

Factorizations for Data Analysis

By Anna Seigal

Factorization breaks an object into building blocks that we can understand and interpret: e.g., a number into primes, a variety into irreducible components, or a matrix into rank-one summands. This process underpins classical paradigms for data analysis, including *principal component analysis* (PCA) via the eigendecomposition. But because modern datasets record information from various contexts and modalities, classical factorizations can no longer sufficiently analyze them. Can new factorizations hold the key to human-interpretable understanding of today's complex systems?

Mathematically, the challenge involves the factorization of an interconnected collection of matrices or tensors, which is achievable through algebraic insights. Here, I will overview three classical factorizations in traditional data analysis tools and then present two new factorizations for the analysis of multi-context data.

The following is a general framework for data analysis. We model observed random variables X as an unknown mixture of unknown latent (unobserved) random variables Z (see Figure 1). When the mixture occurs via a linear map A, then $X=AZ$. The factors A and Z are both unknown.

Our goal is to recover the mixing matrix A and latent variables Z from samples of X. The building blocks A and Z define components that explain structures in the data — for example, identifying gene modules in gene expression data, separating signal from artifacts (such as eye blinks) in electroencephalogram data, and providing axes for visualization in dimensionality reduction.

We recover the latent variables Z and mixing map A by turning the relationship $X=AZ$ into a factorization problem. The first cumulant of X is its mean and the second is its covariance: the $p\times p$ positive semidefinite matrix Σ_X that records at entry (i,j) the way in which variables X_i and X_j vary together. The relationship $X=AZ$ implies that the covariance matrices of X and Z relate via congruence action

$$\Sigma_X = A\Sigma_Z A^\top.$$

When Σ_X is known and Σ_Z and A are unknown, this is a matrix factorization problem. In practice, we do not have access to the true Σ_X and instead work with the sample covariance matrix,[1] which is denoted by S. Classical data analysis tools live in this factorization framework, as I will demonstrate next.

PCA Is the Eigendecomposition

In PCA, observed variables are an orthogonal transformation of uncorrelated latent variables (see Figure 2a, on page 3). So

$$S = VDV^\top,$$

where the columns of V are the principal components—which express each latent variable as a linear combination of observed variables—and D is a diagonal matrix that records the variance of the latent variables. The eigendecomposition proves that a real symmetric matrix has such a factorization (V is the matrix of eigenvectors and D is their eigenvalues), and that it is unique for general S.

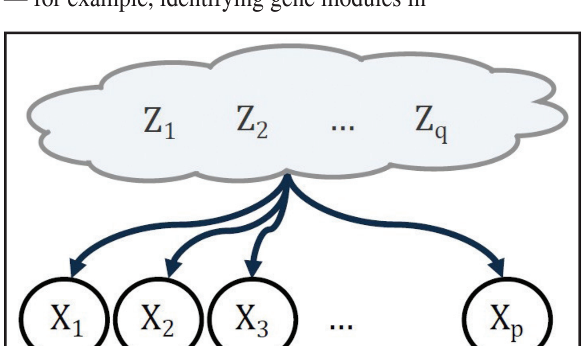


Figure 1. *Observed variables X are describable via latent variables Z. Figure courtesy of the author.*

Linear Structural Equation Models Are the LDL Decomposition

We can model variables X to relate via noisy linear dependencies: $X=BX+Z$ (see Figure 2b, on page 3). In such a *linear structural equation model* (LSEM), b_{ij} is the effect of variable X_j on X_i and Z is a vector of exogenous noise variables (typically assumed to be independent) [10]. We usually further assume that the dependencies follow a directed acyclic graph, where $b_{ij}=0$ unless $j\to i$ is an edge in the graph. It is then possible to reorder the variables to make B strictly lower triangular. We obtain $X=AZ$ for $A=(I-B)^{-1}$ and hence

$$S=(I-B)^{-1}D(I-B)^{-\top},$$

where D records the variances of the latent variables. This is the LDL decomposition.

In both of the previous examples, the latent variables have diagonal covariance because they are uncorrelated. But the factorization $ADA^\top$ would not be unique without an additional structure on A, which is orthogonal in PCA and becomes lower triangular in the LSEM. This extra structure makes the factorization unique; the uniqueness of the eigenvectors $\mathbf{v}$ or weights b_{ij} aids downstream analysis.

I have only focused on covariance thus far, but a distribution has a dth cumulant[2] $\kappa_d(X)$ for any positive integer d. If $X=AZ$, then the cumulants relate via a higher-order congruence action

$$\kappa_d(X) = A\bullet\kappa_d(Z),$$

which specializes to matrix congruence when $d=2$. For the $p\times p\times p\times p$ cumulant (i.e., kurtosis tensor), the (i,j,k,l) entry of $\kappa_4(X)$

See **Factorizations** *on page 3*

1 For mean-centered data $\mathbf{x}^{(1)},\ldots,\mathbf{x}^{(n)}\in\mathbb{R}^p$, the sample covariance is the average of the outer products of the data points: $S=\frac{1}{n}\sum_i \mathbf{x}^{(i)}\mathbf{x}^{(i)\top}$.

2 The dth order cumulant is the tensor of order d terms in $\mathbf{t}=(t_1,\ldots,t_p)$ in the cumulant-generating function $\log\mathbb{E}(\exp(\mathbf{t}^\top X))$.

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

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

siam news
Volume 58/ Issue 7/ September 2025

DS25 Panel Addresses Essential Facets of Interdisciplinary Research

By Jillian Kunze

Research in the mathematical sciences—and particularly in dynamical systems—provides opportunities to foster rich relationships with other fields and delve into a diverse array of applications. Scientists who pursue interdisciplinary projects encounter an exciting range of possibilities in their work but must also contend with questions about funding, publication, and career advancement.

"The most interesting thing about interdisciplinary [work] is thinking about a problem from lots of different angles and tackling it with different tools," Dorit Hammerling of the Colorado School of Mines said during the 2025 SIAM Conference on Applications of Dynamical Systems,[1] which was held in Denver, Colo., this past May. Hammerling took part in an interdisciplinary research panel[2] that also featured Daniel Abrams of Northwestern University, Chris Budd of the University of Bath, Mari Kawakatsu of the University of Pennsylvania, and Jonathan Rubin of the University of Pittsburgh. Cecilia Diniz Behn of the Colorado School of Mines and Igor Belykh of Georgia State University chaired the session, which addressed the intricacies of working at the interface of multiple scientific fields.

A panel of researchers who work at the intersection of applied mathematics and other fields discussed the challenges and opportunities of interdisciplinary projects during a session at the 2025 SIAM Conference on Applications of Dynamical Systems, which took place in Denver, Colo., this past May. From left to right: Chris Budd of the University of Bath, Daniel Abrams of Northwestern University, session chair Igor Belykh of Georgia State University, Mari Kawakatsu of the University of Pennsylvania, session chair Cecilia Diniz Behn of the Colorado School of Mines, Dorit Hammerling of the Colorado School of Mines, and Jonathan Rubin of the University of Pittsburgh. SIAM photo.

The panelists' own career histories exemplified the varied pathways that can lead to interdisciplinary research. Their individual backgrounds span fields such as mathematics, engineering, and physics, and they currently work in areas that include geoscience, mathematical biology, and industrial mathematics. For instance, Kawakatsu began college as a physics major, but classes in the social sciences inspired an interest in collective behavior that—combined with an inclination towards mathematical modeling—has shaped her graduate and postdoctoral studies. "Applied math programs tend to be a bit more flexible about the kinds of projects you can explore," she said. "It looks a little like I'm meandering, but there's a core interest in collective behavior."

When diving into a novel domain, it is important to identify collaborators who possess expertise on the problem of interest, either within or outside of the mathematical sciences. "People see problems in a completely different way when they come from different backgrounds," Abrams said. "You don't need a collaborator to get started, but you do need to find someone to talk to eventually so you know how people with different backgrounds view your ideas."

Opportunities for new professional partnerships can emerge in unexpected places, but one surefire way to make connections and learn the priorities of various research disciplines is through conferences. "Go to conferences of all different types, immerse yourself in different fields, and see what people in those fields care about," Rubin said. Some scientific gatherings even schedule structured sessions for attendees to build relationships and work together. "In my experience as a graduate student and postdoc, I found smaller-scale workshops with dedicated time for project work to be helpful," Kawakatsu said.

Partaking in a variety of activities close to home—such as seminars at one's own university—can be similarly beneficial. "Having local collaborators can't be beat, especially when you're getting started in a field," Rubin said. "There can be a steep learning curve, so thinking globally but acting locally is a good strategy." The panelists agreed that even casual social interactions may lead to interesting and unexpected collaborations. "The key is talking to people you don't know," Abrams said. "Lots of people can find common, interdisciplinary interests."

Certain openings are particularly advantageous for students who wish to explore several research pathways and make connections early in their careers. "During my graduate training, I was fortunate to have the opportunity to go to different kinds of conferences and be exposed to interdisciplinary research," Kawakatsu said. "You need to know the cultures of different disciplines to do cool work." Budd extolled the benefits of online and in-person brainstorming sessions—such as the European Study Groups with Industry[3]—that encourage Ph.D. students from diverse disciplines to drive the development of new ideas. SIAM also offers several programs that allow students to engage with mathematical modeling in a team-driven, application-based setting, including the Graduate Student Mathematical Modeling Camp and Mathematical Problems in Industry Workshop.[4]

While academics who are beginning to explore interdisciplinary research may initially be unsure of the funding process, these types of projects are often appealing to funders. In addition to federal grants, monetary support can stem from private foundations, discipline-agnostic fellowships at universities, and directly from industry. "If you're doing interdisciplinary work, there's a much broader funding landscape out there," Budd said. "Be aware of it and use it to your advantage." Collaborators must also recognize that principal investigators in different fields will have unique grant needs and strategies; for instance, biology laboratories typically have higher overhead costs than most applied mathematics groups.

Once a project is underway, researchers must determine the most suitable platform for publication — should they target a journal that focuses on mathematics, the application domain, or interdisciplinary science? A complicating factor is that many interdisciplinary journals are high impact and thus quite competitive; there are not very many smaller, more specialized interdisciplinary journals that can serve as a middle ground. A number of other questions are also at play, such as what venues will best advance junior researchers' careers, which journals are most relevant to collaborators, and how one can effectively reach the intended readership. "Trying to understand your audience and communicate with them is really important," Budd said.

Multiple SIAM journals offer cross-cutting platforms between applied mathematics and other disciplines, and another option has just been made available: the newly minted *SIAM Journal on Life Sciences*,[5] of which Rubin is editor-in-chief. "Hopefully there will now be a perfect place to publish anything on math and the life sciences," he said. "The idea is to have a journal that puts mathematics in the center of each paper—not hides it away in the supplements—but

See **Interdisciplinary Research** *on page 4*

[1] https://www.siam.org/conferences-events/past-event-archive/ds25
[2] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=84700
[3] https://ecmiindmath.org/study-groups
[4] https://www.siam.org/programs-initiatives/programs/graduate-student-mathematical-modeling-camp-and-mathematical-problems-in-industry-workshop
[5] https://www.siam.org/publications/siam-journals/siam-journal-on-life-sciences

siam news

ISSN 1557–9573.

Mathematical Methods in Origami: A Path From Math to Art

By Robert J. Lang

It feels a bit odd for me to be writing for *SIAM News*, as my education was in engineering and physics and my current career is a mixture of engineering and art. Nevertheless, math has been the key to making the intellectual connections and career transitions that led to my current situation, which combines mathematics, technology, and art: specifically, the art of origami.[1]

In high school, Martin Gardner's books and *Scientific American* columns[2] inspired my passion for all things mathematical. A variety of mathematical activities soon followed: math team competitions in my home state of Georgia and beyond; a summer program at the University of Chicago, where I learned number theory from Arnold Ross; and, when the time came, an undergraduate education across the country at the California Institute of Technology (Caltech).

I arrived at Caltech with every intention of becoming a mathematician, but the spark wasn't there for me in the core freshman mathematics class. Instead, I discovered digital electronics; it made computers make sense and allowed me to build tangible objects that did interesting things. I got hooked on engineering, became an electrical engineer, and put math aside — or so I thought.

CAREERS IN MATHEMATICAL SCIENCES

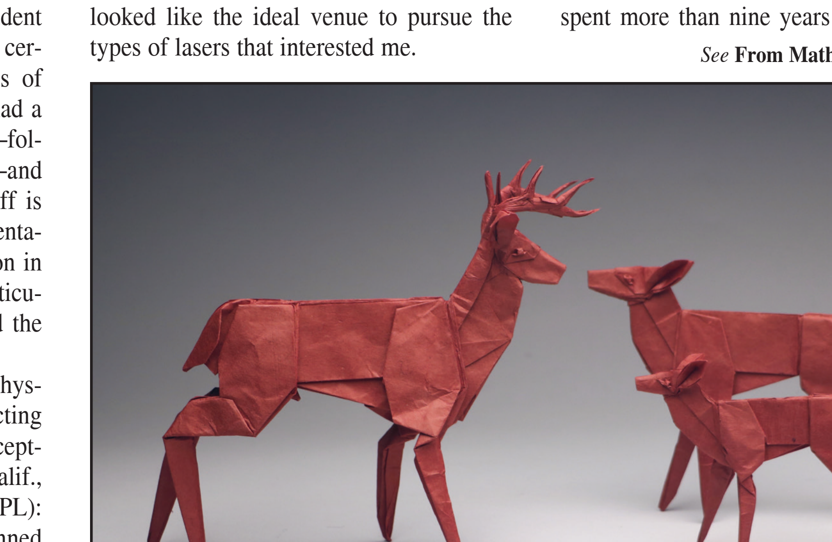
After a brief stint at Stanford University to pick up a master's degree in electrical engineering, I returned to Caltech to pursue lasers and optics for my Ph.D. Although I had been a fairly hardcore experimentalist as an undergrad, the first question I tackled as a new Ph.D. student was mathematical in nature: analyzing certain anomalies in the noise properties of diode lasers. Within a few months, I had a solution to the governing equations—followed by my first journal article—and thought, "Wow, this mathematical stuff is fun!" I didn't fully abandon experimentation, but I did find immense satisfaction in building mathematical models — particularly when they helped me understand the functionality of real-world devices.

Upon earning my Ph.D. in applied physics, I spent a year in Germany conducting research on diode lasers before accepting a position back in Pasadena, Calif., at the Jet Propulsion Laboratory[3] (JPL): NASA's lead center for the unmanned space program. At JPL, those in the "science" part of the organization essentially study the workings of the Earth, planets, and universe. Undergirding that research is the "technology" side of the house, where engineers develop the underlying technologies that enable the scientists to do their science. Semiconductor lasers and optoelectronics comprise part of this technological base. When I first arrived, JPL was in the process of establishing a new laboratory, which looked like the ideal venue to pursue the types of lasers that interested me.

And so I pursued them, working on a phenomenon called *filamentation* (a nonlinear pattern of spatial oscillations similar to solitons) and the theory of complex diffraction gratings within diode lasers. After several years, I was approached by Spectra Diode Laboratories (SDL), a commercial laser diode company that needed a theoretician to support some of their research projects. I accepted the offer and spent more than nine years there, working

See **From Math to Art** *on page 5*

[1] https://langorigami.com
[2] https://www.scientificamerican.com/author/martin-gardner
[3] https://www.jpl.nasa.gov



Whitetail Family BP (2018). In this origami family of white-tailed deer, each figure is folded from a single uncut square. A deer with antlers was the inspiration for Robert Lang's development of tree theory in origami design. Figure courtesy of the author.

Factorizations

Continued from page 1

is $\sum_{i',j',k',l'=1}^{q} a_{ii'}a_{jj'}a_{kk'}a_{ll'}(\kappa_4(Z))_{i'j'k'l'}$. The tensor $\kappa_d(X)$ is known (or estimated from data), while A and Z are unknown. This is now a tensor factorization.

Independent Component Analysis Is Symmetric Tensor Decomposition

Independent variables have diagonal cumulants. If $X = AZ$ for independent variables Z_i, then the congruence transformation yields

$$\kappa_d(X) = \sum_{i=1}^{q} \lambda_i \mathbf{a}_i^{\otimes d},$$

where $\mathbf{a}_i$ is the ith column of A and λ_i is the dth cumulant of Z_i. This is the usual symmetric tensor factorization. Under the correspondence between symmetric tensors and homogeneous polynomials, the factorization seeks to decompose a polynomial into a sum of powers of linear forms — a method that dates back to the 19th century [7]. We can impose additional structure on A, such as orthogonality [11] or $A = (I - \Lambda)^{-1}$ [5], but doing so is not required; the uniqueness of tensor factorization [1] makes *independent component analysis* (ICA) identifiable for general matrices A, including in the "overcomplete" case when $q > p$ [2, 3, 9].

We have now explored the factorizations behind three classical tools. In present-day experiments, we aim to understand systems by collecting data across a range of contexts. This process requires new factorizations, as evidenced by the following two examples.

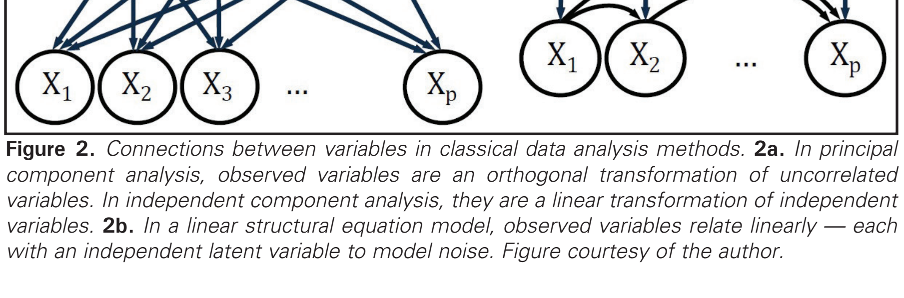


Figure 2. *Connections between variables in classical data analysis methods.* **2a.** *In principal component analysis, observed variables are an orthogonal transformation of uncorrelated variables. In independent component analysis, they are a linear transformation of independent variables.* **2b.** *In a linear structural equation model, observed variables relate linearly — each with an independent latent variable to model noise. Figure courtesy of the author.*

Linear Causal Disentanglement Is the Partial Order QR Decomposition

The three preceding methods assume uncorrelated latent variables. In contrast, *causal disentanglement* is an area of machine learning that seeks latent variables with causal dependencies between them. In *linear* causal disentanglement (LCD), observed variables X are a linear transformation of latent variables Z that follow an LSEM (see Figure 3a) [6]. The covariance therefore has factorization

$$\Sigma_X = A(I-B)^{-1}D(I-B)^{-\top}A^{\top}.$$

Too many parameters exist for unique recovery from Σ_X. Instead, LCD is appropriate for data that are observed under multiple contexts that are related via interventions on a latent variable. We characterize the number of required contexts for identifiability and provide an algorithm to recover the parameters. To do so, we define the *partial order QR factorization*: a version of the QR factorization[3] for matrices whose columns observe a partial order rather than the usual total order.

Contrastive ICA Is Coupled Tensor Decomposition

To describe a foreground dataset (i.e., an experimental group) relative to a background dataset (i.e., a control group), we attempt to jointly model variables across the two contexts. In *contrastive ICA* [8], we model the foreground and background as two related ICA models (see Figure 3b). The dth cumulants of the foreground and background are respectively

$$\sum_{i=1}^{q} \lambda_i' \mathbf{a}_i^{\otimes d} + \sum_{i=1}^{r} \mu_i \mathbf{b}_i^{\otimes d} \quad \text{and} \quad \sum_{i=1}^{q} \lambda_i \mathbf{a}_i^{\otimes d}.$$

We jointly factorize the two cumulant tensors. For matrices, we can always take a best low-rank approximation as a sum of orthogonal terms. However, this is no longer true for tensors; we must find a tradeoff between accuracy and orthogonality. We first use the subspace power method [4] for accuracy, then incorporate a new hierarchical tensor decomposition for orthogonality.

As datasets continue to increase in richness, their complexity presents an opportunity for mathematicians to reveal the structure in modern data by advancing and applying the mathematics of factorizations. There are many open directions, including the development of linear and multilinear algebra ideas to establish the existence and uniqueness of new factorizations, sample complexity investigations, numerical algorithms, and extensions to nonlinear transformations.

[3] The QR factorization writes a matrix as the product of an orthogonal multiplied by an upper triangular matrix.

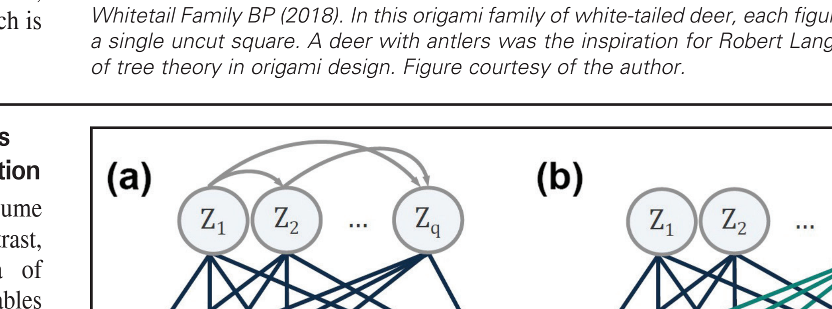


Figure 3. *Connections between variables in two new data analysis methods.* **3a.** *In linear causal disentanglement, observed variables X are a linear transformation of latent variables with causal dependencies between them.* **3b.** *In contrastive independent component analysis, observed variables are a linear transformation of independent latent variables, some of which only appear in the foreground (those connected via teal arrows). Figure courtesy of the author.*

References

[1] Alexander, J., & Hirschowitz, A. (1995). Polynomial interpolation in several variables. *J. Algebr. Geom.*, *4*, 201-222.

[2] Comon, P. (1994). Independent component analysis, a new concept? *Signal Process.*, *36*(3), 287-314.

[3] Eriksson, J., & Koivunen, V. (2004). Identifiability, separability, and uniqueness of linear ICA models. *IEEE Signal Process. Lett.*, *11*(7), 601-604.

[4] Kileel, J., & Pereira, J.M. (2019). Subspace power method for symmetric tensor decomposition. Preprint, *arXiv:1912.04007*.

[5] Shimizu, S., Hoyer, P.O., Hyvärinen, A., & Kerminen, A. (2006). A linear non-Gaussian acyclic model for causal discovery. *J. Mach. Learn. Res.*, *7*(72), 2003-2030.

[6] Squires, C., Seigal, A., Bhate, S., & Uhler, C. (2023). Linear causal disentanglement via interventions. In *ICML'23: Proceedings of the 40th international conference on machine learning* (pp. 32540-32560). Honolulu, HI: Journal of Machine Learning Research.

[7] Sylvester, J.J. (1851). On a remarkable discovery in the theory of canonical forms and of hyperdeterminants. *London Edinburgh Dublin Philos. Mag. J. Sci.*, *2*(12), 391-410.

[8] Wang, K., Maraj, A., & Seigal, A. (2024). Contrastive independent component analysis. Preprint, *arXiv:2407.02357*.

[9] Wang, K., & Seigal, A. (2024). Identifiability of overcomplete independent component analysis. Preprint, *arXiv:2401.14709*.

[10] Wright, S. (1934). The method of path coefficients. *Ann. Math. Stat.*, *5*(3), 161-215.

[11] Zhang, T., & Golub, G.H. (2001). Rank-one approximation to high order tensors. *SIAM J. Matrix Anal. Appl.*, *23*(2), 534-550.

Anna Seigal is an assistant professor of applied mathematics at Harvard University. Her research explores applied algebra and the mathematics of data science, with a focus on factorizations for data analysis.

Computational Experiments

Continued from page 1

you're new to Git, the free *Pro Git* book[8] is an excellent starting point [1].

Separate Experiments From Figures

A common pitfall in computational experiments is the *direct* generation of figures from experimental runs. I'm sure we've all written codes that do exactly this, but I urge you to instead save the raw data that can later be translated into a figure.

Of course, the desire to immediately generate a figure is quite natural. We often begin with *ad hoc* experiments to informally test our methods, and it is normal to want to visualize the results in some way. But these initial *ad hoc* experiments do become formal at some point, and I encourage you to save the data that you used to create your figure — perhaps even in a greater level of detail than the figure provides.

This type of separation allows you to recalculate metrics (e.g., median versus mean), adjust visual elements (e.g., axis labels), and generate subsets of results for different audiences (see Figure 1, on page 1).

Personally, I recommend tools like PGFPLOTS[9] for figure generation, which integrates well with LaTeX and ensures reproducibility of visuals.

Create Human-digestible Logs

In addition to saving data files for the production of figures, I advocate for saving detailed, human-digestible logs of your experiments by tooling your scripts and codes to print regular status messages. I address logs in more detail in the next point, but here I want to stress that you and your coauthors should be able to read through these records to better understand your computational experiment.

Ultimately, the logs serve as artifacts for your experiment that persist even if you can never reproduce it exactly. In large language models, for instance, the fact that floating-point addition is not strictly associative means that different parallel summation orders in different runs can yield slightly different final results.

Log Details of Individual Runs

Besides being digestible by humans, your logs should include the necessary details to reproduce individual experiments. I highly recommend saving the random seed for every run, not just the first one. Otherwise, you might find yourself in a situation where you must complete 75 runs before you can redo the 76th.

For this reason, each experimental run should produce a unique, identifiable log that includes the following:

- Git hashes for code and data (and diff logs if you don't commit before every run)
- Random seeds
- Input parameters
- Fine-grained metrics like error after each iteration
- Timestamps.

Use unique identifiers (e.g., script name plus timestamp) to name artifacts, which will enable spot-checking and ensure the traceability of each run. Ideally, these artifacts should become part of your repository, forming a complete record of your computational experiments.

Use Scripts for Automation

Automation is your future self's best friend. Scripts allow you to rerun experiments after code changes, perform parameter sweeps, incorporate feedback from collaborators and/or referees, and apply the same methods to new datasets or scenarios. They also make it easier to share your work with coauthors and reviewers. A well-organized set of scripts can preprocess raw input data, recreate individual runs, regenerate all runs, collate results, and generate figures.

[8] https://git-scm.com/book/en/v2
[9] https://www.youtube.com/@UnlockingLaTeXGraphics

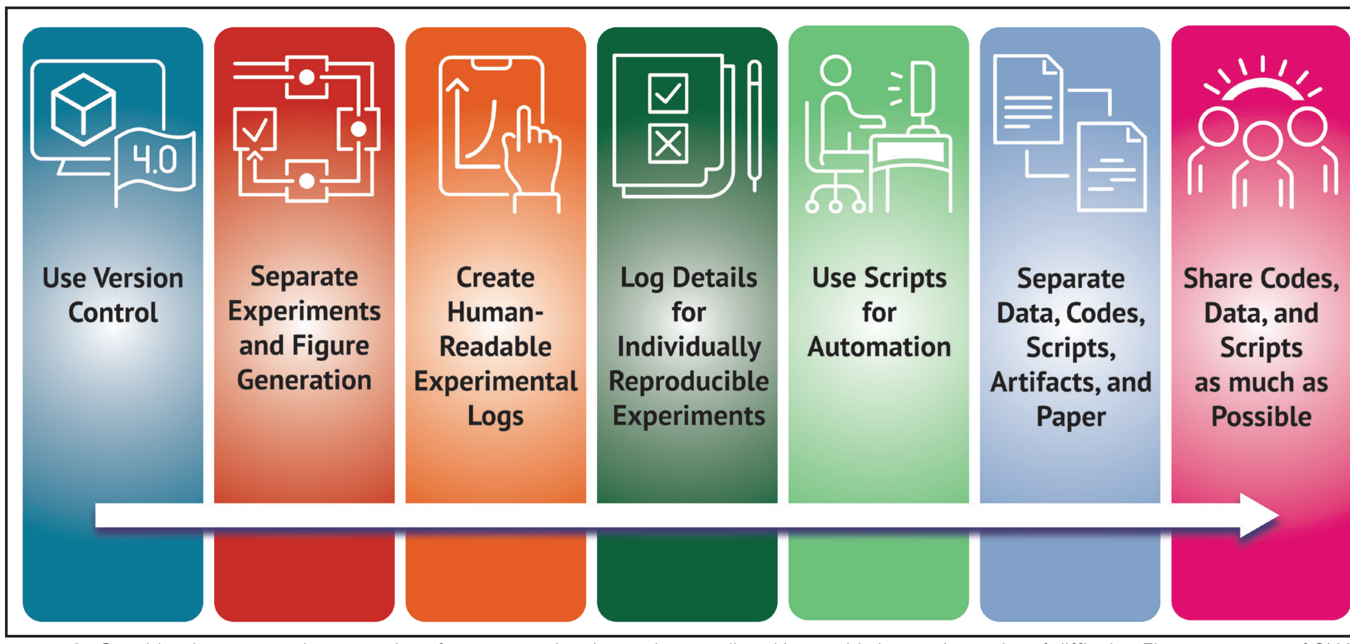


Figure 2. *Consider these seven best practices for computational experiments, listed in roughly increasing order of difficulty. Figure courtesy of SIAM.*

Separate and Organize Your Project Components

A typical computational project includes multiple components:

- **Datasets:** Inputs for your experiments, ideally with README files and scripts that describe the original data sources and preprocessing.
- **Codes:** Implementations of your algorithms, ideally reusable and well-documented with a potential life beyond the paper in question. You will likely also have other codes for methodology comparisons.
- **Scripts:** Scripts to perform experiments that are specific to the paper or study, often involving multiple runs and configurations.
- **Outputs:** Various outputs of the computational experiments, such as (i) *logs*: numerous human-readable summaries from individual experiments; (ii) *raw data*: machine-readable data files from individual experiments; and (iii) *summaries*: aggregated results used in figures and tables.
- **Paper:** A publication wherein the computational experiments act as supporting evidence for a certain finding.

Avoid the temptation to keep everything in a single folder. Instead, organize the materials and consider using multiple Git repositories if some components (e.g., datasets or software packages) are valuable beyond the current project. If nothing else, consider keeping the paper in its own repository, as you can much more easily link to the online Overleaf editor.

Share Your Code, Data, and Experimental Logs

Even if your code isn't perfect, sharing it is invaluable. I highly recommend Randall LeVeque's 2013 *SIAM News* article[10] titled "Top Ten Reasons to Not Share Your Code (and why you should anyway)" [3]. In this piece, LeVeque develops an analogy between publishing code and publishing proofs of mathematical theorems. There are plenty of good reasons not to share a mathematical proof — for instance, it might be too ugly to show anyone else! Of course, we would never publish an important math theorem without a proof, and the same should be true for computational experiments.

LeVeque further contends that "[w]hatever state it is in, the code is an important part of the scientific record and often contains a wealth of details that do not appear in the paper, no matter how well the authors describe the method used" [3]. There is much to be learned even without running the code, and I heartily agree with LeVeque's claim that the ability to examine the code is typically more valuable than the ability to rerun it exactly.

I would also argue for the importance of sharing the input data and output logs of computational experiments. Too often, preprocessing of the input data is undocumented. Output logs are invaluable to determining the success (or failure) of experimental reproduction and can provide insights that the summary data might not capture.

[10] https://www.siam.org/publications/siam-news/articles/top-ten-reasons-to-not-share-your-code-and-why-you-should-anyway

Sharing codes, data, and experimental logs is beneficial for science and fosters transparency, collaboration, and scientific progress. But you don't have to be noble! Sharing likewise encourages the broad citation of your own work because it allows others to understand your methods more deeply, build upon your research, and compare their techniques to yours.

Final Thoughts

These seven practices are not just about making your work reproducible — they're about making it credible, collaborative, and impactful (see Figure 2). They help your coauthors validate results, enable your future self to revisit past experiments, and inspire trust in your findings as the foundation for further studies.

I presented these ideas during an invited talk[11] at the 2025 SIAM Conference on Applications of Dynamical Systems[12] in Denver, Colo., this past May, after which several attendees commented on the lack of value that is placed on extra work (in the short term) to ensure reproducibility and easy access to codes. As such, I would advocate for promotion letter writers to evaluate software contributions and stress the importance of such work. If you have benefited from the availability of someone else's data, code, and results, be sure to provide appropriate citations and perhaps even send a note to acknowledge their influence on your own work.

Whether you're a graduate student starting your first project or a seasoned researcher managing a large team, these principles can help you tame the chaos of computational experiments. Let's make reproducibility not just an aspiration, but a habit.

[11] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=84659
[12] https://www.siam.org/conferences-events/past-event-archive/ds25

References

[1] Chacon, S., & Straub, B. (2014). *Pro Git* (2nd ed.). New York, NY: Apress.

[2] Dubner, S.J. (Host), & Kulman, A. (Producer). (2024, January 10). Why is there so much fraud in academia? [Audio podcast episode]. In *Freakonomics Radio*. Renbud Radio. https://freakonomics.com/podcast/why-is-there-so-much-fraud-in-academia.

[3] LeVeque, R.J. (2013, April 2). Top ten reasons to not share your code (and why you should anyway). *SIAM News*, *46*(3), p. 8.

Tamara G. Kolda is a consultant under the auspices of her California-based company, MathSci.ai. She previously worked at Sandia National Laboratories. Kolda specializes in mathematical algorithms and computational methods for data science, especially tensor decompositions and randomized algorithms. She is a SIAM Fellow, co-founded and was editor-in-chief of the SIAM Journal on Mathematics of Data Science, and currently serves as SIAM's Vice President for Publications and chair of the SIAM Activity Group on Equity, Diversity, and Inclusion.

Interdisciplinary Research

Continued from page 2

nevertheless has accessibility to everyone in the life sciences."

Interdisciplinary researchers must often make special considerations when navigating the hiring and tenure processes, as their publication records may deviate from the industry standard and journal impact factors can vary by field. When working towards academic tenure, faculty must pay close attention to departmental expectations and maintain a broader understanding of the discipline. Ultimately, however, the panelists concurred that it is most important to pursue intriguing problems and publish in relevant places, even though this approach may involve a philosophical choice between an optimal career strategy versus more personal interests and goals. "We should trust our intuition on what matters and do good stuff, and it will work out," Hammerling said.

Difficulties and failures are an inevitable part of the interdisciplinary process, and things do not always go as planned. To get a sense of a specific research direction's promise while keeping the stakes low, faculty can potentially assign the prospective problem to a class or undergraduate assistant. This initial investigative step can provide intel as to whether a project is too simple and hence easily solvable with existing tools, or too difficult to be worth the time and effort. "There's a decision of whether you're willing to put in all that work, and if it's in that sweet spot of what you're working on," Hammerling said.

Though potential collaborators may share the same general interests, it is essential to clearly communicate goals and intentions when developing a project to ensure that everyone is willing and able to approach the problem in the same way. As a study progresses, one of the biggest issues can be maintaining clear communication between disparate teams and researchers who may use clashing terminology and have different levels of familiarity with certain techniques. Frequent updates on research progress, questions, and roadblocks throughout a project's entire lifecycle can help keep everything on track. "You have to face the fact that interdisciplinary research is hard and accept when it doesn't work," Budd said. "Don't be discouraged, and learn from your mistakes."

Yet despite the challenges, interdisciplinarity can be incredibly rewarding. This unique avenue of research allows scientists to explore pressing problems that interface with multiple fields in exciting ways — as long as they are prepared to address any dilemmas that might arise. "Some things will not work out or go as fast as you hope they do," Abrams said. "If everything works out exactly as you expect, you probably aren't trying things that are difficult."

Jillian Kunze is the associate editor of SIAM News.

From Math to Art

Continued from page 3

on high-power diode lasers, grating-defined cavity lasers, unstable resonator lasers, and so forth. SDL was a small business when I joined but it grew over the years, as did my responsibilities. I advanced from Section Manager to Senior Section Manager and eventually to Chief Scientist, which seemed like my dream job; I was involved in a wide range of cutting-edge research and worked with many talented people.

It is the general nature of career growth that as one assumes increasingly higher levels of responsibility, there are fewer and fewer opportunities to get down and dirty with differential equations. And so when I became Vice President of Research and Development at SDL, I mainly managed contracts, funding, and special products for select customers while my group engaged in the exciting research and technical challenges that stemmed from the exponential growth of the late-1990s dot-com boom.

But during those years, I maintained one mathematical pursuit: the mathematics of origami. I had been creating new origami designs since childhood and began writing my first book with my own origami designs in graduate school. I continued to create and write about origami throughout my lasers and optoelectronics career. Many of my designs were quite complex; in fact, they included some of the most intricate origami figures of the time. Along the way, I developed several geometric techniques that I implemented in my designs — techniques that relate the intended shape to the crease pattern (CP) in the paper and ultimately give rise to the folded form (FF).

The goal of a mathematical physicist is often to follow some version of this procedure: determine how to mathematically describe the phenomenon in question, then use math-based tools to accomplish particular objectives (e.g., learn more about a physical phenomenon or achieve a specific design). In physics, this method works because the studied phenomena frequently obey rules whose simplicity allows known mathematics to provide a good approximation of what is actually happening. This also seemed to be the case in origami.

The following is a very simple rule for origami, particularly the relationship between CP and FF. If we mark two dots on an unfolded paper and subsequently fold the paper into a two- or three-dimensional shape, then the distance between those two points—measured by traveling along the FF—must be less than or equal to their original separation on the unfolded paper. Folding can reduce the distance between the dots but never increase it (only cutting or ripping can do that). A simple inequality thus governs the positions of any two points $\mathbf{p}$ and $\mathbf{q}$ in the CP and FF:

$$|\mathbf{p}_{\mathrm{CP}} - \mathbf{q}_{\mathrm{CP}}| \geq |\mathbf{p}_{\mathrm{FF}} - \mathbf{q}_{\mathrm{FF}}|.$$

This rule must hold for any pair of points in an origami figure: the head and tail of an animal, the tips of an arm and leg, or any two fingers. For all origami subjects—regardless of complexity—we can hence establish a system of these equations between all possible pairs of points that constrains their relative positions.

While the constraint equations are *necessary*, they are not necessarily *sufficient* for the existence of a design. But it turns out that there are folding patterns within the world of origami models that we can apply to make them sufficient! In particular, I (and others) identified families of patterns—now called *molecules*—that were key to the sufficiency condition. If we have an arrangement of points that satisfy the distance conditions, we can then decorate the arrangement with these molecules and achieve a CP that is guaranteed to be foldable into the desired shape.

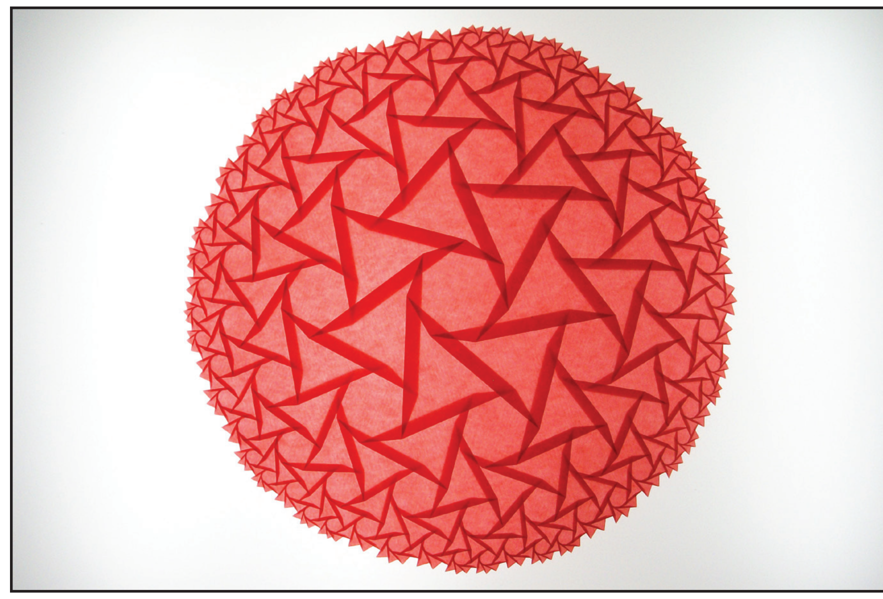
The theory that arose from this line of inquiry revolutionized the world of origami design. Figures that had previously seemed near-impossible—insects, spiders, and multi-legged, -horned, -winged, and -scaled creatures of all kinds—were now readily designable and foldable. Origami artists around the world, including myself, went on a designing and folding spree.

In my laser work, I didn't just write equations to describe lasers; I wrote computer codes to assist others with their designs. I did the same thing with my origami mathematics and wrote a computer program called *TreeMaker*[4] for the design of origami figures. Users would first construct a mathematical graph to represent the shape, after which the program solved all of the inequality conditions that were linked to the graph and filled in the resulting arrangement of points with the appropriate molecules to complete the CP.

I worked on *TreeMaker* over a period of years, utilizing it to test my theories and find and plug logical holes that resulted from unwarranted assumptions. By the mid-1990s, *TreeMaker* was powerful enough that I could use it to design figures that were more complex than basic intuition would have allowed. I showed the program to a computer science friend at the Xerox Palo Alto Research Center, who suggested that I submit it to a computational geometry conference. So I did, and it was accepted. That paper pulled me back into mathematics, particularly computational geometry. It got my name into the scientific literature, and presently people who were working on folding problems began to ask for my help.

Throughout a decade of writing about origami, I had always envisioned a book that was more than a collection of directions, e.g., "here's how to fold an X." I wanted to write a book about designing your own origami — and not necessarily using explicit mathematics. Many concepts in origami design can rely on simple geometric ideas, such as packing balls in a box rather than crafting algebraic inequalities. But during my years of laser work, I made very little headway towards this goal. I therefore concluded that writing such a book would need to be a full-time project with no other distractions.

[4] https://langorigami.com/article/treemaker



3^7 Hyperbolic Limit, Opus 600 (2014). A single-sheet tessellation fold of a hyperbolic tiling that uses the Poincaré projection of hyperbolic geometry. Figure courtesy of the author.

Thus came a decision point: do I continue what I've been doing, or do I write this book? I had done pretty well as a laser physicist, but there are a lot of laser physicists in the world. Anything that I could accomplish in lasers could probably be accomplished by someone else (perhaps even better). But I felt like I was the only person who could write the book that I wanted to write — a book that I felt needed to be written.

So in 2001, I left my job in physics (the dot-com bust provided additional incentive) and set out to write my envisioned text. I also hung out my shingle as a professional origami artist and began to respond to opportunities that I'd previously needed to turn down when I had a full-time job.

It turned out that origami has quite a few applications. In addition to artistic projects—e.g., private art commissions and commercial art for advertising purposes—some companies and products need folding to accomplish their goals: medical devices for which origami's no-cuts requirement preserves sterility, or the deployable aspect enables laparoscopic surgical implements; collapsible forms for backpacking and shelters; and space applications like the Eyeglass telescope,[5] where large, flat shapes (lenses, reflectors, antennas, and shrouds) must be compactly folded for stowage and travel.

During the early 2000s, the mathematical applications of origami were also coming into the mainstream. Mathematicians had been occasionally looking at folding for decades, and the first conference about origami's use in math and science took place in 1989. But by the 2000s, mathematicians like Thomas Hull and computational geometers like Erik Demaine were establishing the fundamental laws of folding and fundamental rules of its algorithms and complexity. New design tools entered the field, ranging from Tomohiro Tachi's *Origamizer*—which did for shell-like structures what *TreeMaker* had done for tree-graph-like structures—to Jun Mitani's *ORI-REVO*, which took on solids of revolution and curved shapes with axial symmetry. For many years, the mathematics of origami had been a side project for researchers (including myself) and was not deemed a worthy academic pursuit. But that mindset was changing.

In 2011 and 2012, the U.S. National Science Foundation (NSF) put out a call for proposals in their Emerging Frontiers in Research and Innovation program[6] that specifically asked for research in folding: underlying theory, materials, devices, and applications. It turned out to be one of the most popular initiatives of all time, with more than 100 initial responses. Over the course of two years, the NSF funded a total of 14 awards, each of which supported several professors and their students at various universities for a total of four to five years.

I ended up working on a few of these award programs. But most importantly, this funding lit a fire within the world of mathematical, scientific, and engineering-related study of origami and folding. It brought professors directly into the realm of mathematical origami and inspired many graduate students to become professors themselves and pass the torch to subsequent generations. The NSF funding eventually ended, of course, but it prompted continued interest from other government agencies and commercial companies — all of which have witnessed folding's potential to solve real-world practical problems. In tandem with these applications, there is a continued need for mathematical tools to solve such problems as they arise.

Robert J. Lang is an origami artist and consultant based in Altadena, California, with a background in laser physics. He is the author, coauthor, or editor of 21 books, more than 100 refereed journal papers, and 50 patents in the fields of lasers and folding.

[5] https://langorigami.com/article/eyeglass-telescope

[6] https://www.nsf.gov/eng/efma/emerging-frontiers-research-innovation

Pentasia (2014). This modular origami form—made from 500 sheets of paper—replicates Pentasia, a mathematical surface that was conceived of and analyzed by Barry Cipra and John H. Conway and serves as a three-dimensional version of the famous Penrose kite/dart tiling. Figure courtesy of the author.

Photos From the Third Joint SIAM/CAIMS Annual Meetings

Marsha Berger of New York University and the Flatiron Institute (right) accepts the 2025 John von Neuman Prize—SIAM's highest honor and flagship lecture—from SIAM President Carol Woodward at the Third Joint SIAM/CAIMS Annual Meetings (AN25), which were held this summer in Montréal, Québec, Canada. Berger, who was recognized for her foundational work in adaptive mesh refinement and embedded boundary methods for partial differential equations, presented an engaging talk at AN25 titled "Thirty Years of Cartesian Cut-cell Methods: Where Are We Now?" SIAM photo.

SIAM President Carol Woodward (left) congratulates Timothy Davis of Texas A&M University on his receipt of the 2025 I.E. Block Community Lecture at the Third Joint SIAM/CAIMS Annual Meetings, which took place this summer in Montréal, Québec, Canada. The lecture is named for I. Edward Block—cofounder and former managing director of SIAM—and is meant to foster public appreciation of the excitement and vitality of science. Davis delivered a visually and auditorily appealing talk titled "An Unexpected Journey: From Music to Art Via Math." SIAM photo.

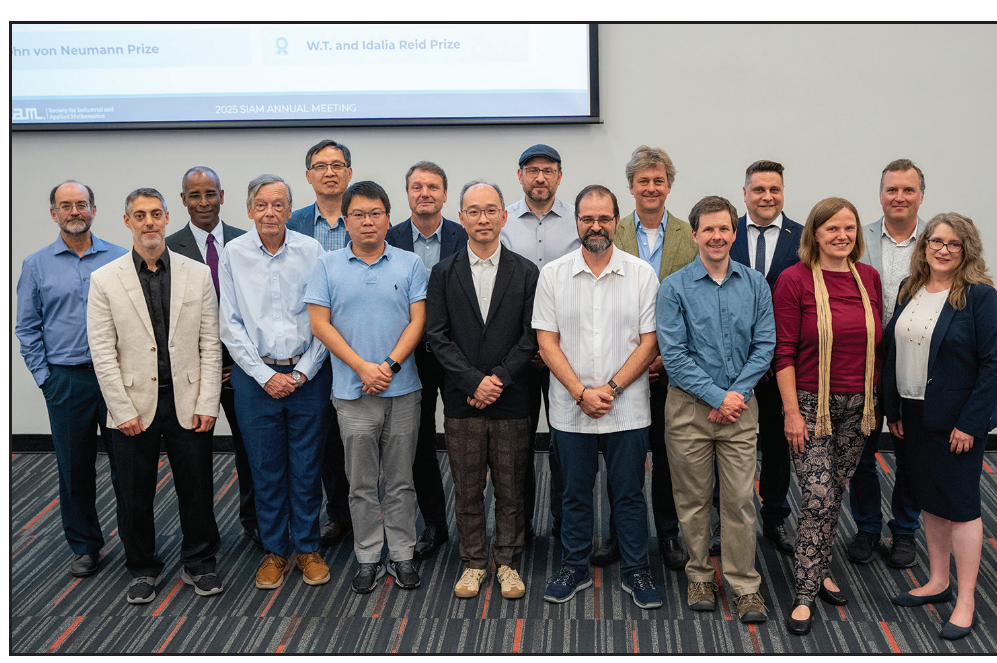
At the Third Joint SIAM/CAIMS Annual Meetings, which took place this summer in Montréal, Québec, Canada, SIAM President Carol Woodward (left) presents Tamara Kolda of MathSci.ai with the 2025 SIAM Prize for Distinguished Service to the Profession. Kolda—a SIAM Fellow, current SIAM Vice President for Publications, and chair of the SIAM Activity Group on Equity, Diversity, and Inclusion—received the award "in recognition of her extensive leadership and service to multiple applied mathematics communities, including SIAM and the National Academies, and promotion of equity, diversity, and inclusion." SIAM photo.

View more information about all SIAM prize recipients from the Third Joint SIAM/CAIMS Annual Meetings at *https://www.siam.org/publications/siam-news/articles/2025-july-prize-spotlight*

A complete list of 2025 SIAM Fellows is available at *https://www.siam.org/publications/siam-news/articles/siam-announces-2025-class-of-fellows*

During the Third Joint SIAM/CAIMS Annual Meetings, which took place this summer in Montréal, Québec, Canada, SIAM President Carol Woodward (left) and Association for Women in Mathematics (AWM) President-Elect Raegan Higgins (right) acknowledge Yongjie Jessica Zhang of Carnegie Mellon University for her receipt and delivery of the 2025 AWM-SIAM Sonia Kovalevsky Lecture. Zhang is widely known for her pioneering research in computational geometry and finite element methods, with profound impacts across biomedical and engineering applications. Her prize lecture was titled "From Neurological Disorders to Additive Manufacturing: Integrating Isogeometric Analysis With Deep Learning and Digital Twins." SIAM photo.

Richard Allen of Pfizer (right) was the inaugural recipient of the newly established SIAM Industry Prize during the Third Joint SIAM/CAIMS Annual Meetings, which took place this summer in Montréal, Québec, Canada. He accepted the award from SIAM President Carol Woodward, who applauded Allen for his outstanding contributions to the effective application of mathematical sciences to industry — specifically his creation of quantitative systems pharmacology models for drug development to treat diseases such as COVID-19. Allen later spoke about "Bringing Medicines to Patients with Mathematical Biology" at the conference. SIAM photo.



During the Honors and Awards Luncheon at the Third Joint SIAM/CAIMS Annual Meetings, which were held this summer in Montréal, Québec, Canada, members of the 2025 class of SIAM Fellows gathered for a group photo to commemorate their outstanding contributions to areas of study that are served by SIAM. From left to right: Frank Sottile of Texas A&M University, Lior Horesh of IBM Research, Steven Lee of the U.S. Department of Energy's Office of Advanced Scientific Computing Research, Thomas Hagstrom of Southern Methodist University, Wei Kang of the Naval Postgraduate School, Lili Ju of the University of South Carolina, Lars Grüne of the University of Bayreuth, Eric Chung of the Chinese University of Hong Kong, Serkan Güğercin of Virginia Tech, Luis Chacon of Los Alamos National Laboratory, Jonathan Mattingly of Duke University, David Gleich of Purdue University, Gianluigi Rozza of Scuola Internazionale Superiore di Studi Avanzati, Andrea Walther of Humboldt-Universität zu Berlin, Matthias Heinkenschloss of Rice University, and SIAM President Carol Woodward. SIAM photo.

BRL-CAD: An Open Source Solid Modeling System From the U.S. Army

By Aaron Hagström

SOFTWARE AND PROGRAMMING

BRL-CAD[1] is the U.S. military's primary system for solid modeling in computer-aided design (CAD). Its roots trace back to the MAGIC computer simulation program, which was developed in 1968 by the Mathematical Applications Group, Inc., to analyze vulnerabilities in military vehicles [5]. In 1979, Mike Muuss of the U.S. Army Ballistic Research Laboratory (now the Army Research Laboratory[2]) at Aberdeen Proving Ground in Maryland created the first version of BRL-CAD as a tool to facilitate the simulation and analysis of combat vehicle systems and environments; this preliminary effort marked a shift from punch cards to digital modeling [3]. Unified development began in 1983, followed by a public release in 1984 [1].

As such, BRL-CAD is the oldest public version-controlled code repository in the world. Since its debut, the system has evolved into a suite of more than 400 tools that support a wide range of geometric representations. It is rooted in constructive solid geometry but also allows for uniform B-spline surfaces, nonuniform rational B-splines, n-manifold geometry, and faceted mesh geometry [1]. Application areas include defense, medicine, mechanical design, and education. Today, the U.S. military utilizes BRL-CAD extensively for vulnerability and lethality analyses of ballistic weapons systems; the U.S. Army Combat Capabilities Development Command[3] maintains the software.

"Being a jack-of-all-trades for geometry, we need to support it all," lead BRL-CAD software architect Christopher Sean Morrison said. "Our priorities are to close the gaps between things that cannot be represented, converted, or analyzed effectively. The CAD industry does not make that easy; there are lots of formats and representation types."

In 2004, Morrison seized the opportunity to accelerate code development by acquiring more partners and successfully advocating for the code to be made open source. "[This] lifted the shackles on development, enabling rapid growth with no real downsides," he said.

Now, BRL-CAD has global contributors and regularly participates in the Google Summer of Code[4] and various university capstone projects. In fact, the system's ability to run in parallel on Windows stems directly from an open source contribution made by high school students.

BRL-CAD presently serves as a fundamental component of the U.S. Army's Advanced Joint Effectiveness Model[5] (AJEM): a joint forces modeling scheme that predicts vulnerability and lethality in threat and target interactions. The U.S. Department of Defense (DOD) has integrated BRL-CAD into a suite of software tools to estimate the probability of kill for systems that are under a ballistic threat. The Fast Shotline Generator employs BRL-CAD to generate shotlines (i.e., rays through a target) that the Computation of Vulnerable Area Tool (COVART) then utilizes to evaluate penetration, component damage, and overall vulnerability [2]. "The vulnerability analyses used by the DOD have become much higher order and higher fidelity," Morrison said. "Modern vehicles are far more complex, with action-reaction systems and redundancy."

BRL-CAD's unique ray tracing engine is crucial to this type of vulnerability analysis. The engine is built on BRL-CAD's flagship `librt` library,[6] which manages geometry loading, spatial partitioning, and ray-target intersections. While it can render accurate images as well, the library's primary role is to support other programs in simulating the path of ballistic weapons that may strike military vehicles.

More recently, Morrison has been working to upgrade this ray tracer by incorporating modern techniques like advanced spatial partitioning and optimization methods for cache management, central processing unit performance, and distributed computing. These improvements have reduced analysis times by more than half, significantly boosting BRL-CAD's performance. The ray tracer is now capable of processing tens to hundreds of millions of rays for highly detailed analysis; in tandem, the team is also developing a real-time ray tracing interface.

Morrison remarked that BRL-CAD is typically three to six orders of magnitude faster than other CAD systems when conducting ray tracing and loading the extremely detailed geometries of military vehicles. For instance, he tested one commercial package that loaded a geometry model in 30 minutes and shot roughly 1,000 rays per second; in contrast, BRL-CAD opened the same model in five seconds and shot from 100,000 to over a million rays per second. This dramatic difference in performance greatly expands the analytical possibilities of tools such as COVART. "Supporting an entire assessment in core memory is hard for most CAD engines to handle," Morrison said. "A unique aspect of BRL-CAD is the efficiency with which `librt` represents geometry in memory."

However, Morrison noted that one must continually evaluate the tradeoffs between speed and accuracy. The team has been incorporating graphics processing units to speed up computations for almost 10 years, but they have not yet been able to guarantee accuracy. "Is it accurate, or just 100 times faster?" Morrison asked.

A key calculation in ray tracing involves determining the distances from the ray's starting point to the entry and exit points on an object, such as a sphere. Figure 1 (on page 8) illustrates this process [4]. Rays are cast from a central grid plane that is aligned with the target's orientation and defined by parameters like grid size, cell size, and attack angle. Given an azimuth angle α and elevation angle θ,

See **BRL-CAD** *on page 8*

[1] https://www.brlcad.org
[2] https://arl.devcom.army.mil
[3] https://devcom.army.mil
[4] https://summerofcode.withgoogle.com
[5] https://dsiac.dtic.mil/models/ajem
[6] https://brlcad.org/docs/api/da/d12/group__librt.html

BRL-CAD

Continued from page 7

$$W_{B_x} = -\cos\alpha\cos\theta$$
$$W_{B_y} = -\cos\alpha\sin\theta$$
$$W_{B_z} = -\sin\theta,$$

where the azimuth and elevation angles are measured in the positive axis direction. When both azimuth and elevation angles are set to 0°, the rays are fired head-on at the target. Changing the azimuth to 90° positions the attack from the target's left side, while setting the elevation to 90° indicates an attack from directly above.

We can calculate the intersection distances R_{in} and R_{out} by simultaneously solving the ray equation and equation of the intersected geometrical shape. The ray equation is

$$X = \mathbf{XB} + \mathbf{WB}\cdot S, \tag{1}$$

where $\mathbf{XB} = (x_B, y_B, z_B)$ is a fixed point on the ray and $\mathbf{WB} = (W_x, W_y, W_z)$ are the direction cosines of the ray. For any value of the scalar S, this equation will yield a point $X = (x, y, z)$ along the ray.

The equation of a sphere with radius R about the point $\mathbf{V} = (V_x, V_y, V_z)$ for any point X on the surface is

$$(X - \mathbf{V})^2 = R^2. \tag{2}$$

Substituting the X from (1) into (2) results in

$$(\mathbf{XB} + \mathbf{WB}\cdot S - \mathbf{V})^2 = R^2,$$

$$S^2(\mathbf{WB})^2 + 2S(\mathbf{XB} - \mathbf{V})\cdot(\mathbf{WB}) + (\mathbf{XB} - \mathbf{V})^2 - R^2 = 0.$$

We must then solve for the constant S to find the distances to the entry and exit intersects.

Next, we relabel the coefficient of the $2S$ term in the quadratic expression as

$$B = (\mathbf{XB} - \mathbf{V})\cdot\mathbf{WB}$$

and the constant term as

$$C = (\mathbf{XB} - \mathbf{V})^2 - R^2.$$

The solution for S is thus given by

$$S = -B \pm \sqrt{B^2 - C}.$$

If $B^2 - C < 0$, no real intersection occurs. But if $B^2 - C = 0$, then the ray is tangent to the sphere:

$$R_{\text{in}} = -B - \sqrt{B^2 - C}$$
$$R_{\text{out}} = -B + \sqrt{B^2 - C}.$$

Verification and validation are essential to BRL-CAD; in analytical applications, they may even mean the difference between life and death. Morrison explained that the development team has dedicated much of the past year to such efforts — a key strength that sets the system apart from other CAD tools and content modelers, such as Blender or Autodesk Maya. "Our focus on fidelity is pretty intensive," he said. "We spend an incredible amount of time validating that a ray fired at a geometry hits it when it should hit and misses it when it should miss, and that there are no geometric issues even when the geometry is corrupt or fundamentally flawed. We pride ourselves on the behavior of our code being more scrutinized than any other system."

Geometry conversion is closely linked to fidelity, and Morrison and his colleagues have developed dozens of converters. "Our intent is to be this sort of Swiss Army knife of conversions that have awareness of analytic properties," he continued. "We must be able to [determine] whether the mesh is well-formed, without holes or dangling triangles. If there are errors, we need routines for eliminating them."

The BRL-CAD group recently received multiyear, multimillion-dollar funding from the DOD to support the open source development of a STEP file converter, as obtaining access to this ISO standard involves significant cost. "STEP is often referred to as the 'yin' of all CAD formats because of its vast complexity and ability to represent nearly everything in CAD," Morrison said. "Before BRL-CAD's work [on this converter], no open source STEP file importer was available."

Another significant focus area is geometry management, which allows for the cataloging, batch processing, conversion, indexing, and visualization of large volumes of files. One prospective usage could be the preparation of multi-format files for three-dimensional printing without the need to open each one individually. "We have various customers who use BRL-CAD and have anywhere from dozens to tens of thousands of geometry files," Morrison said. "We put a lot of time and effort into creating tooling [to manage these files]." He noted that whereas other CAD systems might support one or two formats, BRL-CAD is unique in that it supports about a dozen.

Finally, Morrison hopes to make BRL-CAD even more user-friendly overall. "For decades, the program was used by experts who could call on experts if they had issues," he said. "So [usability] has not had much attention until recently; fundamental data structures have had to change."

References

[1] BRL-CAD documentation. (n.d.). *About BRL-CAD.* Retrieved from https://brl-cad.github.io/docs/index.html.

[2] Defense Systems Information Analysis Center. (2019). *Vulnerability toolkit.* Retrieved from https://dsiac.dtic.mil/models/vulnerability-toolkit.

[3] Gruber, W., Nagel, R., Goldstein, R., Mittelman, P.S., & Kalos, M.H. (1967). *A geometric description technique suitable for computer analysis of both the nuclear and conventional vulnerability of armored military vehicles* (Technical Report MAGI-6701). White Plains, NY: Mathematical Applications Group, Inc.

[4] Naval Weapons Center. (1971). *MAGIC computer simulation analyst manual part I* (Final Technical Report TN 4565-3-71, Vol. II). Aberdeen, MD: Joint Technical Coordinating Group for Munitions Effectiveness.

[5] Peddie, J. (2019). *Ray tracing: A tool for all.* Cham, Switzerland: Springer Nature.

Aaron Hagström is a journalist and graduate of the Annenberg School of Journalism at the University of Southern California. He mainly writes about mathematics and technology and is based in Minneapolis-Saint Paul, Minnesota.

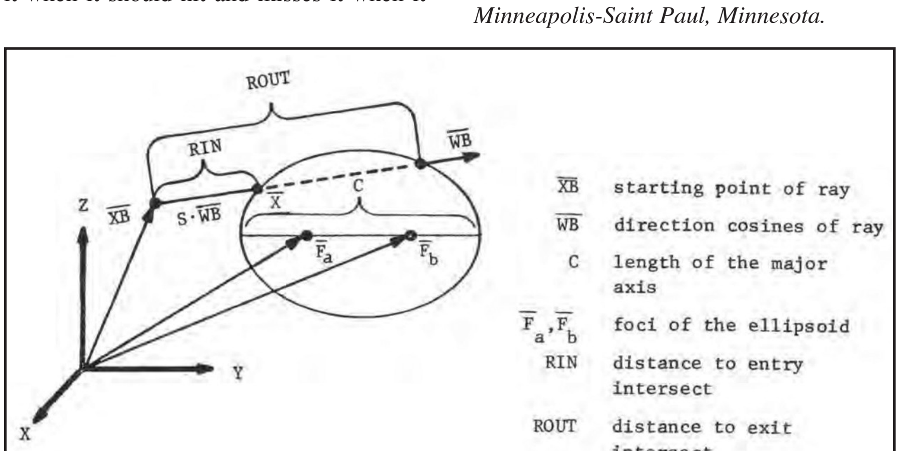


Figure 1. *Intersection distance calculations of a ray with a sphere from the original MAGIC computer code. Figure courtesy of [4].*

Will Humans Travel to the Stars? Challenges and Motivations

BOOK REVIEW
By Ernest Davis

Starbound: Interstellar Travel and the Limits of the Possible. *By Ed Regis. Cambridge University Press, Cambridge, U.K., March 2025. 300 pages, $29.95.*

Between December 21, 1968, and December 14, 1972, 24 men traveled from Earth to the Moon; of those, 12 actually set foot on the Moon for a total of about seven man-days. Since then, no human has ventured more than roughly 250 miles from the Earth's surface. Five manmade space probes have attained escape velocity from the Sun's gravitational field: Pioneer 10 and 11,[1,2] launched in 1972 and 1973; Voyager 1 and 2,[3] launched in 1977; and New Horizons,[4] launched in 2006. We are very far from sending an astronaut to the stars and have made little direct progress toward that goal over the last 50 years. Nevertheless, some scientists and futurists continue to argue that it is both feasible and important for humans to do so; as such, they labor zealously to accomplish just that.

Starbound: Interstellar Travel and the Limits of the Possible, by philosopher and science writer Ed Regis, reviews and evaluates these arguments and plans. The title of the book is deliberately ambiguous; is humanity destined to reach the stars or forever bound to a single star? Regis claims not to have a decisive answer:

> It is no part of the purpose of this book to argue that human interstellar travel is impossible (although it might well be) … It is also no part of the purpose of the book to argue that interstellar travel is easy, or that it is going to happen anytime soon.

In fact, however, *Starbound* argues strongly that there is no reason to believe that human interstellar travel is possible. It asserts that achieving such a feat would require overcoming many difficulties which may well be insuperable; that all of the plans thus far are hopelessly inadequate or completely farfetched; and that there is no justification for the claim that doing so would be worthwhile, even if possible. In my mind, Regis makes a convincing case.

The first and most obvious difficulty is the method of propulsion. To reach a star that is 10 light-years away within a time span of 1,000 years, one must travel at 1/100th the speed of light — that is, 3,000 kilometers per second (for context, the fastest spacecraft on record is the Parker Solar Probe,[5] which reached speeds of 192 kilometers per second). Proposed methods range from complete unknowns (e.g., controlled fusion or solar sails) and those of dubious feasibility (e.g., propulsion with immensely powerful lasers) to those that are very likely infeasible (e.g., propulsion by nuclear bombs or the use of antimatter) to pure fantasy (e.g., warping spacetime). If a spacefarer does not want to wait a millennium, then the issue of propulsion becomes correspondingly greater and further problems appear. For instance, if a spacecraft is traveling at a significant fraction of the speed of light, then hitting even a small particle will create a sizable explosion.

The second major setback is human survival on a lengthy trip through outer space. Astronauts who are in space for long stints tend to develop both temporary and lasting health problems. Weightlessness and exposure to cosmic rays are particularly unhealthy over an extended period of time. While solutions or workarounds for these issues might exist, there is no guarantee. Moreover, if 30 generations are to spend their entire lives on a millennium trip, then the population cannot be small and the spacecraft would have to be large and extremely complex to carry all necessary supplies. Size exacerbates the propulsion problem, while complexity increases the chances of a catastrophic breakdown.

Some of these complications could be ameliorated if passengers were placed into a state of suspended animation, wherein they do not age and have minimal metabolic requirements. But there is no evidence that doing so is possible. Another option would be to modify the human body via genetic engineering, but we again do not know with any certainty what kinds of alterations would be useful or even workable; furthermore, the ethical issues in such deliberate teratology are formidable.

Starbound: Interstellar Travel and the Limits of the Possible. By Ed Regis. Courtesy of Cambridge University Press.

The third problem is the destination. At the end of the long voyage, the travelers would have to arrive at a hospitable exoplanet. And though astronomers have detected almost 6,000 exoplanets over the last two decades, very few of them would be comfortable for human habitation. Regis writes:

> Teegarden's Star b and TOI-700 d are the two top candidates for habitability in The Habitable Worlds Catalog: both tidally locked to dim red dwarf stars, and neither of which is known to have a breathable atmosphere. Other members of the catalogue's top 20 candidate exoplanets lie at distances ranging from 11 to 1,193 light-years from Earth. Without exception, all of the 20 orbit M-type red dwarf stars, the smallest and coolest stars which would be unlikely to support human vision in the form of visible light.

A useful point of comparison is Antarctica. It would be thrilling if we found an exoplanet that seemed as hospitable as Antarctica. It has the right atmosphere, the right gravity, the right kind of sunlight (during the summer), plenty of (frozen) water, the proper magnetic field to shelter inhabitants from cosmic rays, and advanced native species; plus, it is only a two-hour flight from southern Chile. Antarctica is certainly cold and dark during its six-month winter, but that is survivable; people have been overwintering there since 1899. Still, the population of the entire continent is presently only about 5,000 during the summer and 1,000 during the winter.

Enthusiasts for human interplanetary travel tend to have a can-do attitude, noting that technology has achieved many things that were once thought to be impossible and proudly citing the fact that Apollo 11 landed on the Moon a mere seven years after President John F. Kennedy announced the goal. However, there are plenty of things that human technology simply cannot accomplish. While we may be able to cleverly build a variety of tools, there are limitations to our prowess.

Finally, what is the point? What would human interstellar travel accomplish that would be worth the enormous expense? Regis sorts through the justifications, finding none of them convincing. While we do expect the Sun to turn into a red giant in roughly four billion years, possibly destroying the Earth and certainly making it uninhabitable, why should we concern ourselves with that now? How likely is it that humans will even exist in their current form by then? Four billion years is a long time, even in geological terms; four billion years ago, Earth hosted either no life at all or only the most primitive forms. In all likelihood, the last human will have perished eons before that (though a long time from now). While this might seem like a sad thought, the last human will be no better off dying on some barely livable exoplanet, let alone mid-voyage on a starship.

An even less cogent justification is that exploration is *in the nature of our deep inner soul*, *part of our DNA*, and so on. It isn't. Long-distance migration is presumably built into the DNA of Arctic terns, monarch butterflies, humpback whales, and so forth. But many people have led happy, productive lives without ever journeying more than 100 miles from their birthplace, let alone venturing into the unknown.

Historically, migrations have mostly been carried out by people who were hoping for conquest, wealth, or better lives for themselves and their children, and who were willing to suffer hardships and risk danger to attain their goals. But it is difficult to imagine why anyone would willingly volunteer to endure the discomfort, tedium, and risk of an interstellar space voyage so their descendants—30 generations in the future—can survive on some barely habitable exoplanet.

Regrettably, Regis dilutes his many strong arguments with weak ones. He proffers the failure of the Roanoke Colony as a warning, but in light of the overwhelming success of Europeans' migration to the Americas, proponents of space travel are unlikely to find the so-called "Lost Colony" discouraging. Similarly, as scientists have now identified nearly 6,000 exoplanets, there is no reason for Regis to spend two pages describing Peter van de Kamp's announced discovery of an exoplanet in 1963 that turned out to be an error. Regis also demonstrates at length that Christopher Mason's argument that the human species has a moral obligation to ensure its continued existence is not an Aristotelian syllogism, but this demonstration in no way establishes Mason's argument as invalid. Regis' often intemperate language further detracts from his claims.

It seems to me that the obsession with this impossible dream of spacefaring does two kinds of actual harm. First, it distracts from the many urgent problems that face us here on Earth. Powerful and influential people argue that we should focus on colonizing space—first within the solar system and then outside it—rather than addressing climate change, which is a frivolous and irresponsible suggestion. Even in the realm of astrophysics, there are much more urgent concerns than the Sun's eventual evolution into a red giant. The recurrence of a solar flare on the scale of the Carrington Event of 1859 would do untold damage to our electronic infrastructure, but we have no capacity for advance detection, no method to shield ourselves, and no contingency plans for dealing with the aftermath [1].

Second, the fixation on human space travel sidetracks attention from the amazing accomplishments in unmanned space exploration. Voyager 2 is now in the interstellar medium—three times as far away as Pluto—and still sending us information![6] Rovers are traveling around the surface of Mars, analyzing soil samples and launching drones through the Martian atmosphere. The James Webb Space Telescope[7] sits in stationary orbit at the L2 Lagrange point, where it probes the utmost depths of the universe and delivers a steady stream of eerily beautiful images of the extraordinary entities that populate the heavens. Personally, I find all of these triumphs more exciting than the thought that an astronaut may set foot on Mars in the near-ish future, and much more inspiring than the fantasy that—in the far distant future—some spaceship with human passengers might land on a planet that is orbiting another star.

References

[1] Graham, D.A. (2015, September 9). When the lights go out. *The Atlantic*. Retrieved from https://www.theatlantic.com/technology/archive/2015/09/how-safe-is-the-us-electrical-grid-really/402640.

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

[1] https://science.nasa.gov/mission/pioneer-10
[2] https://science.nasa.gov/mission/pioneer-11
[3] https://science.nasa.gov/mission/voyager
[4] https://science.nasa.gov/mission/new-horizons
[5] https://science.nasa.gov/mission/parker-solar-probe
[6] https://science.nasa.gov/mission/voyager/voyager-2
[7] https://science.nasa.gov/mission/webb

AN25 Panel Considers Career Possibilities in Industry, Government, and the National Laboratories

By Lina Sorg

CAREERS IN MATHEMATICAL SCIENCES

The rapid growth of novel research directions in industry and government settings—especially given continued advancements in artificial intelligence (AI), machine learning, and other technologies—provides a plethora of exciting employment prospects for applied mathematicians, computational scientists, and data scientists. During the Third Joint SIAM/CAIMS Annual Meetings,[1] which took place this summer in Montréal, Québec, Canada, a lively panel discussion[2] explored the characteristics of scientific career opportunities beyond academia. The session, which was chaired by SIAM Vice President for Industry Nessy Tania (Pfizer[3]), featured panelists Stéphane Alarie (Hydro-Québec[4]), Stéphane Gaudreault (Environment and Climate Change Canada[5]), Guido Jajamovich (Amgen[6]), Helen Moore (University of Florida's Laboratory for Systems Medicine[7]), and Pablo Moriano (Oak Ridge National Laboratory[8]).

The speakers introduced themselves by summarizing their respective career trajectories. Moriano, who was born and raised in Colombia, studied electrical engineering before moving to the U.S. for a graduate program in computer science. He had every intention of becoming a university professor until his advisor helped him land an industry internship that piqued his interest in alternative pathways. "That helped me realize different places where I could have an impact," Moriano said, adding that he later learned about the U.S. Department of Energy's 17 National Laboratories.[9] "It's been a journey because my aspirations changed over the course of all this, but I'm glad that I was able to see different opportunities and make my way to the labs."

Jajamovich's Ph.D. studies involved statistical modeling of DNA sequences and gene expression, while his ensuing postdoctoral work focused on biomedical image processing. He ultimately sought a career that encompasses both applications. During a subsequent postdoctoral stint at Merck,[10] he joined a team that guided the protocols for a new drug — an application that got him hooked. Jajamovich has worked in industry ever since.

Like Jajamovich, Moore has also established herself within the biopharmaceutical industry [1]. Her initial foray into the domain resulted from a chance encounter at a party that led to a job at Genentech.[11] Moore has worked at five different biopharma companies over the years, including Bristol Myers Squibb[12] and AstraZeneca;[13] her current appointment at the Laboratory for Systems Medicine focuses on the optimization of drug regimens and the early prediction of cancer patient response to immunotherapy. One of her favorite parts of this pursuit is the occasional chance to meet the end user, i.e., the patient. "It's great getting to see the impact of some of the work that you and your colleagues do," she said.

Alarie echoed Moore's comments about the exciting and satisfying nature of industry research. "Industry is absolutely not boring because every concept has to be redefined," he said, explaining that scientists are constantly revising existing protocols and methods to optimize results. In many cases, a system may undergo a complete transformation over the course of several decades.

Given this lengthy timescale, Alarie cited repetition as the key to forward progress. He explained that industry employees should be prepared to clearly demonstrate and sell their ideas—multiple times over if necessary—in the form of small projects with clear, tangible markers of success. "Think about the timing of your work and how to make themes," Alarie said. "Use your expertise to see where we are going and where society is going, what kinds of problems we have, and what tools we need." Sometimes, a project that initially fails to gain traction might resurface in the future; in fact, Alarie still revisits problems from 20 years ago that remain relevant in some way.

Gaudreault reminded the audience to embrace the thoughts and suggestions of other individuals in the workforce, even if they overlap with or contradict your own. "It's important to remain open to new ideas," he said. "There is always tension between pushing our scientific ideas and listening to other ideas that could improve or even replace our work."

Conversation then turned to the realities of preparing and searching for jobs outside of academia. Gaudreault noted that employers often struggle to find appropriate candidates with the right expertise for a particular project, given the work's often specific nature. As such, he feels that organizations should make a strong effort to connect with universities and provide students with guidance about the proficiencies that are especially beneficial in industry. "It's important for industry and government to be engaged with the academic community," Gaudreault said. "If we want young scientists who are competent, we need to help train them correctly or help them get the skills that they need."

Moore, who has actively participated in the hiring process at multiple organizations, urged students to complete industry-based internships before seeking full-time employment. She mentioned that many biopharma companies offer graduate student internships for candidates with a background in disease modeling or pharmacometrics. Furthermore, some universities maintain partnerships with companies that may provide opportunities for students to interact with industry researchers, which bolsters the desirability of these applicants to hiring committees.

In a similar vein, Moriano commented that educational institutions and individual professors occasionally collaborate directly with national laboratory staff — a valuable relationship that permits students to spend time at the labs and better understand the culture. "Students can access the network of mentors at the lab, as well as their facilities and expertise," he said. Moriano also encouraged interested students to apply to the summer programs that are available at national laboratories around the country.

Even if students are unable to secure a relevant internship, attending and presenting at conferences—like the SIAM Annual Meeting—serves as an opportunity to network, increase their visibility within the community, and engage with other scientists who can assess their communicative prowess and applications of their research. Some professional societies, including SIAM, also sponsor online webinars and events that allow attendees to connect to industry. For example, the SIAM Industry Committee[14] hosts an annual "Meet the SIAM Industry Committee" virtual session during which participants can converse with seasoned industry professionals via breakout rooms.

When it comes to the availability of positions for individuals with master's degrees versus Ph.D.s, the panelists concurred that expectations vary widely based on location, organization, and job responsibilities. Alarie—who holds a master's degree—affirmed that in Canada, companies seem to be more concerned with a candidate's ability to generate tangible results than their level of education. "What's important is whether you produce what is expected," he said. "If yes, it doesn't matter what your degree is." In fact, he finds that some industries are more willing to hire applicants with master's degrees than doctorates, as the latter might be seen as overeducated for the specific need.

See **Career Possibilities** *on page 12*

During a panel session about careers in industry, government, and the national laboratories at the Third Joint SIAM/CAIMS Annual Meetings—which took place this summer in Montréal, Québec, Canada—Helen Moore of the University of Florida's Laboratory for Systems Medicine (left) discusses her career trajectory in biopharmaceuticals while moderator and SIAM Vice President for Industry Nessy Tania of Pfizer looks on. SIAM photo.

[1] https://www.siam.org/conferences-events/past-event-archive/an25
[2] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=85334
[3] https://www.pfizer.com
[4] https://www.hydroquebec.com/residential
[5] https://www.canada.ca/en/environment-climate-change.html
[6] https://www.amgen.com
[7] https://systemsmedicine.pulmonary.medicine.ufl.edu
[8] https://www.ornl.gov
[9] https://www.energy.gov/national-laboratories
[10] https://www.merck.com
[11] https://www.gene.com
[12] https://www.bms.com
[13] https://www.astrazeneca.com
[14] https://www.siam.org/get-involved/connect-with-a-community/committees/industry-committee

Chinese Academy of Sciences SIAM Student Chapter Demonstrates Continued Endurance With 14th Annual Meeting

By Yuxin Li

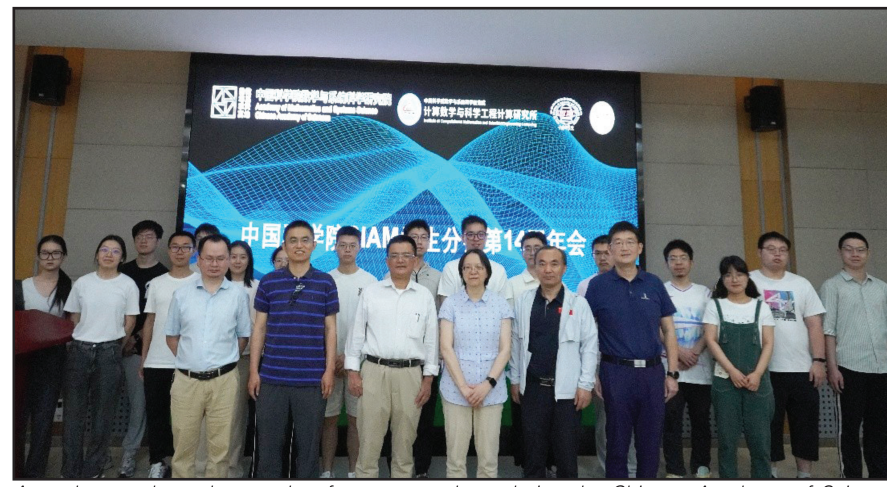
This past June, the Chinese Academy of Sciences (CAS) SIAM Student Chapter[1] hosted its 14th Annual Meeting at the CAS Academy of Mathematics and Systems Science (AMSS). Support for the event was generously provided by SIAM, AMSS, the State Key Laboratory of Scientific and Engineering Computing, and the Institute of Computational Mathematics and Scientific/Engineering Computing. Graduate students, early-career researchers, and professional scholars came together for a day of presentations, learning, and networking; attendees hailed from a variety of institutions, including AMSS, Tsinghua University, Xiangtan University, Beihang University, and even the University of California, San Diego (UCSD).

This year's annual meeting featured four distinguished speakers from AMSS, Tsinghua University, and UCSD. Their in-depth lectures showcased recent breakthroughs in their respective research areas and underscored the conference's strong academic orientation. While the talks were presented by faculty members, each session sparked active student engagement. Participants asked thoughtful questions, shared their own perspectives, and exchanged ideas with the speakers and one another.

The meeting began with introductory remarks by Xin Liu of AMSS and a brief photo session. The academic program then commenced with a lecture by Jiawang Nie of UCSD, an acclaimed expert in polynomial optimization and recipient of the 2018 SIAM Activity Group on Linear Algebra Best Paper Prize.[2] Nie's presentation introduced a polynomial optimization framework for the computation of Nash equilibria via moment and sum-of-squares relaxations. The talk provided both theoretical guarantees and practical examples, offering new insights into the algebraic structure of game theory.

[1] https://lsec.cc.ac.cn/~siamstuc

[2] https://www.siam.org/programs-initiatives/prizes-awards/activity-group-prizes/siam-activity-group-on-linear-algebra-best-paper-prize



Attendees and speakers gather for a group photo during the Chinese Academy of Sciences (CAS) SIAM Student Chapter's 14th Annual Meeting, which took place in June 2025 at the CAS Academy of Mathematics and Systems Science. Photo courtesy of Yuxin Li.

Jiawang Nie of the University of California, San Diego, presents a lecture about "Nash Equilibrium and Polynomial Optimization" at the Chinese Academy of Sciences SIAM Student Chapter's 14th Annual Meeting, which was held this past June. Photo courtesy of Yuxin Li.

Zuoqiang Shi of Tsinghua University next spoke about "Surface Reconstruction Based on Modified Gauss Formula." Using techniques from potential theory and numerical integration, Shi proposed efficient methods to reconstruct continuous surfaces from discrete point clouds. He effectively illustrated these concepts with vivid visual examples that demonstrated the practical applications and results of his approach.

After a short coffee break, Chao Ding of AMSS delivered a lecture on "Adaptive Regularized Newton-CG for Nonconvex Optimization" that addressed the longstanding tradeoff between global complexity and local convergence in nonconvex optimization. His proposed adaptive algorithm integrates conjugate gradient methods with negative curvature monitoring, thus achieving optimal global complexity $(O(\epsilon^{-3/2}))$ while enabling quadratic local convergence.

Jizu Huang of AMSS concluded the program with his talk on "Derivatives of Tree Tensor Networks and Their Applications in Runge-Kutta Methods." By deriving high-order derivatives of tree tensor networks, Huang's framework offers rigorous order conditions for Runge-Kutta schemes and revealed scenarios in which standard methods can achieve higher-order convergence.

The CAS SIAM Student Chapter was established in 2011 through the initiative of then-SIAM President Lloyd Nick Trefethen of the University of Oxford, with support from CAS faculty advisor Ya-xiang Yuan. In subsequent years, the chapter has grown to include more than 200 members across various disciplines.

The success of this year's conference further reinforced the chapter's role in building an active and engaged research community. The CAS SIAM Student Chapter is grateful to all speakers and attendees for their participation in the 14th Annual Meeting and looks forward to hosting more events that continue to foster collaboration across institutions and throughout generations of mathematical scientists.

Yuxin Li is a Ph.D. student at the Academy of Mathematics and Systems Science of the Chinese Academy of Sciences (CAS), where her research focuses on stochastic optimization. She currently serves as president of the CAS SIAM Student Chapter.

Career Possibilities

Continued from page 11

Moore's experience in the U.S. biopharma community elicited a different opinion. "There's a real preference for Ph.D.s," she said, adding that she can only recall a few people who held comparable roles to her own with just a master's degree — all of whom did eventually earn Ph.D.s. In some cases, a company might even pay for employees to get their doctorates.

When asked about the educational coursework that proved most relevant to their daily tasks, Moriano spoke highly of his class on nonlinear control theory. "Conceptually, that provides a strong mathematical foundation to understand many complex problems," he said, acknowledging the subject's relation to complexity science and the modeling of natural phenomena via networks or graphs. "The blending of these things allowed me to better characterize later problems that arose in my career."

Moore touted the value of optimization, dynamical systems, ordinary differential equations, and coding before admitting that she wished she had taken a statistics course as a student. "In industry, you're working with real-world data," she said. "You have data and equations, and you need stats to put those two things together." She also mentioned the starkly different communication styles between industry and academia. Because industry professionals frequently collaborate with people whose proficiencies diverge significantly from their own, Moore encouraged students to hone their writing and speaking abilities for various audiences. "How do you present your ideas so somebody whose expertise is completely different would get it?" she asked.

From left to right: Pablo Moriano of Oak Ridge National Laboratory, Stéphane Gaudreault of Environment and Climate Change Canada, and Stéphane Alarie of Hydro-Québec converse during a career-based panel discussion at the Third Joint SIAM/CAIMS Annual Meetings, which were held this summer in Montréal, Québec, Canada. The panelists spoke about their respective experiences in industry, government, and the national laboratories while fielding questions from the audience. SIAM photo.

Panelists next addressed the use of AI in the workforce. Gaudreault feels that generative AI is becoming increasingly important, though he warned users to remain aware of its limitations. "Tools are powerful enough to generate reasonably good code for simple problems, but we have to be careful," he said. At the moment, he mostly utilizes AI tools on a case-by-case basis, e.g., to experiment with possible improvements to his own workflow.

Given the growing excitement around AI, Alarie finds that employees are often eager to use it even when it's not necessarily appropriate for the task at hand. "They think that it's magic and will resolve all the problems," he said. "But we have to understand the problems and understand what the right tool is for them. There's a huge need, but we have to know when to apply it."

Like his colleagues, Moriano—who does employ AI on a regular basis to polish his writing or speed up code—cautioned against sole reliance on the technology and expressed concern about its effects on independent thinking and communication skills. "The caveat is that you need to be super careful in checking the output of the systems," he said. "I'm also worried by how the use of these tools, especially for people in the process of learning, can have some effect on the way that their writing develops."

As the panel drew to a close, the speakers mutually emphasized the value of effective teamwork between both internal and external collaborators. "You can do some things alone, but if you want to do things with real impact, you'll need to work in a team," Gaudreault said. Moriano agreed, advising researchers to learn from each other and embrace their varied backgrounds to grow their collective knowledge. "The human component is key to success, both inside your organization and at conferences," he said. "Try to embrace opportunities to expand your network, talk to different people, and learn about their experiences. Eventually, you'll see that those engaging opportunities are helpful for you to connect on a human level."

References

[1] Moore, H. (2023, May 1). Medical mathematics outside of math departments. *SIAM News*, *56*(4), p. 7.

Lina Sorg is the managing editor of SIAM News.

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

siam | PROGRAMS AND AWARDS

Nominate | Apply | Network

Nominate a Colleague for 2026 Major Awards

siam.org/deadline-calendar

The SIAM Prize Program provides an opportunity to honor members of our community — from lifetime contributions to student and early career recognition. Being nominated recognizes and rewards outstanding accomplishments, brings honor and prestige to your place of work, and demonstrates the importance of your field to students, research funders, and the scientific community at large.

2026 Major Awards

- AWM SIAM Sonia Kovalevsky Lecture*
- George Pólya Prize in Mathematics
- I. E. Block Community Lecture
- John von Neumann Prize
- Julian Cole Lectureship
- Richard C. DiPrima Prize
- SIAM Industry Prize
- SIAM Prize for Distinguished Service to the Profession
- SIAM Student Paper Prizes*
- W. T. & Idalia Reid Prize

The deadline for nominations is October 15, 2025.
Submit your nominations at *go.siam.org/prizes-nominate*.

*Open dates and deadlines may vary. Contact *prizeadmin@siam.org* with questions.

Applications Are Being Accepted for the 2026 Class of MGB-SIAM Early Career Fellows

siam.org/msec-fellowship

The MGB-SIAM Early Career Fellowship recognizes the achievements of early career applied mathematicians—particularly those whose talents and voices have been historically missing from the mathematical sciences in the United States—and provides support for professional activities and career development.

SIAM encourages all qualified individuals to apply. The MGB-SIAM Early Career Fellowship is a joint program of Mathematically Gifted & Black (MGB) and SIAM.

Fellows receive:

- Complimentary SIAM membership for the duration of the fellowship
- Complimentary registration to SIAM Annual Meetings and one additional SIAM Activity Group conference
- Travel support to attend SIAM conferences
- Mentoring and professional development opportunities
- Leadership and conference organization experience

The deadline to apply is November 1, 2025.

SIAM Postdoctoral Support Program Seeks Applicants

siam.org/postdoctoral-support

The SIAM Postdoctoral Support Program provides financial support for postdoctoral scholars to receive mentoring and collaboration opportunities that enable successful career advancement. Up to $15,000 in financial support is provided for postdoctoral researchers to work with a mentor from a different institution. The goal is to foster direct research experience and professional development. Up to two postdoc/mentor pairs are selected annually. **Applicant teams design and describe a mentoring, research, and collaboration plan that works best for them.**

The application will remain open until annual funding is expended, but the **priority deadline for applications is November 1, 2025.**

Apply Now for the SIAM Science Policy Fellowship Program

siam.org/science-policy-fellowship

The SIAM Science Policy Fellowship Program develops postdoctoral fellows and early career researchers into strong advocates for U.S. federal support in applied mathematics and computational science. The program enables participants to gain in-depth knowledge of the policy processes that determine science funding and policy decisions while still pursuing their research and teaching.

The SIAM Science Policy Fellowship Program is open to SIAM members currently working and living in the United States. SIAM encourages all qualified individuals to apply.

Three to five fellowship recipients will be selected each year to serve two-year terms that include:

- In-person and remote training
- Attending biannual SIAM Committee on Science Policy meetings
- Interfacing with federal officials, congressional staff, and policy-makers
- Participating in an advocacy day on Capitol Hill in Washington, D.C.

The deadline to apply is November 1, 2025.

Nominate a Colleague for 2026 SIAM Activity Group Prizes

siam.org/deadline-calendar

SIAM is accepting nominations for activity group prizes that will be awarded at 2026 conferences. These prizes identify outstanding contributions to specific fields by recognizing published papers and individuals in various stages of their careers.

Every nomination counts! Visit the website for full eligibility requirements and required materials.

2026 SIAM Activity Group Prizes

- Dénes König Prize
- Gábor Szegő Prize
- Martin Kruskal Lecture
- SIAG/DATA Career Prize
- SIAG/DATA Early Career Prize
- SIAG/IS Best Paper Prize
- SIAG/IS Early Career Prize
- SIAG/LS Early Career Prize
- SIAG/MPE Prize
- SIAG/MPE Early Career Prize
- SIAG/OPT Best Paper Prize
- SIAG/OPT Early Career Prize
- SIAG/OPT Test of Time Award
- T. Brooke Benjamin Prize

The deadline for nominations is October 15, 2025.
Submit your nominations at *siam.org/deadline-calendar*.

Contact *prizeadmin@siam.org* with questions.

siam Fellow

Nominations Close October 15 for the SIAM Fellows Class of 2026! Make your nomination at *siam.org/nominate-fellows*.

FOR MORE INFORMATION: ***siam.org/programs*** AND ***siam.org/prizes-recognition***

siam | MEMBERSHIP

Network | Access | Outreach | Lead

Renew your SIAM membership for 2026 and remain a part of our international and interdisciplinary community. Go to *my.siam.org* to renew today.

There are lots of reasons to renew...

STAY CURRENT

- *SIAM Review*, *SIAM News*, and *Unwrapped*, SIAM's electronic newsletter
- SIAM Presents, a collection of talks and tutorials from SIAM conferences and virtual webinars
- Science policy electronic mailing list — keeps you informed on policy and funding opportunities

ADVANCE YOUR CAREER

- Access to career information through the SIAM career webpages, SIAM Engage community site, job board, and conferences
- Recognition through prizes, awards, and the SIAM Fellows Program
- The Postdoctoral Support Program helps recent Ph.D.s advance their research agenda by funding travel to work with a new mentor

- Career Fairs (in-person and virtual) connect you to recruiters who are looking for applied math, computational, and data science skills
- Careers in the Mathematical Sciences in *SIAM News*, an ongoing series of career-related articles by members of the SIAM community
- Discounted memberships for those early in their careers

NETWORKING OPPORTUNITIES

- 23 SIAM Activity Groups provide opportunities to network with professionals with similar research interests and enhance your visibility within these specialized communities
- Conferences connect you with other professionals who share similar research interests, with discounted registration for members
- SIAM Section activities allow you to meet peers in your geographic region
- Committees, activity groups, and chapters provide volunteer and leadership opportunities

Nominate two students for free membership!
siam.org/Forms/Nominate-a-Student

SIAM JOURNALS AND BOOKS

- Free subscription to print and electronic versions of *SIAM Review*, SIAM's flagship journal that contains articles of broad interest to the community
- 19 peer-reviewed journals as well as an online journal archive (Locus), both available to members at a discounted rate
- Access to quality research via print or electronic format with 600+ books at member discounts of at least 30%
- Price break for students on books adopted by a SIAM member for classroom use

RESOURCES FOR STUDENTS

- $205,000 in funding for SIAM Student Travel Awards
- $59,000+ in funding for SIAM Student Chapters
- Free student memberships for those who attend a member institution, are in a SIAM Student Chapter, or are nominated by a SIAM member
- Discounts on membership and conference registrations
- SIAM-Simons Undergraduate Summer Research Program, providing mentored research for 10 students per year
- Graduate Student Math Modeling Camp for graduate students and advanced undergraduates, feeding into Mathematical Problems in Industry Workshop, where teams of students and faculty work on real-world problems in collaboration with industry partners
- Gene Golub SIAM Summer School (G2S3), a free graduate-level workshop
- Student Days events at the SIAM Annual Meeting designed to foster community and support student attendees
- *SIAM Undergraduate Research Online* (SIURO), a publication showcasing student research
- Visiting Lecturer Program (VLP), a roster of experienced and inspirational applied mathematicians and computational scientists working in industry, government, and academia, available to speak on topics that are of interest to developing professional mathematicians

PUBLIC AWARENESS

- SIAM promotes understanding of the value of mathematics both in daily life and in the advanced sciences
- SIAM speaks on behalf of its members to key congressional representatives and organizations in Washington, D.C., to promote important research funding and the development of science policy
- Community outreach programs—including MathWorks Math Modeling Challenge, a high school math modeling competition organized by SIAM—advance the application of mathematics and computational science

What's New at SIAM?

- SIAM launched its 19th journal! *SIAM Journal on Life Sciences* (SIALS) will publish work that substantively uses quantitative methods—including modeling, computing, and mathematical analysis—in the study of biological systems and associated applications.
- The SIAM Activity Group on Equity, Diversity, and Inclusion held its first in-person business meeting at AN25 in Montréal, Canada.
- Nine new student chapters were established in 2025. Consider starting or re-starting a chapter at your academic institution.
- SIAM established a new section in New England. They plan to hold their first annual meeting in 2026.
- SIAM's career development opportunities will include industry panels, and a virtual career fair happening in spring 2026.
- The SIAM Activity Group on Data Science began hosting a new webinar series called "WebMDS: Mathematics of Data Science."
- SIAM Student Days took place at AN25 in Montréal, Canada. 22 chapters from around the world sent representatives, who had opportunities to network, attend student-oriented sessions, and meet SIAM VIPs!

Take Advantage of Special Dues Rates

If you are a student, an early career member, unemployed, retired, or a member of a mathematical society with which SIAM has a reciprocity agreement, you qualify for reduced membership rates. Go to *siam.org/membership/individual* or contact customer service.

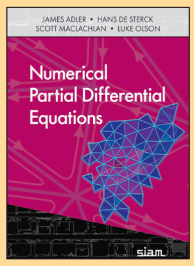
Renew Your SIAM Membership at *my.siam.org*

Consider checking the "auto-renew" box to have your membership renew automatically at the end of 2026.

FOR MORE INFORMATION ON SIAM MEMBERSHIP: *siam.org/membership* siam® | BOOKS

Quality and Value in Mathematical Science Literature

New Titles from SIAM

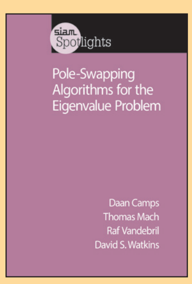


Numerical Partial Differential Equations

James H. Adler, Hans De Sterck, Scott MacLachlan, and Luke Olson

This comprehensive textbook focuses on numerical methods for approximating solutions to partial differential equations. The authors present a broad survey of these methods, introducing readers to the central concepts of various families of discretizations and solution algorithms and laying the foundation needed to understand more advanced material. The authors include 100+ well-established definitions, theorems, corollaries, and lemmas and summaries of and references to in-depth treatments of more advanced mathematics when needed.

2025 / xiv + 591 pages / Softcover / 978-1-61197-827-8
List $86.00 / SIAM Member $68.00 / CS32

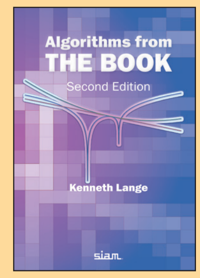


Pole-Swapping Algorithms for the Eigenvalue Problem

Daan Camps, Thomas Mach, Raf Vandebril, and David S. Watkins

This book focuses on pole-swapping algorithms, a new class of methods that are generalizations of bulge-chasing algorithms and a bit faster and more accurate owing to their inherent flexibility. The pole-swapping theory developed by the authors sheds light on the functioning of the whole class of algorithms, including QR and QZ. The only book on the topic, it describes the state of the art on eigenvalue methods and provides an improved understanding and explanation of why these important algorithms work.

2025 / viii + 96 pages / Softcover / 978-1-61197-836-0
List $49.00 / SIAM Member $34.30 / SL07



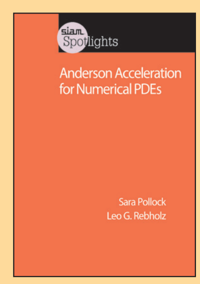
Algorithms from THE BOOK

Second Edition

Kenneth Lange

Most books on algorithms are narrowly focused on a single field of application. This unique book cuts across discipline boundaries, exposing readers to the most successful algorithms from a variety of fields. Since publication of the first edition, the number of new algorithms has swelled exponentially, with the fields of neural net modeling and natural language processing leading the way. These developments warranted the addition of a new chapter on automatic differentiation and its applications to neural net modeling. The second edition also adds worked exercises and introduces new algorithms in existing chapters.

2025 / xiv + 343 pages / Softcover / 978-1-61197-838-4
List $74.00 / SIAM Member $51.80 / OT204

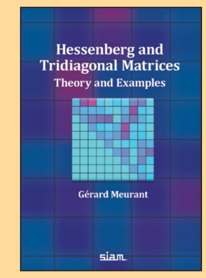


Anderson Acceleration for Numerical PDEs

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 (PDEs). 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. The 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.

2025 / viii + 114 / Softcover / 978-1-61197-848-3
List $54.00 / SIAM Member $37.80 / SL08



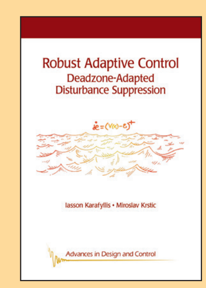
Hessenberg and Tridiagonal Matrices

Theory and Examples

Gérard Meurant

This is the only book devoted exclusively to Hessenberg and tridiagonal matrices. Hessenberg matrices are involved in Krylov methods for solving linear systems or computing eigenvalues and eigenvectors, the QR algorithm for computing eigenvalues, and in many other areas of scientific computing. Matrices that are both upper and lower Hessenberg are tridiagonal. Their entries are zero except for the main diagonal and the subdiagonal and updiagonal next to it. The book presents known and new results; describes the theoretical properties of the matrices, their determinants, LU factorizations, inverses, and eigenvalues; illustrates the theoretical properties with applications and examples as well as numerical experiments; and considers unitary Hessenberg matrices, inverse eigenvalue problems, and Toeplitz tridiagonal matrices.

2025 / xii + 231 pages / Softcover / 978-1-61197-844-5
List $74.00 / SIAM Member $51.80 / OT206



Robust Adaptive Control

Deadzone-Adapted Disturbance Suppression

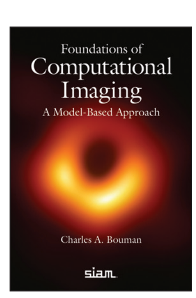
Iasson Karafyllis and Miroslav Krstic

This book presents a solution to a problem in adaptive control design that had been open for 40 years: robustification to disturbances without compromising asymptotic performance. This original methodology builds on foundational ideas, such as the use of a deadzone in the update law and nonlinear damping in the controller, and advances the tools for and the theory behind designing robust adaptive controllers, thus guaranteeing robustness properties stronger than previously achieved.

2025 / xii + 178 pages / Hardcover / 978-1-61197-842-1
List $84.00 / SIAM Member $58.80 / DC43

Order online: *bookstore.siam.org*
Or call toll-free in U.S. and Canada: 800-447-SIAM; worldwide: +1-215-382-9800
Outside North and South America contact *service@siam.org* for international shipping discounts.

Also of Interest



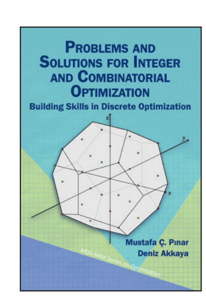
Foundations of Computational Imaging

A Model-Based Approach

Charles A. Bouman

Collecting a set of classical and emerging methods not available in a single treatment, this is the first book to define a common foundation for the mathematical and statistical methods used in computational imaging. The book brings together a blend of research with applications in a variety of disciplines to address a collection of problems that can benefit from a common set of methods. Readers will find basic techniques of model-based image processing, a comprehensive treatment of Bayesian and regularized image reconstruction methods, and an integrated treatment of advanced reconstruction techniques.

2022 / xii + 337 pages / Softcover / 978-1-611977-12-7
List $84.00 / SIAM Member $58.80 / OT180



Problems and Solutions for Integer and Combinatorial Optimization

Building Skills in Discrete Optimization

Mustafa Ç. Pınar and Deniz Akkaya

This is the only book offering solved exercises for integer and combinatorial optimization. It contains 102 problems of varying scope and difficulty chosen from a plethora of topics and applications. It has an associated website containing additional problems, miscellaneous material including suggested readings, and errata. Topics covered include modeling capabilities of integer variables, network optimization models, shortest path problems, optimum tree problems, maximal cardinality matching problems, VRP formulations, and dynamic programming.

2023 / xii + 125 pages / Softcover / 978-1-61197-775-2
List $29.00 / SIAM Member $20.30 / MO33

FOR MORE INFORMATION ON SIAM BOOKS: ***siam.org/books***

SIAM | CONFERENCES

A Place to Network and Exchange Ideas

Upcoming Deadlines

SIAM Conference on Mathematical & Computational Issues in the Geosciences (GS25)

October 14–17, 2025 | Baton Rouge, Louisiana, U.S.
siam.org/gs25 | #SIAMGS25

ORGANIZING COMMITTEE CO-CHAIRS
Luca Formaggia, *Politecnico di Milano, Italy*
Chris Kees, *Louisiana State University, U.S.*

EARLY REGISTRATION RATE DEADLINE
September 16, 2025

HOTEL RESERVATION DEADLINE
September 12, 2025

SIAM Conference on Analysis of Partial Differential Equations (PD25)

November 17–20, 2025 | Pittsburgh, Pennsylvania, U.S.
siam.org/pd25 | #SIAMPD25

ORGANIZING COMMITTEE CO-CHAIRS
Helena J. Nussenzveig Lopes, *Universidade Federal do Rio De Janeiro, Brazil*
Michael Vogelius, *Rutgers University, U.S.*

EARLY REGISTRATION RATE DEADLINE
October 24, 2025

HOTEL RESERVATION DEADLINE
October 24, 2025

SIAM Conference on Uncertainty Quantification (UQ26)

March 22–25, 2026 | Minneapolis, Minnesota, U.S.
siam.org/uq26 | #SIAMUQ26

ORGANIZING COMMITTEE CO-CHAIRS
Robert Gramacy, *Virginia Tech, U.S.*
Robert Scheichl, *Heidelberg University, Germany*
Li Wang, *University of Minnesota, U.S.*

SUBMISSION AND TRAVEL SUPPORT DEADLINES
September 22, 2025: Contributed Lecture, Poster, and Minisymposium Presentation Abstract Submissions

December 8, 2025: Travel Support Application

SIAM Conference on Nonlinear Waves and Coherent Structures (NWCS26)

May 26–25, 2029 | Montréal, Québec, Canada
siam.org/nwcs26 | #SIAMNWCS26

ORGANIZING COMMITTEE CO-CHAIRS
Jason Bramburger, *Concordia University, Canada*
Manuela Girotti, *Emory University, U.S.*

SUBMISSION AND TRAVEL SUPPORT DEADLINES
October 28, 2025: Minisymposium Proposal Submission

November 25, 2025: Contributed Lecture, Poster, and Minisymposium Presentation Abstract Submissions

February 26, 2026: Travel Support Application

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, Poster, and Minisymposium Presentation Abstract Submissions

March 23, 2026: Travel Support Application

Upcoming SIAM Events

SIAM Conference on Mathematical and Computational Issues in the Geosciences
October 14–17, 2025
Baton Rouge, Louisiana, U.S.
Sponsored by the SIAM Activity Group on Geosciences

2nd SIAM Northern and Central California Sectional Conference
October 27–28, 2025
Berkeley, California, U.S.

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 – 13, 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
Sponsored by the SIAM Activity Group on Nonlinear Waves and Coherent Structures

Students and Early Career Researchers: Apply Now for Conference Support

SIAM is dedicated to giving students and early career professionals the support they need to be successful. The SIAM Travel Awards Program awards $240,000+ in conference travel funding yearly to these two groups. Apply now at *siam.smapply.org/prog/travel_awards_program*.

Information is current as of August 18, 2025. Visit *siam.org/conferences* for the most up-to-date information.

FOR MORE INFORMATION ON SIAM CONFERENCES: ***siam.org/conferences***