Characterizing Musical Sounds with Topological Data Analysis

By Guo-Wei Wei

“Can one hear the shape of a drum?” Mathematician Mark Kac posed this famous question in 1966, and it has intrigued researchers ever since [4]. If you hear the sound of a drum—i.e., the set of overtones that it produces—can you infer its shape? Mathematically, the essence of this spectral geometry question wonders whether one can uniquely determine a shape based on the eigenvalues of the Laplacian operator that is defined on the shape. Many examples of isospectral manifolds are not isometric in settings with two or more dimensions [3]. But the problem is not yet closed, as listeners can indeed discern the shapes of certain geometric types according to their sounds. Kac’s thought-provoking query also impacts a myriad of fields beyond mathematics, including architectural acoustics, audio forensics, pattern recognition, radiology, imaging science, and musical science.

Composers commonly use drum sets with multiple pieces of varying sizes (rather than a single drum) to facilitate a tonic harmonic progression: the foundation of harmony in modern music. Drum sets can train the human brain to distinguish the overtones of individual drums via a comparative training/learning process that teaches listeners to hear the shape of a particular drum from the set. To create tonal harmony, artisans in ancient China built a set of 65 chime bells—known as the Zenghouyi Bells—that date back to between 475 and 433 B.C.E., in the Warring States Period (see Figure 1a). They designed the shape of each chime bell to produce a distinct sound. The 65 bells gradually vary in size and weight, ranging from 153.4 centimeters (60.4 inches) to 20.4 centimeters (8.0 inches) in height and of the speakers shared a collection of resources—including funding pathways for education-focused projects as well as opportunities for pedagogical research—that can help the mathematical community better communicate modeling research to educational audiences.

Karen Yokley (Elon University) and Nicholas Lord (North Carolina Agricultural and Technical State University) began offering a yearly collaborative National Science Foundation (NSF)-funded Research Experiences for Undergraduates (REU) program4 in the summer of 2020. Faculty from Elon and North Carolina A&T have since mentored 10 undergraduates in mathematical biology research projects each summer. This REU is unique because it explicitly provides opportunities for students with little to no research experience. At the JMM23 session, Yokley and Luke addressed both the challenges and benefits of running this program during the COVID-19 pandemic. Although recruiting students for remote participation required significant effort, participants were able to complete successful projects, learn about a wide range of biomathematics programming, and build essential career skills. Yokley and Luke also noted that the students wrote a great deal, developed their communication abilities, and interacted with peers from other institutions and back-grounds to broaden their own perspectives. Many external funding opportunities for young faculty members—including the NSF Computer and Information Science and Engineering Research Initiation...
Recapping the 9th Annual Irish SIAM Student Chapter Conference

By Victoria Sánchez-Muñoz

The University of Galway (UGo) SIAM Student Chapter recently organized the 9th Annual Irish SIAM Student Chapter Conference, which took place at UGo on December 9, 2022. This one-day conference united undergraduate researchers in industrial and applied mathematics throughout Ireland and beyond. The SIAM student chapters in Ireland take turns hosting the event each year; the very first iteration was held at UGo (formerly called the National University of Ireland, Galway) in 2014. Last year’s conference, which returned to Galway for the fifth time, was also the first meeting to commence after Ireland fully lifted COVID-19 restrictions. 43 registered attendees from multiple universities in Ireland partook in the day’s festivities. The agenda included two keynote lectures, seven contributed talks, and five poster presentations.

The first keynote speaker was Stephen Russell, a computer vision research engineer at Valeo Vision Systems (one of the meeting’s sponsors). Russell, who graduated from UGo and was a founding member and the first president of the UGo SIAM Student Chapter, spoke about the role of computer vision and applied mathematics in the development of driver assistance systems. Romina Gaburro of the University of Limerick was the second keynote speaker. She presently serves as Ireland’s country coordinator for European Women in Mathematics, (EMi) and for the International Mathematical Union’s Committee for Women in Mathematics.3

Gaburro’s research explores inverse problems related to topics in analysis and partial differential equations, and her talk introduced the concept of the inverse problem: the mathematical technique behind imaging science and material characterization.

The morning session consisted of Russell’s keynote lecture and contributed talks from Robert Garvey of the University of Limerick and Poyun Jeudy of UGo. The subsequent coffee break, which gave attendees an initial opportunity to peruse the posters, also revealed a hidden icebreaker task. Each person’s name badge included a mathematical expression (e.g., a function, matrix, definition, etc.), and participants had to find the individual with their “inverse” and engage in conversation during future breaks. The overall response to this activity was very positive because it encouraged people to interact outside of their own circles.

After two more contributed talks by Lina Stoppato of the University of Limerick and Khang Er Pang of University College Dublin, attendees played several rounds of a popular game show called Countdown during a brief “Mystery Session.” The contest involves two types of 30-second rounds: a number round and a letter round. During the number round, participants had to use a few given numbers—along with basic math operations—to get as close as possible to a number. During the letter round, players were tasked with creating the longest possible word with a set of predetermined letters. Everyone seemed to enjoy this relaxing and fun opening to the conference.

The afternoon session began with another contributed talk by Sarah Murphy of the University of Limerick and Gaburro’s keynote address. After one last coffee break, Caroline Pena and Niall Donlon—both of the University of Limerick—delivered the final contributed talks. Once the organizers awarded prizes for the best presentation and poster, participants had a chance to network with poster the session. The evening concluded with a fully funded dinner at a local restaurant thanks to support from conference sponsors.

One of the conference’s underlying objectives was sustainability. UGo maintains a sustainability event checklist that implements certain measures. For example, participants were highly encouraged to bring their own mugs and water bottles, return badges for reuse, take public transportation if possible, and book any necessary accommodations via a webpage with sustainable choices. The coffee and tea for breaks had a green certification as well.

To save paper, the conference booklet was only available on the meeting’s webpage and via QR code (printed on recycled paper) during the event.

The UGo SIAM Student Chapter would like to thank all participants for a wonderful conference. We also sincerely appreciate the financial support from SIAM, Valeo Vision Systems, and the Stokes Applied Mathematics Cluster at UGo.

If you are interested in learning more about the UGo SIAM Student Chapter, please contact us at ugsiam@gmail.com or follow us on Twitter at @SIAIMeGalway.

Victoria Sánchez-Muñoz is a Ph.D. student in quantum games in the School of Mathematical and Statistical Sciences at the University of Galway. She is currently the president of the University of Galway SIAM Student Chapter.

3 https://www.mathunion.org/activities/annualirishsiamstudentchapterconference
4 https://www valeo com/en/ireland
5 https://www.factorie.ub.edu/centre s/researchcentres/collegeofscience/stokes-cluster
Navigating the World of Journal Publication as an Early-career Researcher

AN22 Panel Offers Tips for Nascent Journal Authors and Reviewers

By Lina Sorg

Students and postdoctoral/early-career researchers must juggle multiple responsibilities while also taking the appropriate steps to strategically advance their budding careers. One important component of this process is consistent publication in reputable scientific journals. SIAM Journal on Applied Mathematics (SIAM) is one of the most well-respected journals in the field and offers advice to authors who were interested in contributing to journals as authors and/or reviewers.

The panel comprised Howard Elman (University of Maryland), SIAM Vice President for Publications; Mark Ainsworth (Brown University), editor-in-chief of the SIAM Journal on Numerical Analysis (SINUM); Hans De Sterck (University of Waterloo), editor-in-chief of the SIAM Journal on Scientific Computing (SIAMC); and Evelyn Sander (George Mason University), editor-in-chief of the SIAM Journal on Applied Dynamical Systems (SIAMDS).

The panelists spoke about effective writing and submission strategies for prospective authors, specified requirements for publication in SIAM journals, and commented on the review process.

“SIAM is the premier publisher of applied math across the board,” Elman said at the session’s start. “You think you have an interesting, good result, you should think of SIAM.” He encouraged early-career researchers to write with careful intention and consult their advisors throughout the process. “It’s hugely important to write well and state your ideas clearly,” Elman continued. “Not everyone will understand what’s in your head.” Authors must consider their draft’s readability from the perspective of potential readers and present proofs, analyses, results, and visuals—such as graphs, tables, and diagrams—in a way that is easily understandable to the intended audience.

During the SIAM Annual Meeting, which took place in Pittsburgh, Pa., last year, a panel of SIAM publication editors fielded questions from attendees who were interested in learning more about the process of writing and reviewing journal papers. SIAM photo.

Musical Sounds

from page 3

from 203.6 kilograms (448.9 pounds) to 2.4 kilograms (5.3 pounds) in weight. The Zenghouyi Bells comprise a tonal range of 20th-century mathematics. This novel construction in reputable scientific journals. This novel construction

persistent Laplacians, which is not reflected in

Laplacians, which is not reflected in the world’s applied mathematics, computational science, and data science communities.

Note that by persistent Betti numbers and persistent Laplacian of the point cloud.

Persistent Laplacian analysis of the point cloud. Here, $b_i$ and $V_i$ are respectively persistent Betti numbers and the first nonzero eigenvalues of the $i$th persistent Laplacian. Note that $b_i$ captures the homotopic shape evolution of data (see the frequency changes after $a=1.5$), which is not reflected in $f_i$. Figure courtesy of Jian Jiang.

Persistent homology delineates the shape topology that employs filtration to create a topological invariant changes that are induced by filtration [6]. When paired with advanced machine learning and deep learning algorithms, it finds tremendous success in the field of data science. Persistent homology has become one of the most powerful tools for simplifying the geometric complexity and reducing the high dimensionality of biomolecular interactions [5], ultimately realizing data visualization and effectively generating emerging viral variants.

However, persistent homology is not directly applicable to the tonal analysis of chime bells. First, one may regard the collection of chime bells as the result of a set of evolving chime bells manifold, rather than the result of point cloud filtration. Additionally, no change in topological invariants is associated with the homotopic shape evolution of chime bells. Finally, persistent homology cannot present a frequency or tonal analysis of chime bells or many other musical instruments.

Recently, researchers proposed an evolutionary de Rham-Hodge method [1] as a multiscale generalization of the classical de Rham-Hodge theory: a landmark of 20th-century mathematics. This novel technique provides a multiscale geometric and topological analysis of filtration-induced manifolds; using these manifolds, one can define a family of evolutionary Hodge Laplacians on the set of chime bells to characterize their tonal evolution. In association with a family of de Rham complexes, evolutionary Hodge Laplacians reveal the full set of topological invariants of such manifolds—in their kernels null space dimension.

The point cloud counterpart of the evolutionary de Rham-Hodge method, persistent Laplacians both return the full set of topological invariants in their harmonic spectra (as does persistent homology) and capture the homotopic shape evolution of data during filtration in their first non-harmonic spectra (see Figures 2b and 2c); persistent homology cannot handle this latter task.

Sheaf theory created a generalization of persistent Laplacians, and the resulting persistent sheaf Laplacians enable the embedding of heterogeneous characters in topological invariants (e.g., encoding non-geometric information in a geometry-based simplicial complex) [10]. Persistent path Laplacians—another generalization that is built from the path complex—are designed for directed graphs and directed networks [9]. These new persistent topological Laplacians lay a mathematical foundation for tonal analysis in musical science and significantly extend the applicable domain and power of TDA.

References


Guo-Wei Wei is an MSU Foundation Professor at Michigan State University. His research explores the mathematical foundations of biological science and data science.
A Pressure Puzzle: More is Less

Water—treated here as an ideal fluid—flows steadily through a pipe with a narrowing, driven by excess pressure \( p \) in the wider portion. Wishing to increase the flow rate, I widen the wider portion even more (see Figure 1) while maintaining the same excess pressure \( p \) as before. Will this widening achieve the desired result and increase the flow rate? Readers may wish to pause here before reading on.

The answer is the opposite of what one might expect: the flow rate will actually decrease. But how can widening any part of the pipe decrease the flow rate? The resolution of this paradox is that I “forgot” that the driving pressure remains fixed. In an extreme case where the pipe barely narrows, one must push water very quickly to sustain the pressure differential. Therefore, narrowing the wide part increases the flow. In other words, a disparity in thickness increases the resistance because a greater disparity in thickness means a greater change of speed when the water enters a narrower section — and this requires more effort.

Here is a formal proof. By Bernoulli’s law,

\[
\frac{v^2}{2} + p + \rho gh = \frac{v_0^2}{2} + p_0 + \rho g h_0,
\]

where \( p \) is the driving pressure and \( v, v_0 \) are the velocities, as marked in Figure 1. Since the water is incompressible, the volumes that enter and leave per second are equal:

\[
A_0 v_0 = A v,
\]

where \( A, A_0 \) are the cross-sectional areas (larger quantities are denoted by capitals). Substituting \( v = \frac{V}{\sqrt{A}} \) into (1) and solving for \( V \) gives

\[
V^2 = 2p_0 \rho / (1 - \frac{A}{A_0})^2.
\]

Fixing the exit cross-section \( A \) and letting \( A_0 \) yield \( V = \infty \), and so the flux \( V \) rapidly increases while maintaining the same excess pressure \( p \). This confirms the aforementioned intuitive conclusion. Maintaining a fixed \( p \) as \( A_0 \) increases huge flux. At the other extreme, widening the supply pipe (\( A_0 \to \infty \)) while still fixing the exit \( A \) leads to a saturation limit for the flux \( V, \) since \( A_0 \) is fixed and

\[
V^2 = 2p \rho / a^2.
\]

according to (2). What does all of this have to do with the well-known fact that water shoots out of a hole in the side of a barrel with velocity \( V \) depending only on the depth of the hole:

\[
V = \sqrt{2gh},
\]

where \( h \) is the depth? One can think of a hole in the barrel as a narrowing in a pipe where the driving pressure is hydrostatic, generated by the water column above the level of the hole and given by \( p = \rho gh \). According to (3), \( V = \sqrt{2gh} \) substituting \( p = \rho gh \) indeed yields \( V = \sqrt{2gh} \). Incidentally, this is precisely the velocity that a free-falling drop (released from rest) would gain after distance \( h \).

The idea of the previous sentence provides an alternative and immediate derivation of \( V = \sqrt{2gh} \) for the velocity of the water that is shooting out of the hole in the barrel.

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**Figure 1.** Does widening the supply pipe tend to fail? While maintaining the same pressure increase the flow of water? Pressure excess \( p \) at the wider part over that in the narrower part is the same in both cases. Figure courtesy of Mark Levi.

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**Education and Research**

Continued from page 1

Initiative and the Faculty Early Career Development Program (CAREER)—require proposals that integrate research and education. This stipulation is often difficult for applicants, who may need to fall back on standard boilerplate content. During JMM23, Christopher Musco (New York University) described his experience creating an education plan for a CAREER proposal that combined his personal research in theoretical computer science with his teaching responsibilities.

This information was particularly pertinent for early-career researchers and highlighted the importance of innovative statements in both scholarship and education. Musco—who is actively involved with MathWorks Math Modeling Challenge, a program of SIAM—also emphasized the urgent need for collaborative grant writing between postdoctoral scholars and faculty members, as projects will directly benefit scholars when they eventually become faculty members themselves.

Next, Michail Bezroukov (Emory-Riddle Aeronautical University) detailed his success in growing a course called “Research Projects in Industrial Mathematics”—initiated by Preparation for Industrial Careers in Mathematical Sciences (PIC Math)—into an annual program that effectively matches students with industrial partners. Bezroukov acknowledged the challenge of identifying willing partners in industry; in fact, he found many of them through cold calls or conversations in unusual settings, such as the grocery store. He also reflected on the program’s numerous benefits. For example, involved companies receive “free” analysis of a pertinent real-world problem, and students gain invaluable skills and hands-on experience in industrial settings—many even receive job offers from the organizations with which they collaborate. Most impressive was the diversity of the course’s participants; over half of the students identify as female and more than 80 percent come from historically underrepresented groups.

Adewale Adeola and Ben Galluzzo (both of Clarkson University) focus their research on mathematics education and its connections to real-world problem-solving. During their presentation, they overviewed their current efforts to develop a novel technology called M2Studio that helps secondary students learn mathematical modeling. M2Studio provides affordances that support users’ understanding of math modeling, such as dynamically linked representations. Adeola and Galluzzo shared findings from a qualitative study with three high school students who engaged in mathematical modeling activities with M2Studio. The study revealed that students used feedback from dynamically linked representations to adjust their models. M2Studio also serves as a cognitive tool that encourages students to perform unit analysis, name and relate variables, and identify connections between variables with mathematical operations.

The final component of SIAM’s education-based JMM23 session was a panel that focused on the challenges and benefits of integrating research and teaching. Kathleen Kavanagh (Clarkson University) moderated the panel, which consisted of three mathematicians: Wesley Hamilton (MathWorks), Rebecca Hardenbrook (University of Utah), and Tosin Babasola (University of Bath).

All of the panelists share a passion for blending research with teaching and engaging students with the relevance of mathematics in critical environmental issues. As the speakers recounted stories of student achievement, it was apparent that they found these activities just as rewarding as their students. For instance, Babasola motivated classroom interest in climate change by asking “What is chocolate, and where does it come from?”, which helped students personally connect to the problems at hand. The panelists endorsed a wide range of software tools that engage students with mathematics, including MATLAB, GeoGebra, and the Common Online Data Analysis Platform (CODAP).

Ultimately, the JMM23 session demonstrated that the applied mathematics and computational science communities need more opportunities to exchange resources, case studies, and relevant findings to better combine research and classroom experiences and subsequently broaden the impact of this integration.

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**About the Authors**

Adewale Adeola is a National Science Foundation-funded postdoctoral researcher in the Institute for STEM Education at Clarkson University. Ben Galluzzo is an associate professor of mathematics at Clarkson University. Kathleen Kavanagh is a professor of mathematics at Clarkson University and the Vice President for Education at SIAM.
Journal Publication

Continued from page 3

and value in the context of the existing literature. Because journal submissions are on the rise and acceptance is competi- tive, research editors—SIAM and other- wise—pay particular attention to novelty statements. "It’s important to express why you think an idea is meaningful and how it connects to what is already available in the literature," De Sterck said.

When crafting the abstract and introduc- tion, researchers should also think about their topic’s relevance to the journal in question in order to convince editors that the paper is a good fit. "If you decide to submit to a SIAM journal, make sure that you’re submitting to the right journal," Sander said. For example, a dynamical systems article that does not emphasize applications is not appropriate for SIADS and might instead be better suited for a non-SIAM journal.

Ainsworth disclosed that most of the papers he rejects for SINUM are denied because authors neglected to follow the editorial guidelines. "Pay attention to the basics," he said. "Make sure that you’re fulfilling the criteria and your paper is formatted with the right typeset- ting package. This applies to experienced researchers as well."

To make a submission even more com- pelling, authors can suggest referees, associate editors, and reviewers who are well-qualified to handle the abstract. "This shows that you’ve investigated the jour- nal, gives the editor an idea of how to review the paper, and demonstrates that you see where the paper might fit within the editorial board," Sander said. De Sterck urged writers to recommend at least one associate editor for their papers, noting that the suggested individual(s) should ideally be well-established in their careers and experts with the material at hand.

When attendees asked the editors how they typically distribute papers to their editorial boards, De Sterck revealed that he keeps a file on hand with keywords that per- tain to all of the associate editors at SIAM, which helps him determine the ideal can- didates for the job. Meanwhile, Ainsworth simply sends papers to associate editors who are familiar with the topic. "I make sure it goes to someone who really knows the field and can choose the right reviewers," he said, commenting that he disliked receiving papers in unfamiliar areas when he was an associate editor because he had difficulty evaluating them.

Next, conversation turned to the nuances of the review process. "Reviewing a paper is a weighty responsibility," Elman said. "You want to make the right judgment and be critical but fair." Reviewers must assess the content’s accuracy and determine whether the paper is suitable for and fits the standards of the journal to which it was submitted. Peer-reviewed articles carry a certain level of prestige, and Elman encour- aged reviewers to take their duties seriously. "It’s free labor on your part, but it’s part of being in the community," he said. "Read papers that you think are interesting; give your best shot at a review; and if you think something is wrong, say so."

Ainsworth echoed Elman’s remarks about reviewing as a community duty. "You want people to review your papers, so if someone asks you to review a paper, you should do it unless you have a very good reason not to," he said. "It’s part of being a good citizen. If someone sends me a paper and I know I’m the right person to do it, I’ll agree even if I’m busy," Ainsworth added. If a solicited individual must turn down a review request, they should suggest other possible reviewers rather than simply rejecting the invitation.

Sander pointed out that reviewing anoth- er researcher’s paper can even benefit one’s own career advancement. "If it’s the right paper for you, you should be read- ing to that level anyway and helping to shape it," she said. But she also cautioned against agreeing to serve as a reviewer and failing to follow through, as doing so only delays the publication process and hurts the author. "Being responsible for when you say ‘yes’ is a very important part of the process," Sander said.

While the average time to a first deci- sion for SIAM journals is four months, individual journals may vary widely. If one has not received a decision six to eight months after initial submission, it is perfectly acceptable to follow up with a request for information. Additionally, all four panels discussed that publishing pre- prints to arXiv is worthwhile in terms of both the citations and the exposure.

Ultimately, the panels encouraged all audience members to submit their research to SIAM journals, regardless of career stage or experience level. "SIAM publishes very high-level journals, but don’t feel that you’re not good enough," Ainsworth said. "Talk to people, get advice, but don’t rule it out without trying."

Lina Sorg is the managing editor of SIAM News.

Announcing the SIAM-Simons Undergraduate Summer Research Program

SIAM is delighted to announce the establishment of the SIAM-Simons Undergraduate Summer Research Program. Through support from the Simons Foundation, new applied mathematics and computational science program will provide research, networking, and mentorship opportunities to U.S. students from underrepresented groups — thus allowing the SIAM community to play a strong role in developing, expanding, and diversifying the next generation of researchers and practitioners.

"We are proud to partner with the Simons Foundation over the next five years in our shared efforts to broaden participation and engagement in the mathematical and compu- tational sciences," Suzanne Weekes, Executive Director of SIAM, said. "We continue to work towards the reality of a more robust, diverse, and inclusive STEM community. At SIAM, we are deeply committed to this work, and we are thankful for the Simons Foundation’s investment in our efforts."

Each year, the SIAM-Simons Undergraduate Summer Research Program will establish five sites across the U.S. for a six-week program of research and learning in applied mathematics and computational science. One faculty mentor and two students will work together at each site for these six weeks. Students will learn how to con- duct scientific research, effectively commu- nicate mathematics and computational science principles, and gain an improved understanding of careers in applied math- ematics and computational science. The summers and mentors from each site will also come together via video conference to present their work, participate in profes- sional development activities, and engage in community-building initiatives.

To apply, students must submit a writ- ten statement regarding their interest in the program, their college transcripts, and letters of recommendation. Expenses for lodging, meals, and travel will be covered by the program, and accepted applicants will receive a weekly stipend. They will also visit the Flatiron Institute in New York City and attend the SIAM Annual Meeting the year after their summer research expe- rience to present their work. Faculty mentors—selected from SIAM’s highly qualified member base—will work closely with student participants and SIAM and receive a stipend for their involvement.

"It is deeply important that the identities of scientists and mathematicians reflect the diverse world we inhabit," David Spergel, president of the Simons Foundation, said. "The Simons Foundation is proud to partner with SIAM to diversify the next generation of researchers and practitioners in applied mathematics and computational science."

Read more about the program in the full online announcement. Applications will be reviewed on a rolling basis beginning on March 6 until all spots are filled. SIAM is incredibly grateful to the Simons Foundation for funding this important new program; for more information, please visit the website.

1 https://www.simonsfoundation.org
2 https://www.surveymonkey.com/r/SSUSRP_2023
3 https://www.siam.org/Details/Page/siam-establishes-the-siam-simons-undergraduate-summer-research-program
4 https://www.siam.org/simons

4 https://www.sieves.org}

A panel at the 2022 SIAM Annual Meeting, which took place in Pittsburgh, Pa., last year, addressed various aspects of the writing and review process for journal papers. From left to right: Hans De Sterck (University of Waterloo), Howard Elman (University of Maryland), Evelyn Sander (George Mason University), and Mark Ainsworth (Brown University) offer advice to students and early-career researchers in the audience. SIAM photo.
Self-Promotion and Advocacy Provide Industry With the Mathematicians That It Needs

By Derek Kane

I have spent 22 years at DEKA Research and Development, a company that uses science and engineering to measurably improve people’s lives. The corporation has worked on projects that relate to clean water, mobility for individuals who rely on wheelchairs, prosthetics, and regenerative medicine. During my time with DEKA, I have hired four mathematicians—all of whom have been exceptional. The first was an undergraduate student at Brown University who employed random forests to solve a particularly knotty problem that utilized diagnostic test data to improve predictions of energy-embodied data allowed us to create a test for which physicians previously had to rely on conflicting and non-specific data.

The second mathematician was a summer intern from Worcester Polytechnic Institute who developed the signal processing algorithm for a tabletop magnetic resonance imaging (MRI) demonstrator. He later secured a permanent position at DEKA and spent his time investigating closed-loop physiological control, image processing, and medical safety systems. With no experience writing embedded code, this individual succeeded admirably on each task.

After completing his undergraduate degree at Northeastern University, my third mathematician joined our delivery robot program’s path planning team and investigated optimal robot routing. Although he had never before written embedded code in C, his grasp of path planning’s fundamental elements, ability to clearly explain ideas, and desire to solve problems led to his success. This employee quickly mastered the necessary programming skills and now leads the path planning team.

The most recent mathematician that I hired holds a Ph.D. from the University of Michigan. She has made fundamental improvements to our analysis of test data—despite having no prior experience in this area—and delivered a talk earlier this year to describe her methods to the test group. She also reexamined and improved DEKA’s application of Kalman filters to a medical sensing system, considered alternative predictive filters, and investigated model predictive control for a physiological device. Most recently, she thoroughly explored the physics of diffusion and how to best align experimental results with the governing equations, again explaining her results in a company-wide talk.

These mathematicians possess remarkable flexibility when approaching and understanding complex problems. Their solutions are unique, and they are not afraid to seek answers in disciplines that are not traditionally associated with the problem in question. Furthermore, the level of rigor that they apply to their work is vital for success—certainly in medical products but also in any industry where resources are limited, customers are demanding, or failure is disastrous. Another valuable quality among mathematicians is their absolute fearlessness when facing new challenging endeavors. Graduate study certainly equips mathematicians with the confidence that they can eventually solve a problem by studying it and examining previous work. I believe that these traits are not exclusive to the mathematicians with whom I have been fortunate to work, but instead are fundamental elements of how mathematicians are taught to think.

Given these sterling qualities, why don’t companies hire more mathematicians? In my opinion, mathematicians’ fatal flaw is their fearlessness. Although mathematicians are one of the rare businesses that does not depend on the automated scanning of resumes, instead, our recruiters send me the resumes of mathematicians and other applicants with odd but interesting backgrounds. Because I am a mathematician myself, I can appreciate the value of these individuals. But their resumes are typically sparse, often providing only a thesis title and maybe a list of classes that they’ve taught.

Most businesses scan resumes for keywords that indicate an applicant’s compatibility with some job descriptions. It is thus essential that candidates carefully read the job description and echo its wording. Early-career mathematicians should also learn to appreciate and articulate the way in which their academic background allows them to contribute to the target areas. As a discipline, we must ensure that new mathematicians understand the question: do these drive other fields and recognize their own capability to answer those questions. Mathematicians are trained in the fundamental models of every discipline; they have either explicitly studied these models or possess the necessary tools to comprehend them upon further examination. If a student is interested in water desalination, for example, they will be able to contribute to this subject if they have worked on differential equations, dynamical systems, manifolds, measure theory, Banach spaces, and so forth. These same areas of study will also serve them well in finance, network analysis, remote sensing, computing, and robotics. Any industry that relies on technology (they all do) or analysis (all of the interest in these ones will do) will ultimately want a mathematical model of its particular problem.

In addition to establishing a solid grounding in mathematics, we should insist that some element of coursework or programming translate one’s expertise into company value. Programming on a resume also provides easy justification for hiring, since organizations always need people who write code. If an applicant’s background is purely in theoretical methods or another clearly software-oriented discipline, they should mention all of their relevant skills: system administration, low-level programming, code optimization, etc. Combinators should note all of the applications with which they have worked (i.e., optimization, linear programming, and graph theory) and understand their discipline’s relevance to machine learning, logistics, planning, and the like.

Because all programming is fundamentally the same, the particular tools are largely unimportant. If a mathematician knows how to program in Python or R, that knowledge—plus their understanding of algorithms and the structure of problem solutions—will allow them to quickly master new domains.

Among other projects, DEKA Research and Development works to improve mobility for individuals who use wheelchairs. DEKA and other industry-based companies around the world need mathematicians to help solve society’s most important and difficult problems. Photo courtesy of DEKA Research and Development.

CAREERS IN MATHEMATICAL SCIENCES

MEMBERS OF THE SIAM COMMUNITY ELECTED AS 2022 AAAS Fellows

On October 22, 2022, the American Association for the Advancement of Science (AAAS) elected more than 500 of its members as AAAS Fellows. These individuals were selected based on their outstanding efforts to better serve society through the advancement of science and its applications. They collectively represent the 24 distinct disciplines of AAAS—including categories like Mathematics; Physics; Engineering; and Information, Computing, and Communication—and are honored for their successes in research, technology, teaching and academic administration, industry and government, and/or science communication. Eligible nominees must be AAAS members for at least four continuous years prior to nomination.

The 2022 AAAS Fellows include the following members of the SIAM community:

• Linda M. Abrego, Brown University
• Trudy J. Tarpey, Georgia Institute of Technology, University of California, Irvine
• Lise Getoor, University of California, Santa Cruz
• Abba B. Gumel, University of Maryland, College Park
• Brendan Hassett, Brown University
• Hans G. Kaper, Georgetown University (editor-in-chief of SIAM News)
• Irena Lasiecka, University of Memphis
• Lorenzo M. Polvani, Columbia University
• Purnamrahman, Vanderbilt University
• Pengyu Ren, The University of Texas at Austin
• Robert Rosen, University of Chicago
• Talitha M. Washington, Clark Atlanta University (Clark Atlanta University Center for Mathematics and Computer Science)
• Mohamed J. Zaki, Rensselaer Polytechnic Institute

Congratulations to these individuals on their extraordinary achievement. The class of 2022 Fellows will be acknowledged during the Fellows Forum at the 2023 AAAS Annual Meeting, which will take place in Washington, D.C., in early March.

A full list of all new AAAS Fellows is available online. Visit the webpages for more information about the AAAS Fellows program.

Introducing the SIAM Transformation Society

Over the years, SIAM has benefitted from the generous support of its members—both through gifts that they make during their lifetimes and via their estate plans. Estate gifts are especially important to SIAM because they help the Society look to the future, plan ahead, and prepare to address any unexpected challenges that may arise. Estate gifts allow many of our members to leave a lasting legacy of which they can be proud.

Because estate gifts are so important, we want to especially thank, recognize, and highlight SIAM members who have already graciously included SIAM in their estate plans. To those of you who have created the SIAM Transformation Society: a recognition society for SIAM’s estate gift donors. Transformation Society members will receive periodic updates on the impact of planned giving at SIAM, opportunities to connect with their peers who have similarly dedicated a portion of their estate to SIAM, and special recognition through a variety of channel. Members will also receive a commemorative gift when they join.

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• Through a bequest
• With a gift of real estate or other personal property
• By making SIAM the beneficiary of a life insurance policy or retirement account
• By making a gift that utilizes the Required Minimum Distribution (RMD) from their IRA or similar retirement account

Please contact Abby Addy, SIAM’s Director of Development and Corporate Relations, at am@siam.org or (267) 648-3535 if you haven’t done any of the above, or if you have questions about the Transformation Society.

We look forward to recognizing your philanthropy and thank you for your continued membership and support.
Musings on Mathematics in Mid-20th-century America


As author Alma Steingart writes in the book’s introduction, Axioms: Mathematical Thought and High Modernism is not a history of mathematics. The book contains practically no theorems, proofs, calculations, or conjectures; and despite the title, there are very few axioms. It does include capsule biographies of many mathematicians—which describe how they studied, got hired, taught, wrote textbooks and reports, gave keynote talks on methodology, and raised funds—but there are no accounts of them actually doing mathematics (or any details about their personal lives). Rather, Axioms is a history of “mathematical thought”—that is, thoughts about mathematics—primarily by American mathematicians but also by social scientists, physicists, historians, and others.

The text’s six chapters and epilogue comprise seven loosely connected essays, each of which addresses a different aspect of mathematical thought. Though the titular subject of axioms is a recurrent theme, it is only central in two or three of the essays; meanwhile, the subject of high modernism merely makes an occasional appearance.

Chapter 1 offers a history of frameworks for algebraic topology between 1930 and 1960 and documents its progression through different ideas and forms. Abstraction, illustrated largely by the career of Norman Steenrod. Steenrod studied first set-point topology with Raymond Lous Wilder, a student of Robert Lee Moore; his notes and letters from that period are full of carefully drawn geometric diagrams. He then went to Princeton University to work with Solomon Lefschetz, the leading figure in the development of algebraic topology. Lefschetz penned Algebraic Topology, which does not contain a single diagram, in 1942. George David Birkhoff described the text as “a culmination of the culture of algebraic topology.”

In 1945, Samuel Eilenberg and Saunders Mac Lane introduced category theory as a unifying framework for a wide range of algebraic and geometric theories. Seven years later, Eilenberg and Steenrod published Foundations of Algebraic Topology, which begins with a purely algebraic axiomatization and only later comments on the geometric interpretation. At each stage of topology’s development, some members of the older generations found themselves somewhat resentful of the new approaches. Steingart identifies “high modernism” in mathematics as this unending process of constant revising, restructuring, and recasting.

Chapters 2 and 3 discuss how researchers came to view mathematical abstractions generally and axiomatization specifically as powerful analytic tools across a wide range of fields—including the increasingly abstract mathematics in 20th-century physics, Kenneth Arrow’s axiomatization of social choice theory, and Oskar Morgenstern and John von Neumann’s development of game theory.

Some of these topics are more axiomatic in style than in actual content. For instance, Steingart quotes the following description from a chapter entitled “Choosing an Appropriate Axioms” in Yonna Friedman’s 1975 book, Toward a Scientific Architecture:

The work of architects and planners produces enclosures — separations in space. A separation in space (an enclosure) cannot be the work of architects and planners if it does not have at least one access.

In a system of spatial separations, there must be at least one enclosure that differs from the others in some respect, whether as a result of physical qualities or of others.

These are certainly not axioms in the sense that Euclid or Hilbert used the term.

Chapter 4 describes a vogue among mathematicians in the 1940s and 1950s for describing mathematics as axioms to abstract art; at the time, abstract expressionism in painting was practiced by artists like Jackson Pollock and heralded by critics like Clement Greenberg—was the last word in the avant-garde. Steingart notes that math’s association with art served a number of purposes. It was an easy (if not particularly accurate) way of explaining pure math research outside of lay people, it justified pure math research outside of applications, it allowed pure math to separate itself from its association with the military-industrial complex, and it promoted a Cold War vision of American intellectuels as individualists who carved their own paths. Many mathematicians discussed the comparison, although some—like von Neumann—were opposed to it. The discourse reached an apex in a 1951 speech entitled “Mathematics and the Arts” by topologist Marston Morse, which included this impassioned cri de cœur:

Often, as I listen to students as they discuss art and science, I am startled to see that the science they speak of and the world of science in which I live are different things. The science that they speak of is the science of cold newpov, the ceteris-marked logical core, the page that dares not be wrong, the monstrosity of machines, grotesque deflections of men who have hoped God, the small pieces of temples whose glass have been lost and are not desired, hubs for power by the bithe of power secretly held and not understood. It is science without its perspectiva or its radiation, science after birth, without intimation of immortality.

The creative scientist lives in the wildness of logic where reason is the handmaiden and not the master. I shun all monuments that are held and not understood. It is science without the stability of mathematics over the millennia! Whereas the earlier chapters of Axioms are almost purely descriptive, Steingart explicitly shares her own opinions in this section; the phrase “I think” appears more than once. She contends that the issue—which is still not resolved—is not primarily a historical problem, but rather a problem with the conceptualization of mathematics itself. Through the Platonic view of mathematics is intellectually unsustainable and historically naive, there is not yet a coherent alternative.

The book concludes with a short epilogue that describes mathematicians’ retreat from abstraction and re-engagement with the concrete through activities like Thomas Banchoff and Charles Strauss’ work with computer graphics. To a marked degree, Axioms is a history of institutions: universities, committees, professional organizations, and government agencies. Chapter 1 opens with the 1950 decision by Harvard University’s Department of Mathematics to give a faculty appointment to Claude Chevalley, an algebraist with an abstract approach, rather than Arne Beurling, an analyst who used classical techniques for classical problems. Steingart provides long, detailed accounts of reports, white papers, keynote addresses, and efforts to lobby government funding agencies.

The scope of Axioms is limited in a number of dimensions. The focus is strictly American; Steingart acknowledges some French members of Bourbaki but ignores almost all British, Russian, or other European mathematicians later than Hilbert. In fact, Harvard, Princeton, and the Institute for Advanced Study are much more present than the rest of U.S. academia combined. G.H. Hardy’s A Mathematician’s Apology, the best-known defense of pure mathematics, is omitted. In terms of mathematical fields, Steingart barely discusses mathematical logic—the area that deals most directly with axiomatics. She mentions analysis, number theory, and probability theory even less, and most of the pure mathematicians that appear are algebraists or topologists. The fraught issue of grade-school math education is ignored; the omission of the “New Math” of the 1960s, a famous overreach by the mathematici cal establishment, is particularly striking.

Yet within its scope, Axioms is a groundbreaking accomplishment and a major contribution to the history of mathematics in the 20th century. The extent and care of its research and the depth of its analysis are truly impressive.
SIAM Texas-Louisiana Section Successfully Hosts 5th Annual Meeting

By Yifei Lou

The SIAM Texas-Louisiana (TX-LA) Section1 held its 5th Annual Meeting2 (TXLA22) in Houston, Texas, from November 4-6, 2022. The Department of Mathematics at the University of Houston (UH) hosted the conference,3 which attracted 348 attendees; this record-breaking turnout demonstrates the tremendous growth of the SIAM TX-LA Section. SIAM provided travel support for the plenary speakers, 29 travel awards for undergraduate and graduate students, and care packages for the two keynote speakers.

The three-day conference agenda included a career panel, a hands-on tutorial on data-driven full waveform inversion, four plenary lectures, two poster sessions, and more than 60 minisymposia blocks (each with up to four talks). Presenters reported on cutting-edge methodologies and computational algorithms—such as model order reduction, algebraic geometry, and scientific machine learning—for a wide spectrum of applications that ranged from the geosciences and biomedicine to hydrodynamics, optics, and fluids.

The first special event was a career panel that featured Delzel Holh (Shell), Yousuo Lin (Los Alamos National Laboratory), Rami Nammour (TotalEnergies), Annalisa Quaini (University of Houston), and Carol Woodward (Lawrence Livermore National Laboratory). The panel drew over 50 attendees and stimulated a series of interesting questions and answers between the panelists and the audience.

Two of the career panels also delivered plenary lectures; Holh spoke about deep learning approaches for context-based image retrieval of industrial materials, and Woodward provided an overview of time integration methods and software for scientific simulations. The other two plenary lectures were Karen Willcox (University of Texas at Austin) and Minh-Binh Tran (Texas A&M University). Willcox’s talk pertained to digital twins with applications in aircraft and cancer treatment, while Tran reported on recent advances in wave turbulence theory. All of the plenary lectures were well attended.

TXLA22 boosted two poster sessions to accommodate nearly 80 submissions. The contributed posters covered a wide variety of topics, including computational neural networks, nematic liquid crystals, evi-

tion, and even Sudoku puzzles. Mohammad Shah Alam (University of Houston) presented the winning poster in the graduate category, while Gavin McIntosh (Tarleton State University) won the undergraduate award. Both students received cash prizes for their excellent posters.

For the first time at a TX-LA annual meeting, the SIAM TX-LA Section organized a mentoring lunch to complement the career panel. While the panel offered useful career advice on a more general scale, the one-on-one meetings between senior researchers and students centered more on personal and individualistic topics. The 34 registered graduate students and postdoctoral researchers (the protégés) were matched with 39 participating mentors based on factors like research area, career stage, and general interests. A post-event survey found that roughly 90 percent of participants would recommend this program to colleagues and friends, while more than 93 percent would participate again in the future.

The TXLA22 Organizing Committee comprised a local UH group, the SIAM TX-LA Section officers, and the section’s district liaisons. The UH Organizing Committee was chaired by William Ott and included Lolic Cappanera, Gabriela Jaramillo, Alexander Mamonov, Andreas Mang, Maxim Olihanskii, and Annalisa Quaini. Attendees praised the conference’s vibrant scientific programming and strong student presence in the poster sessions, career panel audience, and mentorship lunch. Its success has inspired the section officers and liaisons to begin planning the first TX LA Annual Meeting, which will take place at the University of Louisiana at Lafayette sometime this year4!

Yifei Lou is an associate professor in the Department of Mathematical Sciences at the University of Texas at Dallas. She currently serves as secretary of the SIAM Texas-Louisiana Section.

1 https://www.siam.org/membership/ sections/detail/siam-texas-louisiana-section-siam-tx-la
2 https://www.siam.org/conferences/cm/conference/edul22
3 https://www.math.uh.edu/siamtxla22

The career panel at the 5th Annual Meeting of the SIAM Texas-Louisiana Section, which took place in Houston, Texas, in November 2022, featured five individuals from academia, industry, and governmental laboratories. From left to right: Mohammad Shah Alam (Los Alamos National Laboratory), Carol Woodward (Lawrence Livermore National Laboratory), Detahl Holh (Shell), Annalisa Quaini (University of Houston), and Rami Nammour (TotalEnergies). Photo courtesy of Yifei Lou.

Industry

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any tool that an employer wants to use. But if one is going to pick up a language, I would recommend Python; its libraries allow the use of its tools, functions already exist for almost any problem of interest, and it’s free.

However, resumes and skillsets comprise only a small fraction of the job-hunting process. Hiring managers want to know that prospective employees will do useful work, and do this work quickly. As such, successful industry experience is the most convincing evidence of one’s utility.

The simplest way to obtain a permanent position at DEKA is via an internship. Interns are relatively easy to hire because they don’t entail the same commitment as full-time employees. Once someone demonstrates strong capability as an intern, hiring after graduation is straightforward. Even if an intern ultimately chooses to seek employment elsewhere, their internship experience offers proof of practical skills and constitutes a ready-made conversation topic for career interviews.

SIAM and other mathematical societies encourage student collaboration with industry through a variety of programs that afford many of the same benefits as internships. I have had the opportunity to participate in SIAM and the Mathematical Association of America’s Preparation for Industrial Careers in Mathematical Sciences (PIC Math) program,5 as well as SIAM’s Mathematical Problems in Industry (MPI) Workshop.6 I was greatly impressed by MPI, as participants were actually able to render an answer of real value in a very short time.

There is plenty of room for professional societies to work with other institutions and ease early-career mathematicians into industry. For instance, a number of industrial organizations—including IRE, the International Society for Optics and Photonics, and SAE International—could help promote the value of mathematicians to their member companies; each company looks for creative people who can respond to novel problems and capitalize on new opportunities. Similarly, human resources associations might have ideas about how to best prepare mathematicians for a variety of positions.

SIAM’s industrial outreach and collaboration is invaluable. Nevertheless, strengthening the capacity of mathematicians in industry also requires considerable effort on the industrial side, with support from strong math advocates and participation in recruitment programs. Companies in such programs likely hope for two things: answers to real problems that provide company value, and access to high-quality candidates for employment. We must find ways to advocate the benefits of mathematicians to companies that have never worked directly with mathematicians.

I have profited tremendously from my own mathematics education, as well as the knowledge and skill of the mathematicians with whom I have been privileged to collaborate. Companies need mathematicians to solve society’s biggest challenges. We must work to ensure that mathematicians have the chance to contribute their capable expertise to critical real-world scenarios.

Derek Kane is a mathematician who has worked at DEKA Research and Development since 2000. He received a B.S. in Mathematics from the University of Michigan in 1996, for which he studied cohomology of division algebras over p-adic fields.

During the 38th Annual Mathematical Problems in Industry (MPI) Workshop, which took place at Worcester Polytechnic Institute in June 2022, graduate student Kathryn Johnston of the University of Washington (left) worked with Darek Kane to address real-world research and design problems that were posed by industrial representatives. Participation in industry/academic collaborations like MPI significantly improves one’s chances of being noticed by a prospective employer. Photo courtesy of David Edwards.

1 https://www.siam.org/membership/ sections/detail/siam-texas-louisiana-section-siam-tx-la
2 https://www.siam.org/conferences/cm/conference/edul22
3 https://www.math.uh.edu/siamtxla22/committee.shtml
4 https://www.siam.org/programs-and-communities/professional-development/pic-math
5 https://www.siam.org/students-education/ programs-initiatives/mathematical-problems-in-industry-workshop