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# On Fairness and Foundations in Machine Learning

*By Erin George, Lara Kassab, and Deanna Needell*

Machine learning (ML) is revolutionizing many aspects of society, but its widespread adoption raises concerns about transparency, fairness, and trustworthiness. An increasing reliance on ML in critical domains like healthcare and criminal justice necessitates a thorough examination of the fairness and reliability of these systems. Traditional ML algorithms often prioritize overall accuracy, potentially leading to inequitable outcomes for specific subgroups within the data. For instance, an algorithm that is trained on a dataset with an imbalanced representation of different demographics may exhibit biased predictions towards certain groups. To address this issue, we must develop techniques that ensure fairness and mitigate bias.

### Fairness Improvement in Nonnegative Matrix Factorization

Full ML transparency requires understanding the algorithmic decision-making process and ensuring that these decisions are interpretable and justifiable. Nonnegative matrix factorization (NMF) is a ML technique that identifies latent themes or patterns in large datasets. Given a nonnegative matrix $\mathbf{X} \in \mathbb{R}^{m \times n}_{\geq 0}$ (e.g., a matrix that represents data samples as rows and features as columns) and a desired lower dimension $r$ (also called a nonnegative rank), NMF aims to decompose $\mathbf{X}$ into a product of two lower-dimensional nonnegative matrices: (i) the representation matrix $\mathbf{W} \in \mathbb{R}^{m \times r}_{\geq 0}$ and (ii) the dictionary matrix $\mathbf{H} \in \mathbb{R}^{r \times n}_{\geq 0}$. The goal is for these factors to approximately explain the data, as in

$$\mathbf{X} \approx \mathbf{WH}.$$

We often interpret the rows of $\mathbf{H}$ as *topics* that capture underlying patterns within the data. Each row of $\mathbf{W}$ then provides an approximate representation of the corresponding data sample in the lower-dimensional space that the topics span.

Because of the imposed nonnegativity, NMF learns interpretable building blocks of the data. For example, a 1999 seminal paper considers data that consist of (vectorized) images of human faces [3]. The "topics" then comprise parts of the face—eyes, noses, ears, and mouths—and the representation vectors encode the way in which those parts rebuild each face. In Figure 1a, we mimic this experiment and run a simple NMF (with rank $r = 25$) on the Yale Face Database.[1] This method is in contrast to other approaches such as principal component analysis, where the components do not have the same interpretability as "parts" of the face (see Figure 1b).

The most common formulation for NMF approximations uses the Frobenius norm to measure reconstruction error:

$$\operatorname{argmin}_{\mathbf{W} \in \mathbb{R}^{m \times r}_{\geq 0}, \mathbf{H} \in \mathbb{R}^{r \times n}_{\geq 0}} ||\mathbf{X} - \mathbf{WH}||_F^2. \quad (1)$$

Many numerical optimization techniques can help us find local minima for the NMF problem in (1), such as alternating minimization—i.e., solving a nonnegative least squares problem in one variable while fixing the other and repeating—or multiplicative updates, which serve as an (entrywise) projected gradient descent algorithm [1, 4].

### A Look at Fairness

We now consider a novel perspective on NMF [2]. Like many objective functions, NMF seeks to minimize the total *reconstruction error* — which implies that the method provides low approximation error *on average*. But because it sums over the entire population, NMF is also agnostic to groups within the population that may have different sizes or complexities. For instance, simply scaling a single data point by an

*See* **Machine Learning** *on page 4*

[1] http://cvc.cs.yale.edu/cvc/projects/yalefaces/yalefaces.html

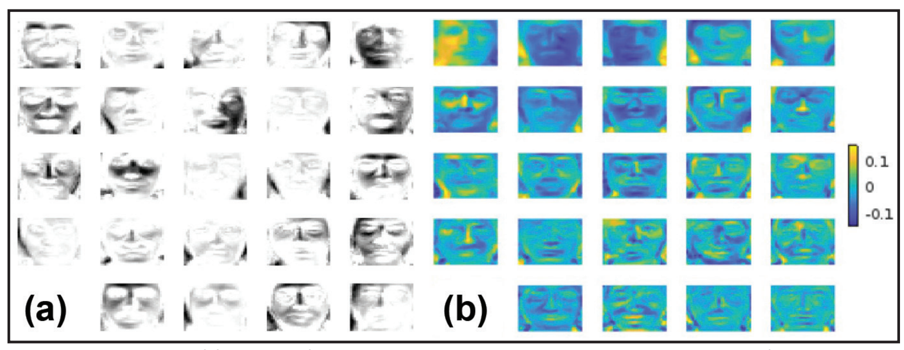


**Figure 1.** *Analysis of face data from the Yale Face Database.* **1a.** *Face "topics" from nonnegative matrix factorization; the scale is 0 (white) to 255 (black).* **1b.** *Face principal components from principal component analysis. Figure courtesy of Deanna Needell.*

# When Artificial Intelligence Takes Shortcuts, Patient Needs Can Get Lost

*By Matthew R. Francis*

A patient checks into the hospital emergency room, where staff rush her to the intensive care unit (ICU). The radiologist feeds her chest X-ray into an artificial intelligence (AI) program,[1] which reports that she likely has pneumonia. Another patient with glaucoma visits his ophthalmologist, who takes a routine image of his retinas. The AI that analyzes the image determines that the patient also has type 2 diabetes.

Both of these conclusions turn out to be correct, but for entirely coincidental reasons. ICU patients are far more likely to have pneumonia than other hospital patients, and type 2 diabetes is more prevalent in older people. In other words, the computer model took a *shortcut* by drawing an inference based on incidental details rather than actual diagnostic factors. To exacerbate the situation, when medical workers require AI systems to control for these details, the models fail to identify actual medical problems from images.

"AI seems to catch patterns about our data acquisition across multiple domains and use them in prediction," Judy Wawira Gichoya, a radiologist and professor at Emory University, said. "Some of those things are visible, and some are invisible. When AI calibrates to the scanner model or social demographic characteristics like race, and those are not things that radiologists can see [in the images], it's very difficult to figure out whether this shortcut is helpful or harmful."

During a session about AI biases[2] at the 2025 American Association for the Advancement of Science (AAAS) Annual Meeting,[3] which took place in Boston, Mass., this February, Gichoya explained that AI shortcuts—much like normal human shortcuts—are meant to save time. "We rely on shortcuts to deal with information overload, [like] when we have to study for a test or when our brains have to process a lot of things," she said. "AI algorithms are trained to mirror the function of the brain, especially neural networks."

Maryellen Giger, a medical physicist at the University of Chicago and moderator of the AAAS session, noted that while "bias" has certain connotations in the context of human experience, it is also a statistical concept. AI models identify patterns within training data and utilize these patterns—based on probability—to infer something about the system that was not part of the training. When the models identify patterns that are irrelevant or tangential to the process of medical diagnosis, the resulting bias is difficult to overcome and leads to potentially troublesome shortcuts.

Human limitations contribute to these shortcuts as well. "In medicine, we need to acknowledge that the problem with shortcuts is that there are some things we don't know," Gichoya said. Sometimes *human* practitioners are unsure of a diagnosis, either due to ambiguous test results or because a patient is experiencing a rare condition. "80 percent of the work in developing a good AI algorithm is data," Giger added, citing the venerable computer adage "garbage in, garbage out." "If you don't have the reference standard, it's not representative of the intended population."

### AI of the Beholder

Ocular diseases are a growing concern around the world, in part because improved global access to medical care is resulting in more diagnoses. While this shift means that treatment is also possible in previously inaccessible locations, the total burden on healthcare systems is increasing.

In 2020, medical researchers developed a groundbreaking diagnostic technique called *oculomics* that uses images of retinas to identify ophthalmological disorders such as macular degeneration as well as a number of other medical conditions, including cardiovascular disease and dementia [3]. These so-called *fundus photographs* are noninvasive,

*See* **Patient Needs** *on page 3*

[1] This is technically machine learning rather than true "artificial intelligence," but standard practice equates these two terms, so I defer to the more common language.

[2] https://aaas.confex.com/aaas/2025/meetingapp.cgi/Session/33938

[3] https://www.aaas.org/events/2025-aaas-annual-meeting

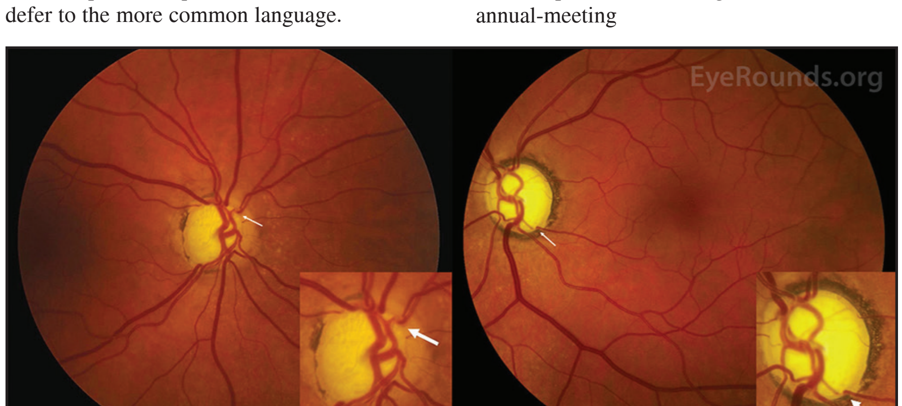


**Figure 1.** *Fundus photograph that shows blood vessels in the eye of a patient with glaucoma. The arrows point to places where glaucoma has caused distortion in the vessels' shape. Some researchers hope to use artificial intelligence to help identify medical conditions from fundus images. Figure courtesy of EyeRounds.org/the University of Iowa under the Creative Commons Attribution-NonCommercial-NoDerivs 3.0 Unported license.*

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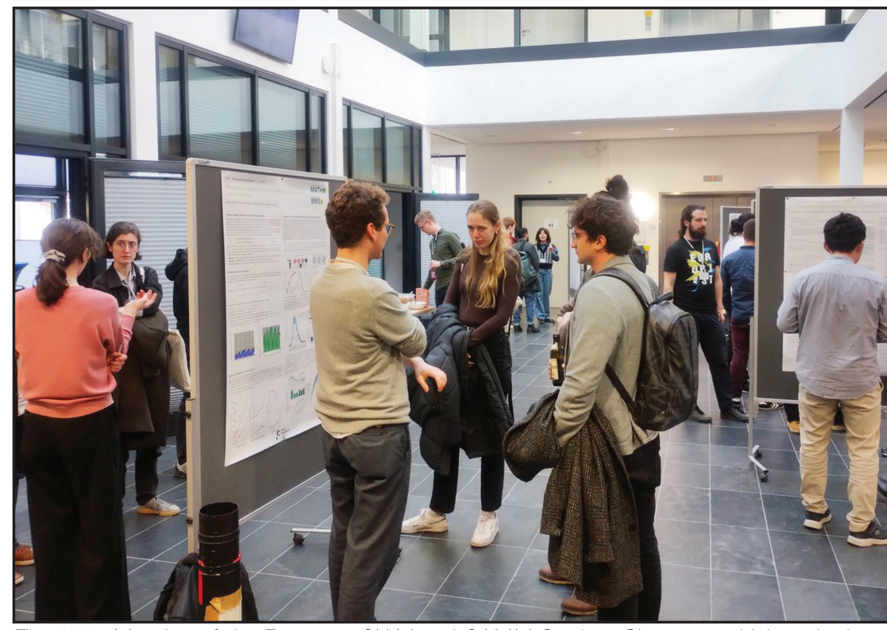
# German SIAM and GAMM Student Chapters Meet in Potsdam for Lively Scientific Exchange

*By Hans Reimann and Josie König*

The biennial Meeting of the European SIAM and GAMM Student Chapters (MESIGA) brings together students in applied mathematics for a convivial gathering where they can share their work, learn from peers and established scientists, and explore a diverse array of topics. After a short hiatus, the University of Trier SIAM Student Chapter[1] revived the long-standing tradition in 2023, then passed the torch to the University of Potsdam SIAM and GAMM Student Chapter[2] and the Berlin Area SIAM Student Chapter to host MESIGA25.[3] The student-organized conference took place at the University of Potsdam from March 10-13, 2025, with a focus on numerical methods in applied mathematics.

The meeting attracted approximately 60 SIAM student chapter members and other participants from the master to postdoctoral level. The festivities kicked off on the evening of March 10 with a welcome event that featured an industry talk by Peter Schlicht of CARIAD,[4] who discussed the development of safe artificial intelligence systems for autonomous driving. The event took place at a popular local bar in Potsdam, which allowed for lively conversation in a relaxed atmosphere.

The first full day of the conference began with an energetic icebreaker activity. Next, SIAM President Carol Woodward of Lawrence Livermore National Laboratory and GAMM[5] treasurer Andrea Walter of the Humboldt University of Berlin presented the opening remarks. Throughout the week, Woodward also engaged directly with the student chapters during several sessions.



*The 2025 Meeting of the European SIAM and GAMM Student Chapters, which took place in March at the University of Potsdam, featured an afternoon poster session that allowed for in-depth research discussions and the exchange of ideas. Photo courtesy of Hans Reimann.*

In addition to networking, the mathematical contributions of early-career scientists were a major focus of the conference. The program[6] included 17 contributed talks and a student poster session with roughly 10 posters, which allowed for the further exchange of ideas. These presentations were complemented by four insightful plenary talks that encompassed a variety of different fields. Martin Stoll of the Chemnitz University of Technology used the graph Laplacian to introduce audience members to the world of data science, and Anne Wald of the University of Göttingen overviewed her research in the field of inverse problems. Later in the week, Julia Grübel of the University of Technology Nürnberg spoke about equilibrium problems and energy market design, while Carmen Gräßle of the Technical University of Braunschweig familiarized attendees with data assimilation in materials science.

After the second day of lectures, participants embarked on a guided tour of the beautiful Sanssouci Park — one of Potsdam's main attractions. Following this afternoon social outing, everyone split into four dinner groups to explore Potsdam's local restaurant scene before reuniting at another pub.

The last day of the conference was dedicated to the remaining contributed talks, further interactions among SIAM and GAMM student chapter members, and a lighthearted soft skills workshop. This latter session aimed to foster presentation capabilities and provide attendees with a toolkit of stylistic devices to captivate an audience. The workshop instructors were members of the popular Berlin poetry slam ensemble Kiezpoeten,[7] and they prepared three interesting topics to help early-career scientists improve their speaking abilities; participants could choose between "Storytelling for Presentation Structure," "Humor for Engaging Your Audience," or "Stage Presence and Confidence."

After a final coffee break, conference attendees parted ways with fresh insights, new friends and connections, and ideas for subsequent individual and student chapter projects. With the second post-COVID-19 MESIGA in the books, we look forward to future meetings and are confident that another chapter will volunteer to organize the 2027 iteration. We have all grown fond of the tradition of MESIGA as a conference "for students by students" that provides junior researchers with the opportunity to present their work in a friendly, curious environment and meet dedicated, like-minded peers.

We are grateful for financial support from the Institute of Mathematics at the University of Potsdam, SFB 1294,[8] SFB Transregio 154,[9] GAMM, and the Berlin Mathematics Research Center MATH+.[10] Finally, we would like to thank SIAM and GAMM for inspiring this event through their promotion of networking and collaboration among early-career researchers and young academics.

*Hans Reimann is a Ph.D. student in mathematical statistics and data assimilation at Heidelberg University. He was vice president of the University of Potsdam SIAM and GAMM Student Chapter during his master's studies and currently serves as secretary of the Heidelberg University SIAM and GAMM Student Chapter. Reimann was a member of the Organizing Committee for the 2025 Meeting of the European SIAM and GAMM Student Chapters. Josie König is a Ph.D. student at the University of Potsdam, where she studies model order reduction for data assimilation. She served as treasurer of the University of Potsdam SIAM and GAMM Student Chapter for two years and co-organized two German student chapter meetings. König was a member of the Program Committee for the 2025 Meeting of the European SIAM and GAMM Student Chapters.*

*Attendees of the 2025 Meeting of the European SIAM and GAMM Student Chapters, which was held at the University of Potsdam in March, gather for a group photo. Photo courtesy of Alexandra Faber.*

1 https://www.uni-trier.de/index.php?id=24339
2 https://www.math.uni-potsdam.de/studium/studierende/default-8819680ed3
3 https://www.math.uni-potsdam.de/studium/studierende/default-8819680ed3/standard-titel
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# Eight Years and Seven Days in the Life of Gottfried Wilhelm Leibniz

**Leibniz in His World: The Making of a Savant.** *By Audrey Borowski. Princeton University Press, Princeton, NJ, November 2024. 320 pages, $35.00.*

**The Best of All Possible Worlds: A Life of Leibniz in Seven Pivotal Days.** *By Michael Kempe. Translated by Marshall Yarbrough. W.W. Norton & Company, New York, NY, November 2024. 304 pages, $32.50.*

BOOK REVIEW
*By Ernest Davis*

Gottfried Wilhelm Leibniz (1646-1716) was first and foremost a mathematician — one of the greatest of his era. Leibniz's supreme contribution was his discovery, independently of Isaac Newton, of the fundamental theorem of calculus: that integration and differentiation are inverse operations. He invented the notation $\int f(x)\,dx$, which still pervades mathematical writing more than 300 years later.

Leibniz made numerous other major contributions to mathematics as well; notably, he developed the matrix representation of linear equations, defined the determinant, and formulated versions of Gaussian elimination and Cramer's rule. He also found the first infinite series for $\pi$, $\pi/4=1-1/3+1/5-1/7\ldots$, though he was not the first person to do so.

What is truly amazing about Leibniz, however, is the number of different fields to which he contributed. He engaged in an impressively diverse collection of studies and appears in many intellectual histories of the late 17th and early 18th centuries. He was a major philosopher; Bertrand Russell's first philosophical work, written almost two centuries after Leibniz's death, was titled *A Critical Exposition of the Philosophy of Leibniz* [4]. My late colleague Martin Davis titled his book about the history of computer science *The Universal Computer: The Road from Leibniz to Turing* [1]. Chapter 1 of Davis' text explores Leibniz's contributions to formal logic, study of binary notation, creation of a mechanical arithmetic calculator, and dream of a "universal characteristic:" a well-defined language through which users can express all knowledge and mechanically carry out all reasoning.

Leibniz's universal characteristic is likewise a subject of discussion in Umberto Eco's *The Search for the Perfect Language* [2]. Paul Hazard's classic history of the early Enlightenment period, *The Crisis of the European Mind: 1680-1715* [3], recalls Leibniz's unsuccessful attempts to persuade Catholic theologian Jacques-Bénigne Bossuet to join him in an effort to reconcile the Protestant and Catholic Churches. Leibniz also had a deep interest in biology—he was perhaps the only mathematician before the 20th century who was more fascinated by microscopes than telescopes—and contributed to the early study of evolution and the history of planet Earth. He conducted significant work in philology and linguistics, as well as historical and philosophical legal research.

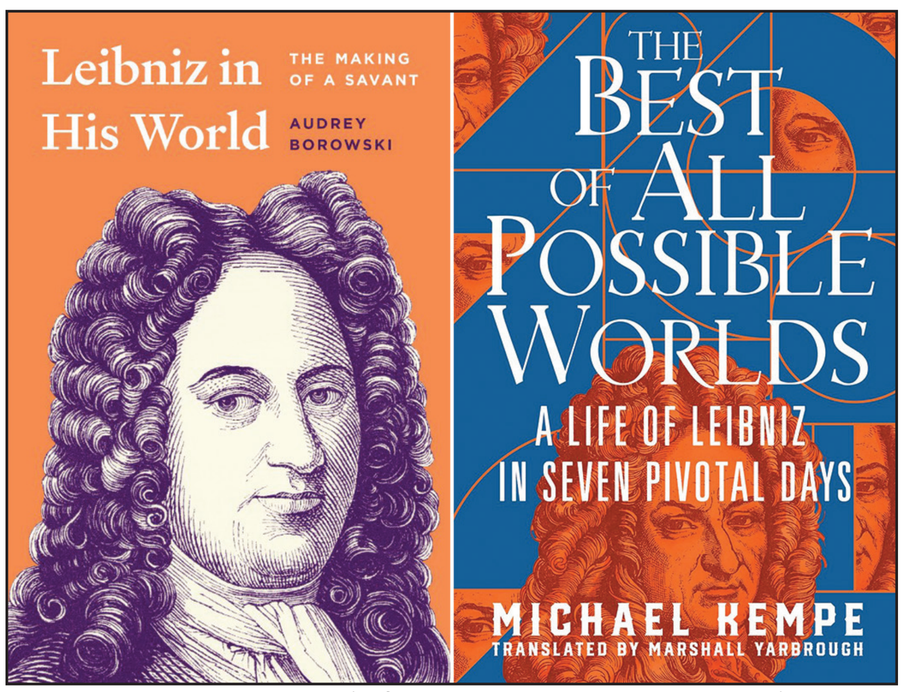
And then there were Leibniz's day jobs, so to speak. He was employed for 40 years at the House of Hanover, a prominent dynasty in Europe, where his chief official responsibility was to write a history of the family of Welf (or Guelph) from whom the Hanovers were descended. Leibniz carried out his historical studies with the same energy and scrupulous precision as his other pursuits, and though he never finished the work, his account was published in three volumes in the 19th century. As court librarian, he developed a cataloging system that was adopted widely across Europe.

Leibniz was also an inventor. In addition to the mechanical calculator, he designed wind-driven propellers, pumps, lamps, and even an early steam engine. Furthermore, Leibniz was involved in myriad practical entrepreneurship and political projects. He helped to establish the silk industry in Germany, which persisted somewhat successfully until the 1960s, and spent years attempting to rectify flooding in the silver mines of the Harz Mountains (to no avail).

While Leibniz published a few books and a substantial number of articles and short pieces in his lifetime, these writings were just the tip of a huge iceberg. Several additional texts that he more or less completed were published decades or even centuries after his death. He wrote roughly 900 letters a year—many of them short essays—to correspondents near and far. Most of all, he produced countless notes on scraps of paper with his thoughts about all sorts of topics. When he could, Leibniz liked to lie in bed for an hour in the morning, just thinking; it sometimes took him most of the day to record all that he had thought during that hour. A project to publish all of Leibniz's writings[1] began in 1901. This endeavor has persisted through two World Wars, multiple regime changes, partition, reunification, and advances in publication technology; when complete, the record will span approximately 170 volumes.

Two recent biographies of Leibniz handle this vast, unmanageable sprawl by limiting their temporal scope. In *Leibniz in His World: The Making of a Savant*, author

*See* **Leibniz** *on page 6*




*Leibniz in His World: The Making of a Savant. By Audrey Borowski. The Best of All Possible Worlds: A Life of Leibniz in Seven Pivotal Days. By Michael Kempe, translated by Marshall Yarbrough. Courtesy of Princeton University Press and W.W. Norton & Company.*

[1] https://www.leibnizedition.de

## Patient Needs

*Continued from page 1*

relatively inexpensive, and now a routine part of eye exams in places that have access to the necessary equipment (see Figure 1, on page 1). In recent years, medical AI researchers have proposed that computers learn this process, as a large number of fundus images are available for training models — much more data than in many other medical subfields. In fact, published studies have claimed that AI models can determine whether patients have conditions like cardiovascular disease or diabetes, and even identify risk behaviors such as tobacco smoking, simply based on these fundus images [4].

But when those same models control for a patient's age, the accuracy drops to no better than random chance. It turns out that the algorithms were using age as a shortcut because all of the conditions and risks that they identified from retinal images increase strongly with age. And while oculomics is an extremely promising premise, another complicating factor is that humans themselves are not very good at diagnosing disease from fundus photos. AI learns best from data that has already been interpreted by humans; it also tends to succeed at things we do well and perform poorly at things we do not do so well. Without proper human guidance, it is likely to create its own shortcuts.

"We hope that we can train the model to correct for age and still get the right answer in terms of downstream diseases," Jayashree Kalpathy-Cramer, a professor of ophthalmology at the University of Colorado who also spoke in the same AAAS session, said. "But you have to be careful about making sure that you're correcting for all of these potential confounders when looking at diseases that are hard for humans to assess. A human cannot look at someone's eye and say how old they are, whether they're a smoker, whether they're male or female, or what their risk of disease is."

### Show Your Work

Just as medical practitioners learn useful shortcuts based on experience, computers can be "taught" with reinforcement that rewards proper conclusions and penalizes the selection of wrong decision-making criteria. Much like the need to show one's work on a math test, proper AI training requires both the "right" answer and the correct steps to find it. However, arriving at this outcome necessitates knowledge of an algorithm's specific criteria, which is not always straightforward — particularly when most AI systems are black boxes.

Gichoya cited a famous example of a problem-solving shortcut from the early 1900s: a horse named Clever Hans whose trainer claimed that he could do math, when in reality he was just very good at discerning cues from the audience. Of course, the stakes of medical AI shortcuts are much higher than Clever Hans' interpretation of human reactions. "What is the model actually learning?" Kalpathy-Cramer asked. "[AI] models are not very transparent, so it's hard to know exactly what information they're using to come up with their answers."

To make matters worse, algorithms are built for efficiency — which sounds good in principle but can be problematic in practice. "When you remove one shortcut, the model just moves to another [because] most datasets appear to have more than one shortcut," Gichoya said.

### Shortcuts and the Giraffe Problem

Radiology researcher Karen Drukker, who works with Giger at the University of Chicago to develop medical AI tools, noted in her own AAAS talk that present-day medical images are not designed for taking measurements. Rather, they offer qualitative data that human practitioners can interpret after years of training via medical school or other intensive practices. For instance, because a human can sufficiently learn to identify a healthy hand from a single image, medical education focuses on teaching students to identify diseased hands. However, this means that computer training data is overwhelmingly dominated by pictures of hands with various conditions, which makes it more difficult for AI models to learn the markers of a healthy hand. "If it involves radiation, you can't just scan healthy hands," Drukker said. "For rare diseases, [lack of data] is even more of a problem."

Drukker pointed out that more data is available than is being utilized, as hospitals and other institutions do not regularly share data with each other — leaving researchers with training materials that have a heavy statistical bias. Additionally, researchers who build medical AI models generally adapt them from systems that analyze images on the web: stock photos, wildlife pictures, and so forth (among other more serious issues, this practice has led to a preponderance of giraffes in AI-generated "art" [1]).

"Data augmentation techniques [are] where you pretend you have more data than you actually have to try to overcome these limitations," Drukker said. "There are a lot of applications that seem promising, but they have to live up to the high standards in healthcare. Groups are looking into generating synthetic data, but of course those can also introduce their own bias. If you have biased synthetic data, then your algorithm is going to learn things from that biased data."

This sort of statistical bias is worrisome enough, but—as Gichoya noted—researchers in the U.S. are currently facing repercussions under the Trump administration for studying human biases around gender, race, national origin, sexuality, and so on. The cancelation of grants from the National Institutes of Health and other vital sources has imposed further setbacks [2].

"Black women continue to die even when there are better treatments for the diseases that they die from," Gichoya said, citing her own work in health equity as a healthcare practitioner. "We understand that some [drivers] are systemic racism and unconscious bias, but if we use models that are able to pick up patterns instead of blaming them, we can improve outcomes for everyone. We're never going to avoid the messiness of real-world data, but as long as we have a human in the loop, the radiologist or doctor could say, 'I need to be more careful when I'm relying on model predictions.'"

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[2] Lazar, K., & Kowalczyk, L. (2025, March 7). NIH abruptly terminates millions in research grants, defying court orders. *STAT News*. Retrieved from https://www.statnews.com/2025/03/07/nih-terminates-dei-transgender-related-research-grants.

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

## Machine Learning

*Continued from page 1*

enormous magnitude will force the NMF factors to account for that scale. Although we can handle this straightforward example by normalizing the data points, its incidence highlights an important phenomenon that also occurs in populations with large majority groups or groups with high complexity, which are much harder to address.

As a simple motivating example, we generate a data matrix $\mathbf{X}\in\mathbb{R}^{m\times n}_{\geq 0}$ as $\mathbf{X}=\mathbf{WH}$, where $\mathbf{W}\in\mathbb{R}^{m\times r}_{\geq 0}$ and $\mathbf{H}\in\mathbb{R}^{r\times n}_{\geq 0}$ are sampled from a uniform distribution over $[0,1)$. We consider three groups: (i) large size with low complexity ($m_1=1000$, $n=20$, and $r_1=3$), (ii) medium size with low complexity ($m_2=500$, $n=20$, and $r_2=3$), and (iii) small size with high complexity ($m_3=250$, $n=20$, and $r_3=6$). Even in this comparatively unextreme and simple case, each group experiences vastly different relative errors, defined as $\|\mathbf{G}-\mathbf{WH}\|/\|\mathbf{G}\|$ for subdata $\mathbf{G}$ (see Figure 2). This discrepancy may lead to unfairness for several reasons. If we employ a method like NMF for topic modeling to understand a set of data, some groups within the population will be less explained than others. And if we utilize NMF for classification or feature extraction, those underrepresented groups may experience far worse predictions, classifiers, allocation of resources, and so forth.

### Towards a Fairer NMF Formulation

Although there are many sources of bias and inequity in ML, we focus on the lack of fairness in NMF that stems from an imbalance in group size and/or group complexity [2]. To overcome such imbalances, we propose an approach called *Fairer-NMF*, with a fairer objective function that is defined as

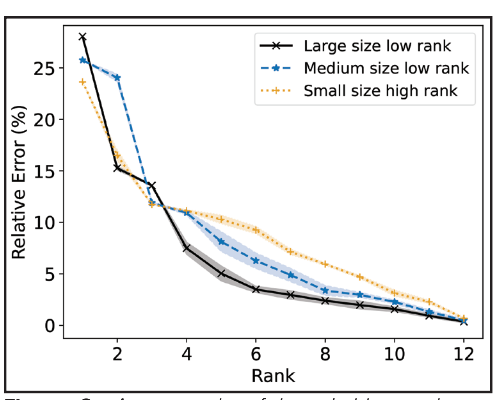


**Figure 2.** *An example of inequitable results on synthetic data when nonnegative matrix factorization is applied to the entire population. The relative reconstruction error of each group is a function of rank. Shading indicates the standard deviation over 10 trials. Figure courtesy of [2].*

$$\min_{\mathbf{W}\in\mathbb{R}^{m\times r}_{\geq 0},\,\mathbf{H}\in\mathbb{R}^{r\times n}_{\geq 0}}\ \max_{\ell\in\{1,\cdots,L\}}\left\{\frac{\|\mathbf{X}_\ell-\mathbf{W}_\ell\mathbf{H}\|-E_\ell}{\|\mathbf{X}_\ell\|}\right\}. \tag{2}$$

Here, $\mathbf{X}_\ell$ is the data matrix for group $\ell$, $\mathbf{W}_\ell$ is the representation matrix for group $\ell$, $\mathbf{H}$ is the common dictionary matrix, and $E_\ell$ is the estimated optimal (nonnegative) rank-$r$ reconstruction error for group $\ell$. Each part of this modified objective seeks to mitigate the unfairness from different sources. The normalization—via the norm of $\mathbf{X}_\ell$—attempts to account for groups of dissimilar sizes or magnitudes, and the subtraction of $E_\ell$ in the numerator addresses the varying complexity of the groups. For instance, if group $\ell$ has low complexity (meaning that $E_\ell$ is small), then the objective incurs a greater penalty if the learned factors do not explain that group well (i.e., the numerator will be larger). The numerator thus attempts to "renormalize" each group's complexities. A reasonable choice for $E_\ell$ could be

$$E_\ell=\mathbb{E}_{\mathbf{X}^*_\ell}\|\mathbf{X}_\ell-\mathbf{X}^*_\ell\|,$$

where the expectation is taken over the $\mathbf{X}^*_\ell$ that we obtain from a specific randomized implementation of rank-$r$ NMF on $\mathbf{X}_\ell$. We can empirically approximate this quantity by averaging over NMF outputs for each individual group.

This formulation aims to minimize the maximum relative reconstruction loss across all groups, balancing for size and adjusting for group complexity to ensure an impartial representation. Ultimately, we hope that our method will allow for a more equitable explanation of data, prediction, and classification outcomes in the context of the entire population.

Readers may wonder why we do not individually perform NMF on each group in the population, thus eliminating the need to rebalance the overall objective. It turns out that this approach typically does not yield desirable outcomes, especially for small groups. In most learning applications, small groups still share a lot of information and similarities with the rest of the population; as such, learning about them within the entire population is far better than extracting a group and working with much less informative data. And in some cases, the goal of the learning task is to determine the correlations and interactions between groups, which means that we must consider them all together. Of course, identifying such groups within the population might itself be an unfair task that introduces bias. All of these considerations are important on an application by application basis.

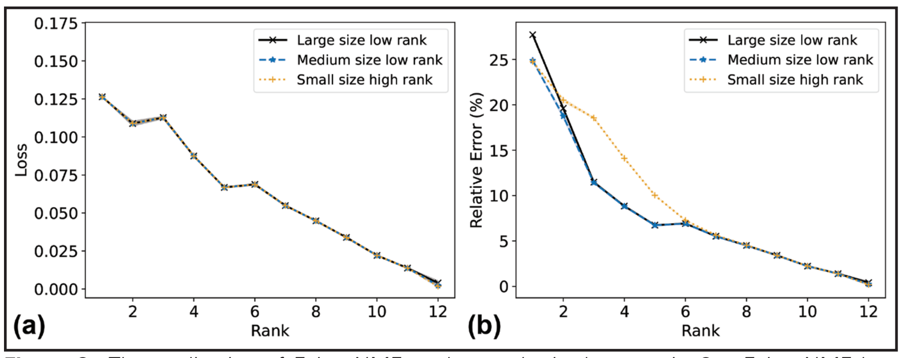


**Figure 3.** *The application of Fairer-NMF to the synthetic data matrix.* **3a.** *Fairer-NMF loss with the alternating minimization scheme.* **3b.** *Fairer-NMF relative error with the same scheme. Figure courtesy of [2].*

### Numerical Experiments

We will now present several experiments that utilize Fairer-NMF [2]. First, we run Fairer-NMF on the same simple synthetic data from Figure 2. Due to the method's construction, the loss—i.e., the term that is optimized in (2)—is the same for all three aforementioned groups in this case (see Figure 3a). Given this unsurprising result, we can also ask about the relative reconstruction error $(\|\mathbf{X}-\mathbf{WH}\|_F/\|\mathbf{X}\|_F)$ for each group (see Figure 3b). When compared to Figure 2, our approach does appear to provide what is perhaps a fairer relative error, especially for higher ranks.

Next, we showcase our technique on the 20 Newsgroups dataset:[2] a common benchmark dataset for document classification, clustering, and topic modeling that contains six groups of news data on six different topics. This dataset exemplifies a population that comprises a large corpus of text that reflects individuals' opinions about specific subjects, reviews of products, and a variety of other materials; the goal is to understand the data at a high level. Figure 4a shows that standard NMF produces very different loss values for each group in the data. In Figure 4b, Fairer-NMF produces equitable losses for all groups as designed.

Interestingly, the standard NMF relative errors appear to be more "equitable," in the sense that they are closer to one another than in the Fairer-NMF variant (see Figures 4c and 4d). For the latter, the "Sale" group experiences much lower relative error than the other groups because of the objective function's design; the "Sale" group had the highest standard loss (likely due to complexity), and equation (2) forced a boosting of the group, as intended. This action may or may not be fairer — an inconsistency that affirms that "fair" is highly dependent on application, and loss functions should be designed to suit the situation at hand. We believe that mathematicians have a duty to highlight possible inequities and present understandable options for end users, and these results move us towards that intention.

To conclude, Fairer-NMF is a promising approach that addresses bias in NMF, ultimately promoting equitable data representation across different groups. Here, we highlighted the importance of fairness in ML to pave the way for the development of more equitable and trustworthy algorithms. But while Fairer-NMF does drive the research community closer to fairer ML, we must remember that fairness is highly context dependent. As such, we should carefully consider the choice of fairness criteria and potential tradeoffs based on the application in question. Further research is needed to address limitations, such as *a priori* knowledge of group partitions.

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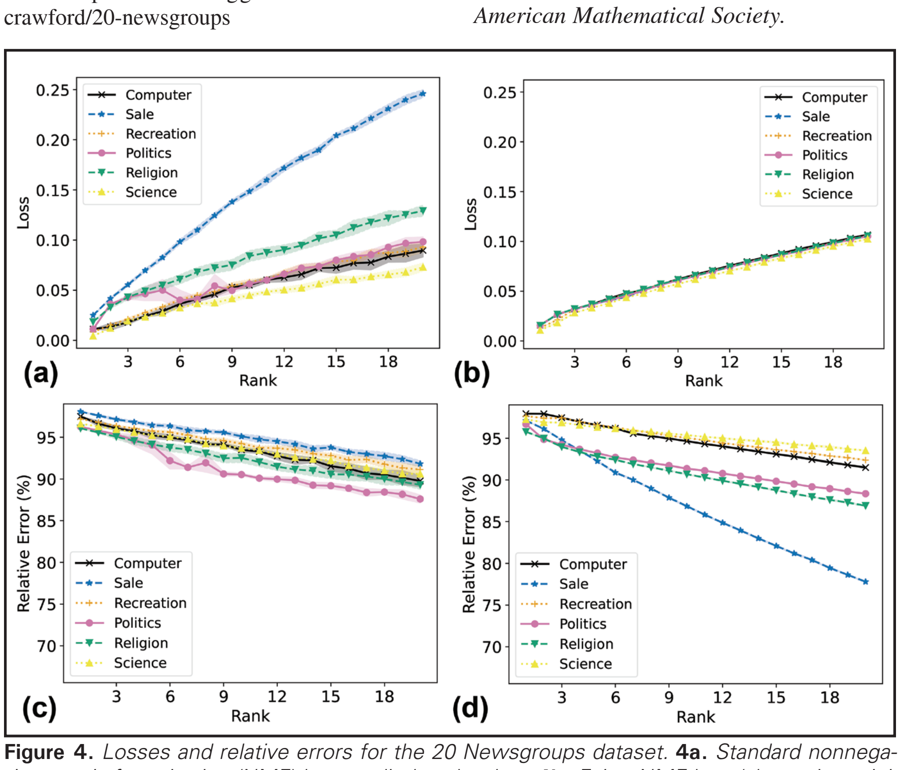



**Figure 4.** *Losses and relative errors for the 20 Newsgroups dataset.* **4a.** *Standard nonnegative matrix factorization (NMF) loss applied to the data.* **4b.** *Fairer-NMF loss (alternating minimization scheme).* **4c.** *Standard NMF relative error.* **4d.** *Fairer-NMF relative error (alternating minimization scheme). Figure courtesy of [2].*

# Photos from the 2025 SIAM Conference on Computational Science and Engineering

*At the 2025 SIAM Conference on Computational Science and Engineering, which was held this past March in Fort Worth, Texas, SIAM President Carol Woodward of Lawrence Livermore National Laboratory (left) awards the inaugural Ivo & Renata Babuška Prize to Omar Ghattas of the University of Texas at Austin. Ghattas was acknowledged for his "groundbreaking interdisciplinary contributions to the theory and algorithms of Bayesian inverse problems and their high-impact application across the geosciences." His corresponding lecture at the meeting detailed his research group's ongoing work in this space. SIAM photo.*


*During the 2025 SIAM Conference on Computational Science and Engineering, which took place in March in Fort Worth, Texas, Julianne Chung of Emory University (left)—chair of the SIAM Activity Group on Computational Science and Engineering (SIAG/CSE)—presents the 2025 SIAG/CSE Early Career Prize to Jiequn Han of the Flatiron Institute. Han was recognized for his "outstanding theoretical, algorithmic, and computational software contributions to the fields of deep learning, stochastic control, stochastic differential equations, and molecular dynamics." At the conference, he delivered a talk that was titled "Solving High-dimensional Partial Differential Equations Using Deep Learning: Original Insights and Recent Progress." SIAM photo.*

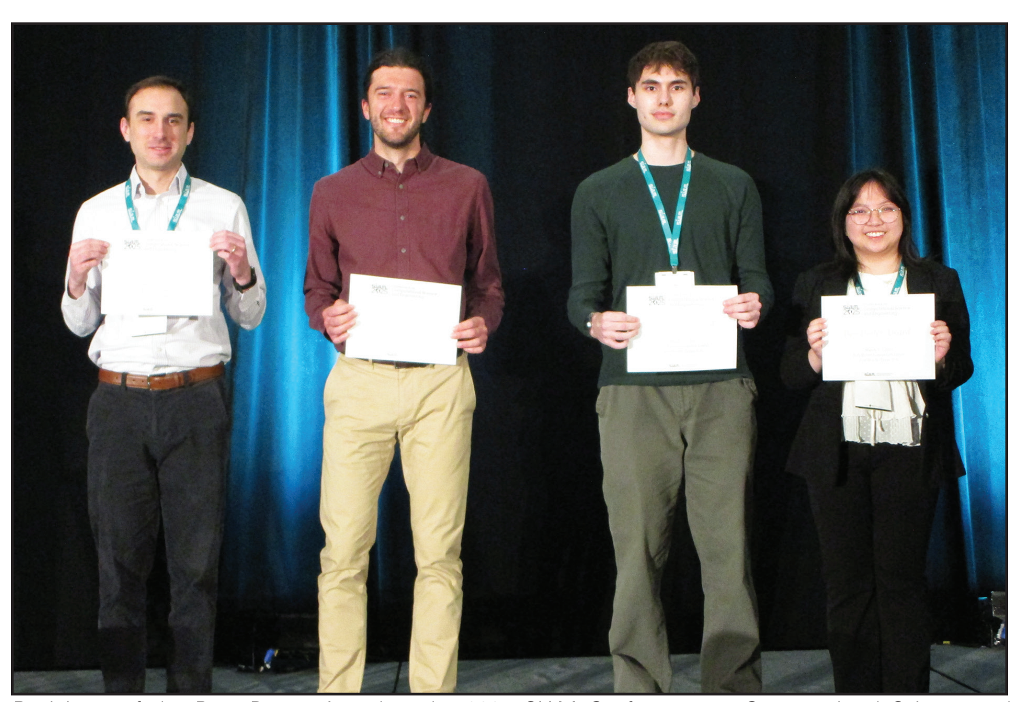
*Erin Carson of Charles University (right) accepts the 2025 James H. Wilkinson Prize in Numerical Analysis and Scientific Computing from SIAM President Carol Woodward of Lawrence Livermore National Laboratory at the 2025 SIAM Conference on Computational Science and Engineering, which took place this past March in Fort Worth, Texas. Per the award citation, Carson was commended for her "impactful contributions to the performance and stability of mixed-precision numerical linear algebra." In her subsequent presentation, she discussed the challenges of designing mixed-precision algorithms. SIAM photo.*

***Read more about the prize recipients at the 2025 SIAM Conference on Computational Science and Engineering (CSE25) at https://go.siam.org/n0oku1.***

***View additional photos from CSE25 on SIAM's Facebook page at https://go.siam.org/sl5nsz.***

*From left to right: Julianne Chung of Emory University—chair of the SIAM Activity Group on Computational Science and Engineering (SIAG/CSE)—congratulates Elizabeth Newman of Emory University, Misha Kilmer of Tufts University, and Lior Horesh of IBM Research for their joint receipt of the 2025 SIAG/CSE Best Paper Prize. The group—along with coauthor Haim Avron of Tel Aviv University (not pictured)—was honored for their 2021 paper, "Tensor-tensor Algebra for Optimal Representation and Compression of Multiway Data," which published in the Proceedings of the National Academy of Sciences. Newman gave an associated prize lecture on behalf of her colleagues at the 2025 SIAM Conference on Computational Science and Engineering, which was held in Fort Worth, Texas, this past March. SIAM photo.*

*At the 2025 SIAM Conference on Computational Science and Engineering, which was held in Fort Worth, Texas, in March, the principal authors of the deal.II project receive the 2025 SIAM/ACM Prize in Computational Science and Engineering for their creation of a highly impactful library that supports finite element calculations. From left to right: Daniel Arndt of Oak Ridge National Laboratory, Wolfgang Bangerth of Colorado State University, Timo Heister of Clemson University, Guido Kanschat of Heidelberg University, Martin Kronbichler of Ruhr University Bochum, Matthias Maier of Texas A&M University, Peter Munch of the Technical University of Berlin, Bruno Turcksin of Oak Ridge National Laboratory, and David Wells of the University of North Carolina at Chapel Hill. Not pictured are Bruno Blais of Polytechnique Montréal, Marc Fehling of Charles University, Rene Gassmoeller of the GEOMAR Helmholtz Centre for Ocean Research Kiel, Luca Heltai of the University of Pisa, and consultant Jean-Paul Pelteret. At the conference, Bangerth delivered a presentation that overviewed the deal.II project. SIAM photo.*



*Recipients of the Best Poster Award at the 2025 SIAM Conference on Computational Science and Engineering—which took place in March in Fort Worth, Texas—proudly display their certificates. The meeting featured an engaging two-hour poster session, during which presenters had the opportunity to share their work and network with other attendees. From left to right: Matthew Dallas of the University of Dallas, Benjamin Zastrow of the University of Texas at Austin, Jack Kelley of Virginia Tech, and Sophia Isabel Perez Ferrer of Hood College. Georgia Brooks of the Colorado School of Mines is not pictured. SIAM photo.*

# A Sprinkler Paradox

MATHEMATICAL CURIOSITIES

*By Mark Levi*

With warmer weather coming to the Northeastern U.S., I would like to introduce a few sprinkler-related questions that occurred to me some time ago [1]. The sprinkler in Figure 1 is an S-shaped tube that pivots on a frictionless hinge, with a steady supply of water to the hinge. Water shoots out of both ends of the tube, causing it to spin. The sprinkler was activated in the sufficiently distant past and is now in steady state.

1. What is the direction of the velocity of the exiting water (as viewed from the top by a ground observer)?

2. What is the ground speed of the exiting water? Is it equal to the speed in the tube?

3. In what direction does water exit a sprinkler with semicircular arms, as in Figure 2?

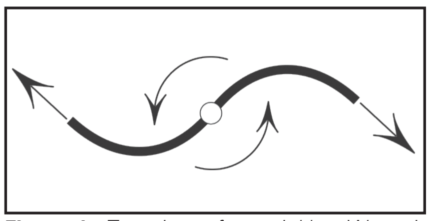


**Figure 1.** *Top view of a sprinkler. Water is supplied at the center hub and shoots out of the ends of the S-tube, causing it to spin.*

4. What shape(s) of the S-tube will maximize the angular velocity? Is it good to maximize this velocity?

5. What is the shape of the water jet (as viewed from the top by a ground observer) after it exits the sprinkler? What is the shape of the same jet when viewed by an observer who spins with the sprinkler?

Here are the answers to some of these questions.

1. Despite the sprinkler's spin, the ground velocity of exiting water is perfectly radial (see Figure 3). Indeed, the angular momentum of water that is supplied at the hinge is zero, and no external torque is applied to the water-tube system because the hinge is frictionless. Exiting water hence has zero angular momentum as well. In short, since the motion is in steady state, angular momentum in equals angular momentum out. And since the former is zero, so is the latter.

2. Exit speed $u$ (relative to the ground) is slower than the speed $v$ in the tube:

$$u = v\cos\theta, \qquad (1)$$

where $\theta$ is the angle between the tangent at the tube's end and the radial ray (see Figure 3).

3. For the sprinkler with semicircular arms in Figure 2, the water exits with zero ground speed and just plops to the ground. This is evident from (1)—with $\theta=\pi/2$—or directly from Figure 3. So, the sprinkler in Figure 2 would only irrigate a circle.

I leave questions 4 and 5 for the reader's possible amusement.

And as a concluding puzzle, the water that exits the "bad" sprinkler in Figure 2 has zero kinetic energy. But the water that enters the sprinkler certainly has positive kinetic energy. What happened to the kinetic energy? The same question applies to the more general sprinkler in Figure 1, since the exit speed $u<v$.

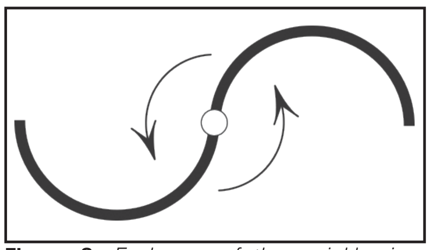


**Figure 2.** *Each arm of the sprinkler is a semicircle. Water has zero ground speed upon exiting the tube.*

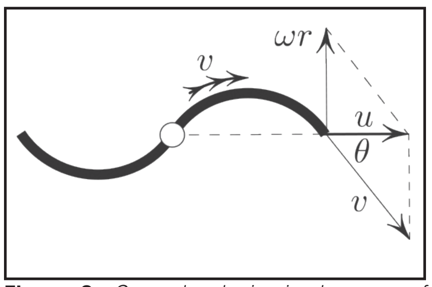



**Figure 3.** *Ground velocity is the sum of two velocities and points radially away from the pivot.*

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*The figures in this article were provided by the author.*

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

## Leibniz

*Continued from page 3*

Audrey Borowski focuses on the eight years from 1672 through 1679. Meanwhile, Michael Kempe's *The Best of All Possible Worlds: A Life of Leibniz in Seven Pivotal Days* concentrates on a selection of important occasions in Leibniz's lifetime.

*Leibniz in His World* is primarily intended for a scholarly audience, as it is a reworking of Borowski's doctoral thesis. She mainly comments on Leibniz's interactions with the other people in his sphere: scientists, philosophers, clerics, intellectuals, aristocrats, and *projectors*. In the 17th and 18th centuries, projectors were people who promoted and carried out some kind of project. These individuals ranged from serious scientists and ambitious entrepreneurs to impractical dreamers and snake oil salesmen — or often a combination of all. Though Leibniz distrusted projectors as a class, he frequently interacted with them and apparently found some to be exciting or fascinating.

Leibniz's endeavors to promote the production and use of phosphorus involved dealings not only with its inventor—alchemist Hennig Brand—but also with inventor Johann Daniel Crafft; physician, alchemist, adventurer, and philosopher Johann Joachim Becher; scholar Jean Gallois; and Leibniz's chief mentor, mathematician Christiaan Huygens. These negotiations were complex and not always aboveboard, and Borowski recounts that Leibniz once commissioned the theft of a cache of letters from Becher's apartment. She also details a number of additional interesting episodes, such as Leibniz's philosophical correspondence with Jansenist philosopher Antoine Arnauld; his attempts to convince the King of France to invade Egypt; his idea for a secret society of enlightened savants who would infiltrate the governments of the world and rule it wisely; his engagement with the Republic of Letters and efforts to create a learned academy; his unsuccessful enterprise to secure a permanent position in Paris; and his negotiations with his eventual employer, the House of Hanover.

Kempe's book, *The Best of All Possible Worlds*, was published in German in 2022 and has now been translated into English by Marshall Yarbrough. It is written for a general readership and aims to convey a sense of some of Leibniz's accomplishments and activities, ways of thinking, and day-to-day affairs. It even explores what it might have been like to be him, to the extent that is imaginable. The book is structured around seven specific days, mostly from Leibniz's later life:

- **October 29, 1675:** Leibniz first pens the integral sign.
- **February 11, 1686:** Leibniz sends a philosophical manuscript to Arnauld.
- **August 13, 1696:** Leibniz begins writing a diary (which he abandoned a few months later).
- **April 17, 1703:** Leibniz receives a letter from Joachim Bouvet, a Jesuit missionary in China who claims that he used Leibniz's writings on binary arithmetic to understand the *I Ching* (a Chinese divination text from the ninth century BCE).
- **January 19, 1710:** Leibniz engages in a long conversation with aristocratic brothers Zacharias and Johann von Uffenbach, who left a record of their impressions of the elderly savant.
- **August 26, 1714:** Two weeks after the death of Queen Anne of Great Britain, Leibniz's boss, elector George of Hanover, is named King George I. Leibniz makes plans to leave Vienna—where he had taken a protracted visit—and return to Hanover in the hopes of accompanying the court to London (in the end, he was not allowed to go).
- **July 2, 1716:** Leibniz meets with Russian Tsar Peter I (known as Peter the Great), who was vacationing at Bad Pyrmont.

It is clear that Kempe carefully chose these days to illustrate the different sides of Leibniz's life, philosophy, and work. He recounts each day in great detail: the many projects in which Leibniz was simultaneously engaged at the time (generally a dozen or more), his thoughts, his current location (as he was constantly on the move), the letters that were piled on his desk, the state of his immediate environs and of Europe at large, and even the weather. The necessary scholarship to pull off this feat is prodigious—indeed, Kempe is director of the Leibniz Research Center and the Leibniz-Archive in Hannover—but on the whole, the book wears its learning lightly.

Occasionally, Kempe does seemingly assume that readers are already thoroughly familiar with Leibniz's life. For instance, the text includes a reproduction of a charming 1795 engraving by artist Johann David Schubert that depicts 15-year-old Leibniz sitting under a tree, captioned "Leibniz Chooses Between the Old and New Philosophy." Kempe indicates that this image is based on a story that Leibniz often told about himself, but there is no endnote and I cannot figure out where Leibniz told the story or how Schubert might have learned about it. Additionally, the book is written in the historical present—presumably to make the account more vivid—though I do not think this style actually adds much.

I find it impossible to wrap my mind around the entirety of Leibniz's life and works, as his accomplishments are too multifarious and his world is too remote. I am therefore grateful to Borowski and Kempe for their vivid portraits of some of the most important aspects of an amazing man and his almost unbelievable career.

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# Forward-looking Panel at CSE25 Contemplates Future Directions of Computational Science and Engineering

*By Lina Sorg*

The field of computational science and engineering (CSE) continues to evolve at a rapid pace, driven by novel computer architectures and advancements in artificial intelligence (AI), machine learning (ML), and other technologies. This interdisciplinary research area unites theory and experimentation to stimulate scientific discovery in a variety of domains, from healthcare and supply chain logistics to transportation and defense. As such, practitioners must ensure the safe deployment and explainability of AI tools; enable the analysis, visualization, and assimilation of large data sets; and promote the design of scalable, flexible, and robust software.

During the 2025 SIAM Conference on Computational Science and Engineering,[1] which took place in Fort Worth, Texas, this past March, a forward-looking panel[2] anticipated future challenges and opportunities for CSE in an ever-changing world. Orly Alter of Prism AI Therapeutics[3] and the University of Utah organized the panel and moderated an engaging conversation between Raymond Honfu Chan of Lingnan University in Hong Kong; Gilles Gnacadja of Amgen;[4] Jungsang Kim of Duke University; and Boris Kramer of the University of California, San Diego (UCSD). The panelists each delivered a brief presentation that outlined their observations and experiences across both academia and industry, after which they collectively discussed potential future directions for CSE within the larger context of science, technology, engineering, and mathematics (STEM).

As a professor of scientific computing at Lingnan University, Chan is deeply familiar with the association between STEM-based curricula and the broader research space. Over the years, he has witnessed the development of increasingly sophisticated methods that necessitate novel mathematical models with improved features and more extensive applicability. Prior to the widespread adoption of AI, this evolution usually occurred fairly gradually, which facilitated the organic incorporation of new methods into educational tracks. But as AI expedites the analysis, prediction, and optimization of complex systems, the structure of Ph.D.-level university programs must adapt more rapidly.

Chan asserted that AI-era Ph.D. programs can certainly still emphasize some of the same core mathematical topics as traditional curricula, such as numerical linear algebra, optimization, and ML. But unlike conventional modules that concentrate predominantly on only one method or application, current and future programs should explore the *adaptation* and *mixing* of existing models — with a focus on multidisciplinary, diverse applications that reflect the changing occupational landscape. This shift is especially important because recent years have seen Ph.D.-level graduates move away from academia in favor of industry positions that often offer higher salaries than traditional academic posts.

To prepare students for newly emerging industry opportunities, Lingnan University's Ph.D. curriculum underscores interdisciplinary fluency, verification and validation, programming skills, the relationship between ethics and society, the integration of AI and ML, and the "4 Cs" — communication, collaboration, critical thinking, and creativity. A core first-year AI course explores the ethics, values, and proper use of AI, and subsequent courses center on automated reasoning, policy, and risk within the AI framework. "AI is ubiquitous," Chan said. "We want [the students] to use it properly, and we want to teach them about the humanistic aspects of AI."

Like Chan, Kramer—who is trained as a mathematician but sits in UCSD's Department of Mechanical and Aerospace Engineering—aims to prepare graduate students for the increasing number of available industry positions. Because many STEM syllabi are already quite full, he recommended that departments create space in existing courses by retaining core concepts but replacing some classical material with modern ML methodology. Kramer listed a myriad of multiscale application areas that benefit from ML and other progressive techniques, including digital twins, climate forecasting, nuclear fusion, hypersonic flight, autonomous driving, drug discovery, precision medicine, quantum computing, and semiconductor design and manufacturing. "If you think about anything that general society or philanthropists are interested in, there's so many problems to solve," he said. "The future is very bright."

Kramer also noted that researchers in data-driven control spaces often seek fast algorithms that are tailored to the specific architecture at hand. "Experts in a field are very happy when someone comes along and says that they can do what they're doing but faster, more accurately, with lower variance, and whatnot," he said, citing relevant CSE competencies in high-performance computing, optimization, uncertainty quantification, surrogate modeling, and inverse problems. "Our community has skills that are and will be in high demand for industrial and societal breakthroughs."

Boris Kramer of the University of California, San Diego, speaks about the important role of artificial intelligence, machine learning, and other emerging technologies in the computational science and engineering space during a panel session at the 2025 SIAM Conference on Computational Science and Engineering, which was held in Fort Worth, Texas, this past March. Background, left to right: panelists Raymond Honfu Chan of Lingnan University, Gilles Gnacadja of Amgen, and Jungsang Kim of Duke University. SIAM photo.

To embrace domain expertise and build experts' trust in AI architectures, AI researchers should regularly communicate with the scientists and engineers who ultimately "sign the blueprint"—a phrase attributed to the late Ivo Babuška [1, 3]—to greenlight a process and endorse its use in the real world. Typically, these individuals want to understand the underlying principles and potential impacts of the tool in question before doing so. "We need some of these architectures to be used because they're powerful, but we need to get the engineers to trust them," Kramer said. "It really unlocks a lot of potential when you work together."

Gnacadja seconded the importance of engaging with the individuals who utilize the models, generate the data, and stand to benefit from the results. "Get close to the end users and practitioners and understand what interpretability means to them," he said, remarking that doing so as a junior scientist can inspire an early sense of ownership — especially since real data is often proprietary. "If there's a way for students and practitioners to see the reality of real data and work on it, it makes that work more impactful."

The pharmaceutical industry relies heavily on data, and Gnacadja spoke about Amgen's efforts to harness state-of-the-art AI technologies to better understand diseases and advance targeted treatments. As the executive director of Amgen's Data Science and Engineering team, he leads a group of engineers and other specialists who execute innovative AI programs to streamline biopharmaceutical processes. "AI and applied math have contributed a lot to reduce the time for pharma and drug models," Gnacadja said. These efforts are especially crucial in the drug delivery phase (e.g., clinical trials), which generally requires the largest investment of time and money.

As Amgen works to improve the quality and speed of processes that are already intact, Gnacadja envisioned the use of generative AI to analyze and enhance documentation. "We produce mountains of documents to submit to agencies at various stages of the [drug development] process," he said. "But I can see a future where instead of sending documents, we send data." While standards are not yet in place to shape the structure and format of data as an alternative deliverable, Gnacadja is confident that the eventual creation of updated protocols could reduce the time and monetary demands of clinical trials.

Another area that will both inspire and benefit from new approaches is quantum computing, and Kim identified quantum superposition and quantum entanglement as two examples of phenomena with enormous potential. In general, quantum computing presents a unique opportunity to train machines and conduct complex calculations with significantly less data. "We need a different framework of thinking," Kim said. "In that sense, quantum computing is fairly interesting because it gives you a fundamentally different way of computing than anything we've had in history."

Kim referenced Peter Shor's 1994 factoring algorithm as a significant breakthrough in the quantum realm [2]. "A quantum computer can factor numbers exponentially faster than classical computers," he said, adding that quantum computing can also turn exponential scaling into polynomial scaling and offer order-of-magnitude improvements. Yet because researchers have only been controlling and testing quantum systems for roughly the last four decades, many open questions remain. Kim identified two important lines of inquiry: *Can quantum models be more compact than classical models, i.e., can researchers build models with fewer parameters but similar structures? And are qubits and gates the most effective solution?* "There are many applications where we don't have enough data for AI to be powerful, but quantum can likely help with this," Kim said. "And if quantum systems present additional degrees of freedom other than qubits and gates, should we take advantage of them? There's a lot of really interesting opportunities here, and I feel like the field is just beginning."

As the session drew to a close, Kim urged attendees to remain open-minded, take risks, stay up to date with new AI tools and other emerging technologies in the CSE space, and train the next generation to venture confidently into a rapidly changing world. "At the end of the day, it's the structure of real-world data that we have to learn," he said. "That's where the foundation and the real knowledge is."

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*Lina Sorg is the managing editor of SIAM News.*

[1] https://www.siam.org/conferences-events/past-event-archive/cse25
[2] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=83064
[3] https://www.prism-ai.com
[4] https://www.amgen.com

During a forward-looking panel session at the 2025 SIAM Conference on Computational Science and Engineering (CSE25), which took place in March in Fort Worth, Texas, a group of educators and scientists envisioned future directions for CSE. From left to right: panelists Raymond Honfu Chan of Lingnan University; Gilles Gnacadja of Amgen; Jungsang Kim of Duke University; Boris Kramer of the University of California, San Diego; and moderator Orly Alter of Prism AI Therapeutics and the University of Utah. SIAM photo.

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Kirsten Morris, *University of Waterloo, Canada*

### SIAM Conference on Computational Geometric Design (GD25)

**July 28–30, 2025 | Montréal, Québec, Canada**
*siam.org/gd25* | #SIAMGD25

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Hendrik Speleers, *University of Rome Tor Vergata, Italy*
Jessica Zhang, *Carnegie Mellon University, U.S.*

### SIAM Conference on Applied and Computational Discrete Algorithms (ACDA25)

**July 28–August 1, 2025 | Montréal, Québec, Canada**
*siam.org/acda25* | #SIAMACDA25

**ORGANIZING COMMITTEE CO-CHAIRS**
Martin Farach-Colton, *New York University, U.S.*
Bora Ucar, *ENS-Lyon, France*

**EARLY REGISTRATION RATE and HOTEL DEADLINE for AN25, CT25, GD25, and ACDA25**
June 24, 2025

Information is current as of April 21, 2025. Visit *siam.org/conferences* for the most up-to-date information.

## Upcoming SIAM Events

**SIAM Conference on Applications of Dynamical Systems**
May 11–15, 2025
Denver, Colorado, U.S.
Sponsored by the SIAM Activity Group on Dynamical Systems

**SIAM Conference on Applied Algebraic Geometry**
July 7–11, 2025
Madison, Wisconsin, U.S.
Sponsored by the SIAM Activity Group on Algebraic Geometry

**SIAM Conference on Financial Mathematics and Engineering**
July 15–18, 2025
Miami, Florida, U.S.
Sponsored by the SIAM Activity Group on Financial Mathematics and Engineering

**The Third Joint SIAM/CAIMS Annual Meetings**
July 28–August 1, 2025
Montréal, Québec, Canada

**SIAM Conference on Control and Its Applications**
July 28–30, 2025
Montréal, Québec, Canada
Sponsored by the SIAM Activity Group on Control and Systems Theory

**SIAM Conference on Computational Geometric Design**
July 28–30, 2025
Montréal, Québec, Canada
Sponsored by the SIAM Activity Group on Geometric Design

**SIAM Conference on Applied and Computational Discrete Algorithms**
July 30–August 1, 2025
Montréal, Québec, Canada
Sponsored by the SIAM Activity Group on Applied & Computational Discrete Algorithms

**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

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# SIAM Section Activities and Updates

Sections are regional or national subgroups of SIAM members that organize lectures, meetings, and other activities to serve members in their region. Here is an update on some of the events that took place throughout 2024:

The 9th annual meeting of the **SIAM Central States Section** was successfully hosted by University of Missouri-Kansas City (Kansas City, Missouri) on October 19–20, 2024. The conference featured more than 220 registered participants from 95 different institutions across 32 states. In addition, three plenary talks, 15 minisymposia, 17 contributed talks, 16 research posters, and an NSF panel were all held. Congratulations to the poster award winners: Amit Rotem (Virginia Tech), Easton Brawley (Missouri S&T), and Yingli Li (Colorado State University).

The **Central States Section** of SIAM annual meeting took place October 19–20, 2024 at the University of Missouri-Kansas City in Kansas City, Missouri.

The SIAM **Great Lakes Section** annual meeting took place on October 12, 2024 at Purdue University Northwest (PNW) Hammond Campus and had over 150 participants, six minisymposia, four sections of contributed talks, and a poster session. The meeting also highlighted four plenary talks from: Chenn Zhou from Purdue University Northwest, Guang Lin from Purdue University West Lafayette, Hengguang Li from Wayne State University, and L. Ridgway Scott from University of Chicago.

The **Great Lakes Section** of SIAM held their annual meeting on October 12, 2024 at Purdue University Northwest (PNW) Hammond Campus, Hammond, Indiana.

The **New England Section of SIAM** was approved by the SIAM Board and Council in December 2024. They will be holding their first meeting August 23, 2025 in Boston Massachusetts. The inaugural officers of the section are: En-Bing Lin, Wentworth Institute of Technology (Chair); Sigal Gottlieb, University of Massachusetts, Dartmouth (Vice Chair); Kasso Okoudjou, Tufts University(Secretary); and Mark Mixer, Wentworth Institute of Technology (Treasurer).

The **Northern and Central California Section** of SIAM held its inaugural meeting on October 9–11, 2024 at the University of California, Merced campus. Nearly 200 students and researchers from academic institutions, industry, and national laboratories registered to participate in this three-day event. Although the participants came primarily from Northern California and the Central Valley, students as far away as Texas and Colorado attended and presented their research. Ten minisymposia were organized on a variety of topics including fluid dynamics, numerical analysis, optimization, inverse problems, scientific and high-performance computing, uncertainty quantification, and scientific machine learning. Plenary talks were held by Michael Mahoney (UC Berkeley and Lawrence Berkeley National Laboratory), Robert Schreiber (Cerebras Systems, Inc.), and Mariel Vazquez (UC Davis). The meeting was a resounding success and was attended by SIAM President Carol Woodward. “The meeting filled a critical need for applied mathematicians working in our region but from numerous institutions and companies to share current work and challenges. It was fantastic to meet so many people working on related topics, all within an easy drive from each other,” said Woodward.

The inaugural **Northern and Central California Section** of SIAM conference took place October 9–11, 2024 at the University of California, Merced in Merced, California.

The **Washington-Baltimore Section** of SIAM (DCBALT) organized the SIAM Washington-Baltimore Section Fall Meeting 2024. This year, the meeting took place on December 6, 2024, in Arlington, Virginia hosted by George Mason University. Two plenary talks were held by speakers Prof. Irene Fonseca (Carnegie Mellon University) and Dr. Sven Leyffer (Argonne National Laboratory) who was SIAM President at the time. In addition, a program officers and panel with representatives from the Air Force Office of Scientific Research, National Science Foundation, and Office of Nava Research was held. Approximately 95 attendees registered for the event.

The **Washington-Baltimore Section** of SIAM annual meeting took place December 6, 2024 at George Mason University in Arlington, Virginia.

## Get Involved with a SIAM Section!

Want to get involved in your section? Sections are a great way to gain experience in organizing meetings and SIAM leadership. Contact us today to put you in touch with the current leadership in your section. Email *sections@siam.org* with any questions you may have.

For more information, visit: *siam.org/membership/sections*.

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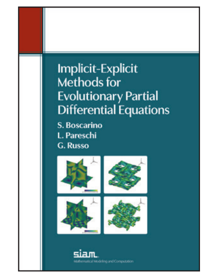
**siam BOOKS**

Quality and Value in Mathematical Science Literature

# Stop by the SIAM Booth at DS25 in Denver

### Implicit-Explicit Methods for Evolutionary Partial Differential Equations

Sebastiano Boscarino, Lorenzo Pareschi, and Giovanni Russo

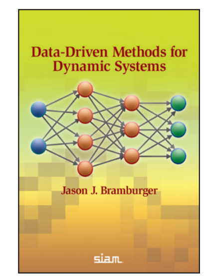



Implicit-explicit (IMEX) time discretization methods have proven highly effective for the numerical solution of a wide class of evolutionary partial differential equations (PDEs) across various contexts. These methods have become mainstream for solving evolutionary PDEs, particularly in hyperbolic and kinetic equations. This first book on the subject provides an in-depth yet accessible approach. The authors summarize and illustrate the construction, analysis, and application of IMEX methods using examples, test cases, and implementation details; guide readers through the various methods and teach them how to select and use the one most appropriate for their needs; and demonstrate how to identify stiff terms and effectively implement high-order methods in time for a variety of systems of PDEs.

*2024 / x + 324 pages / Softcover / 978-1-61197-819-3 / List $89.00 / SIAM Member $62.30 / MM24*

### Data-Driven Methods for Dynamic Systems

Jason J. Bramburger



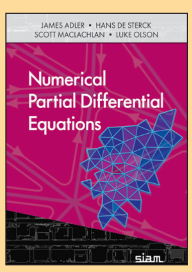

This book brings together modern computational tools to provide an accurate understanding of dynamic data. The techniques build on pencil-and-paper mathematical techniques that go back decades and even centuries. The result is an introduction to state-of-the-art methods that complement, rather than replace, traditional analysis of time-dependent systems. This book provides readers with methods not found in other texts as well as novel ones developed just for this book.

*2024 / x + 169 pages / Softcover / 978-1-61197-815-5 / List $64.00 / SIAM Member $44.80 / OT201*

# New

### Numerical Partial Differential Equations

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

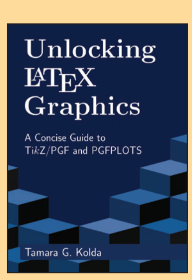



This comprehensive textbook focuses on numerical methods for approximating solutions to partial differential equations (PDEs). The authors present a broad survey of these methods, introducing readers to the central concepts of various families of discretizations and solution algorithms and laying the 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*

### Unlocking LaTeX Graphics *A Concise Guide to TikZ/PGF and PGFPLOTS*

Tamara G. Kolda




If you want to produce high-quality figures for your LaTeX technical documents, then TikZ/PGF and PGFPLOTS are the right tools for you, and this book will enable you to get quickly up to speed. TikZ/PGF draws complex mathematical and technical diagrams, and PGFPLOTS renders line, scatter, and bar plots for scientific data visualization. TikZ/PGF and PGFPLOTS graphics compile right along with your LaTeX document.

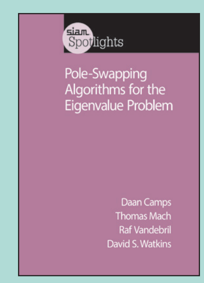
This book boils down 1,800 pages of documentation to focus on the 10% of commands that users need 90% of the time. It also serves as a self-contained reference for most common operations, listing each command with all of the relevant key/value options in one place.

*2024 / iv + 120 pages / Softcover / 979-8-9912295-0-0 List $30.00 / SIAM Member $21.00 / TK1*

# Coming in May!

### Pole-Swapping Algorithms for the Eigenvalue Problem

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

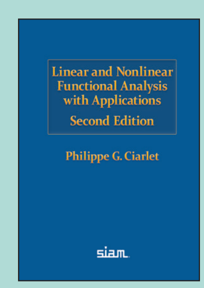



This book focuses on pole-swapping algorithms, a new class of methods that are generalizations of bulge-chasing algorithms and a bit faster and more accurate owing to their inherent flexibility. The pole-swapping theory developed by the authors sheds light on the functioning of the whole class of algorithms, 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 $54.00 / SIAM Member $37.80 / SL07*

### Linear and Nonlinear Functional Analysis with Applications *Second Edition*

Philippe G. Ciarlet

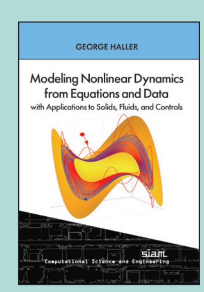



This new, expanded edition covers the fundamentals of linear and nonlinear functional analysis, includes numerous applications, and provides all the basic theorems with complete and detailed proofs. The author has added more than 450 pages of new material, more than 210 problems, and two entirely new chapters, one on locally convex spaces and distribution theory and the other on the Fourier transform and Calderón–Zygmund singular integral operators. The chapter on the "great theorems" of nonlinear functional analysis has been enlarged and split into two chapters.

*2025 / xviii + 1287 pages / Hardcover / 978-1-61197-823-0 / List $114.00 / SIAM Member $102.60 / OT203*

### Modeling Nonlinear Dynamics from Equations and Data with Applications to Solids, Fluids, and Controls

George Haller

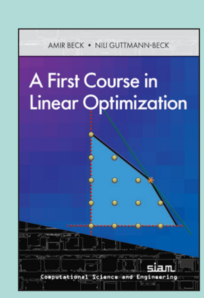



This concise text introduces the emerging area of reducing complex nonlinear differential equations or time-resolved data sets to spectral submanifolds (SSMs). SSMs are ubiquitous low-dimensional attracting invariant manifolds that can be constructed systematically, building on the spectral properties of the linear part of a nonlinear system. SSM-based model reduction has a solid mathematical foundation and hence is guaranteed to deliver accurate and predictive reduced-order models under a precise set of assumptions. This book introduces the foundations of SSM theory to the novice reader; reviews recent extensions of classic SSM results for the advanced reader; and illustrates the power of SSM reduction on a large collection of equation- and data-driven applications in fluid mechanics, solid mechanics, and control.

*2025 / x + 151 pages / Hardcover / 978-1-61197-834-6 / List $62.00 / SIAM Member $43.40 / CS34*

### A First Course in Linear Optimization

Amir Beck and Nili Guttmann-Beck




This self-contained textbook provides the foundations of linear optimization, covering topics in both continuous and discrete linear optimization. It gradually builds the connection between theory, algorithms, and applications so that readers gain a theoretical and algorithmic foundation, familiarity with a variety of applications, and the ability to apply the theory and algorithms to actual problems. To deepen the reader's understanding, the authors provide many applications from diverse areas of applied sciences, and more than 180 exercises.

*2025 / xii + 370 pages / Softcover / 978-1-61197-829-2 / List $74.00 / SIAM Member $51.80 / CS33*

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**Uncertainty Quantification for the Homogeneous Landau–Fokker–Planck Equation via Deterministic Particle Galerkin Methods**
Rafael Bailo, José A. Carrillo, Andrea Medaglia, and Mattia Zanella

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Julian Braun and Maciej Buze

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Zijia Li, Hans-Peter Schröcker, Mikhail Skopenkov, and Daniel F. Scharler

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