SIMONS LAUFER
MATHEMATICAL
SCIENCES INSTITUTE

17 Gauss Way

FALL 2023

SLMATH.ORG

Welcome!

... to 17 Gauss Way, the home address of SLMath and the new name for the Emissary!

IN THIS ISSUE

SLMATH | # 17 Gauss Way

FALL 2023

For a list of Forthcoming Workshops & Summer Activities, please visit the web edition at slmath.org/newsletter-archive.

On the Cover: Summer Research in Mathematics participants (from left to right) Fang-Ting Tu, Angelica Babei, Bella Tobin, Manami Roy, and Holly Swisher in the Hearst Library at SLMath. (Photo: Amira Maxwell Photography)

Below: Young mathematicians read Mathical books at the Brooklyn Center Middle & Senior High School (see page 10).

Questions and comments regarding *17 Gauss Way* should be directed to **newsletter@slmath.org**

The newsletter archive is available online at **slmath.org/newsletter-archive**

To receive monthly updates on Institute events, videos, and other news by email, subscribe to SLMath eNews at **slmath.org/email-news**

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DEPUTY DIRECTOR, SLMATH
Hélène Barcelo

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Joe Buhler
Tanya Khovanova

Please notify us of your change of address. Send changes to **communications@slmath.org**

SLMath, formerly MSRI, has been supported from its origins by the National Science Foundation, joined by the National Security Agency, over 100 Academic Sponsor Institutions, a range of private foundations, and generous and farsighted individuals.

DIRECTOR'S

Update

Tatiana Toro, Director

Coming full circle: MSRI-UP alum Talea Mayo (Emory University) shares her research with students at a MAY-UP 2023 colloquium in Atlanta. (Photo: Duane Cooper)

As I reflect upon last year and consider the future, I have come to appreciate how, at SLMath, new ideas come to fruition as successful activities and initiatives. The Institute's unique dynamism ensures a bright future, and I am optimistic about what we will accomplish together.

Fostering and Communicating Mathematical Research — In All Areas

Generously supported by the Alfred P. Sloan Foundation, the fall 2023 programs in *Algorithms, Fairness, and Equity* and *Mathematics and Computer Science of Market and Mechanism Design* are in full swing, bringing a lively energy to the building once again. These interdisciplinary programs demonstrate the impact of new developments in mathematics in computer science and the social sciences and reflect SLMath's commitment to fostering and communicating mathematical research in a broad range of fundamental topics and applications. Real world problems impacted by the work in these programs include, among many others, complex resource allocation problems, machine learning algorithms, and partitioning problems relevant to recent U.S. Supreme Court decisions regarding political districting.

Developing Talent and Cultivating Belonging & Engagement — At Every Level

Through our Summer Graduate Schools (SGS), we affirm our commitment to our Academic Sponsors. In 2023, SLMath was pleased to host 11 schools, taking place in California, Indiana, Canada, Germany, and Switzerland. Deputy Director Hélène Barcelo highlights our Summer 2023 activities on page 11.

Inspired by MSRI–UP, SLMath has piloted a new program for undergraduates, which was held in May in Atlanta, GA at Georgia State University; it is appropriately named MAY–UP: Mathematically Advancing Young Undergraduates Program. Under the supervision of Duane Cooper (Morehouse College) and research leader Shelby Wilson (Johns Hopkins Applied Physics Laboratory), 12 rising college sophomores explored linear algebra and Python programming in the 2023 program. You can learn more about MAY-UP in this short video featuring 2023 participants discussing their experience: vimeo.com/846755162.

Inspiring Appreciation for Mathematics — By Everyone

The Mathical Books program identifies, promotes, and distributes math-inspiring children's literature as widely as possible and specifically to children from underserved backgrounds. We partner with leading organizations to share Mathical's list of recommended books with children, families, and classrooms and seek to improve access to high quality, math-themed fiction and nonfiction for children in Title I schools throughout the U.S.

Through this program, we are proud to facilitate the distribution of free books. In 2022–23, 2,400+ Mathical Books were distributed in the Bay Area with the assistance of ParentChild+; 32 Title I School Libraries received Mathical Book Prize Collection Development Awards; and, a total of 20 Title I schools, selected by the National Council of Teachers of English (NCTE) and the National Council of Teachers of Mathematics (NCTM), received grants to purchase Mathical books for their classrooms. You can read more about the first ten years of Mathical on page 10.

We are thrilled to announce the upcoming release of our newest mathematical documentary film, in partnership with director George Csicsery (Zala Films). It is the first installment of a two-part film, *Journeys of Black Mathematicians* (see page 18). The film will premiere at the 2024 Joint Mathematics Meetings held in San Francisco in January. All are invited to attend the film screening and panel discussion, in partnership with the National Association of Mathematicians (NAM).

Thank You to the Community

Today, SLMath stands on a solid base, constructed by the Institute's founders and supported by our generous donors. We are grateful to all in the mathematics community and beyond who have contributed to the Institute's success in supporting collaborative, impactful, and cutting edge mathematics research, developing talent, and inspiring an appreciation of the power, beauty, and joy of mathematics.

P.S. Have you seen our new home online? Stop by www.slmath.org to see our new look! We thank SLMath's IT department for their hard work in facilitating this transition.

In Memoriam

Calvin C. Moore, MSRI Co-Founder (1936–2023)

We regret to share the sad news that MSRI Co-Founder Cal Moore, Professor Emeritus of Mathematics at the University of California, Berkeley, passed away in July of this year. Together with Shiing-Shen Chern and Isadore Singer, Cal was one of the founders of MSRI, and he served as the Institute's Deputy Director (1981–85), Treasurer (1981–85), and Chair of the Audit Committee (2005–17).

Cal's devotion to the health and welfare of MSRI was limitless. Significantly, he organized the Institute's administration, facilitated the relationship with UC Berkeley, and led the placement, conception and construction of MSRI's building through his service on the Building Committee.

ANNIE AVERITT

Cal and Doris Moore visit MSRI in Sep 2018.

In addition, he founded MSRI's library and remained a key supporter of MSRI throughout his life. Cal strongly believed that MSRI should open its doors to junior mathematicians, and we had the opportunity to listen to his recording on this topic during our 40th-anniversary symposium earlier this year. We are deeply grateful for Cal's dedication in founding MSRI and for his ongoing support of the Institute.

SLMath and UC Berkeley co-hosted a memorial in honor of Calvin Moore at SLMath on December 1, 2023, from 1–4pm in conjunction with the UC Berkeley Department of Mathematics. For details, contact communications@slmath.org.

—Tatiana Toro

Hagoromo+SLMath

In early 2019, former CNN affiliate Great Big Story visited MSRI to make a micro-documentary as part of their focus on untold and overlooked stories. The resulting tongue-in-cheek video, "Why the world's best mathematicians are hoarding chalk," interviewed visiting researchers about their love of a Japanese chalk brand, Hagoromo, which had been in danger of shutting down in 2014 until a South Korean startup stepped in to purchase the company's equipment and learn their process. Over 28 million views later, the story of mathematicians' love of chalk in the age of whiteboards continues to draw attention online and in news media worldwide.

On October 24, SLMath was honored to host a visit by CEO **Hyeongseok Shin** of Sejongmall (center of photo in green sweater), who met with researchers and shared some of the company's new products. Sejongmall has generously sponsored Hagoromo prizes for the winners of our Tau Day Puzzle Contest, which takes place on June 28 of each year.

AARON FAGERSTROM

Program Article

Fairness, Geometry, and Probability

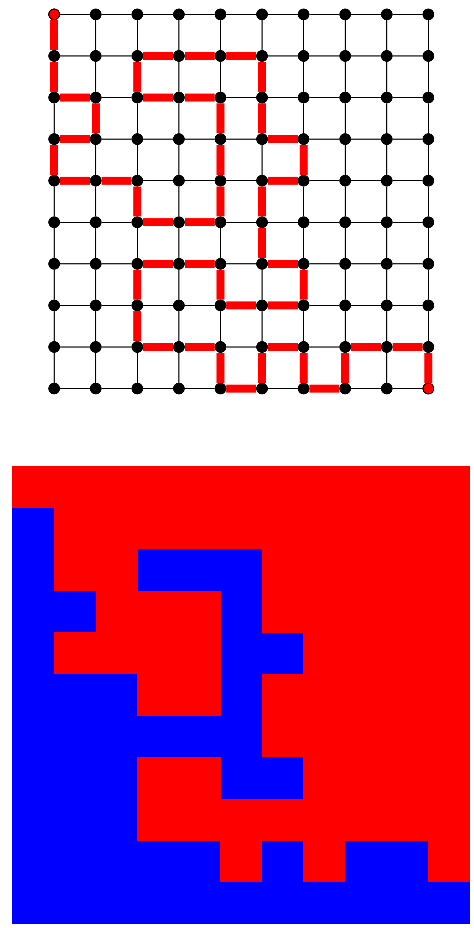
Wesley Pegden

Mathematics has multifaceted and rich connections to notions of fairness, as explored and pursued in this semester's program on Algorithms, Fairness, and Equity. In social choice theory, topics include the mathematical foundations of novel voting systems and even novel democratic systems. At the interface between fairness and machine learning, researchers reckon with foundational questions about the interaction and compatibility of notions of individual versus group fairness. In fair division theory, researchers apply topological and algorithmic approaches to determine when fair allocations of resources are possible, and how they can be efficiently achieved.

One class of questions studied by members of the Algorithms, Fairness and Equity program concerns probability spaces on geometric partitions of regions. One classical fair division question concerns the probability of fairly dividing a cake (and when we wish to divide it into more than two pieces, this remains a subtle question subject to intense research!). What about a different question: Can I cut a cake *randomly*? To be concrete: Is there an efficient procedure to select a cutting of a cake uniformly at random, among all valid cuttings? The subtlety of such questions comes from the interaction of probability and geometry. If I want the cake to be randomly cut into two contiguous pieces, my demand of contiguity is a geometric constraint. Similarly, if I (quite reasonably, perhaps) would prefer to avoid fractal pieces of cake, I might impose additional constraints on the boundaries of the cake pieces, or I might decide to bias my probability distribution by assigning greater weight to partitions whose pieces have, say, smaller total perimeter.

Natural in their own right, these probability spaces on geometric partitions also bear on attempts to understand fairness of partitions of geometric regions that occur in real world settings, especially in relation to political districtings. When a political districting is challenged as a partisan outlier, we wish to be able to conduct statistical analyses to support or reject the validity of such claims, as would be enabled by the availability of good samplers for a space of valid alternative districtings. In several court decisions, testimony from mathematicians employing these very techniques has been leveraged in decisions which ultimately ordered congressional and state legislative districtings redrawn. If we want to go broader, and wish to understand the implications of different types of district-based political systems in various political/geographic contexts, we wish to understand the structure and typical samples of the probability distributions that arise in various geometric settings.

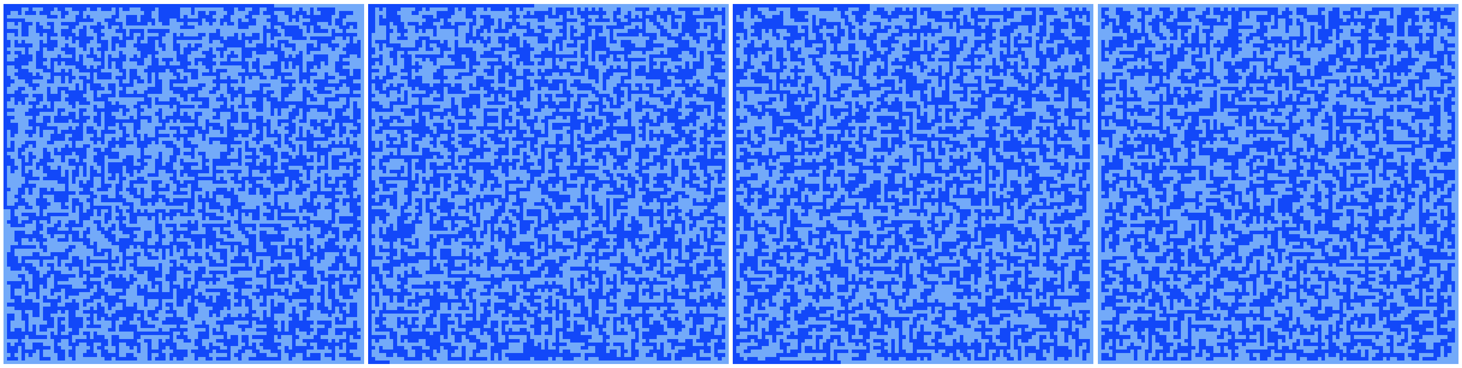
For a given geometric space and set of geometric constraints or priorities on its partitions, we get a probability distribution on partitions. We are interested in the fundamental questions about these distributions: Can we characterize typical samples from these distributions? Can we efficiently sample from these distributions? What about the other direction: Given a randomized algorithm which produces a partition of a geometric space, what can we understand about the probability distribution *it* samples from?



Top: A self-avoiding walk in the 10×10 grid. Bottom: a corresponding partition of the 11×11 grid into two contiguous pieces.

Self Avoiding Walks, Partitions, and Big Numbers

Writing in the journal *Science* in 1976, Knuth pondered the inevitable largeness of finite numbers arising in relatively simple problems. He used the example of self-avoiding walks from the upper-left corner to the lower-right corner in a 10×10 grid. How might one estimate the number of such walks? Knuth considered the algorithm which simply grows a walk iteratively, step by step, beginning from the upper-left corner, and at each step choosing



Glauber dynamics for partitions of the grid into two contiguous parts.

where to go next uniformly at random among the unvisited possibilities which will not trap the walk. This algorithm doesn't choose a walk uniformly at random, but samples a walk $P \sim D$ from a distribution D that we can at least understand on a path-by-path basis. In particular, given a particular walk P of length L, we can, by inspection, compute the exact probability that the walk P would be chosen. Indeed, if P_ℓ denotes the initial segment of the path P of length ℓ, and $1 \leqslant k_\ell \leqslant 3$ denotes the number of valid ways of extending P_ℓ by one edge, then the probability the algorithm returns this particular walk P is precisely

$$s(P) := \prod_{\ell=1}^{L-1} \frac{1}{k_\ell}.$$

For a random P, the quantity $1/s(P)$ seems like a natural estimate for the total size of the set $\mathcal{P}$ of self-avoiding walks from corner-to-corner, and indeed, we have that

$$\mathbb{E}\left(\frac{1}{s(P)}\right) = \sum_{P \in \mathcal{P}} \Pr(P \text{ chosen}) \frac{1}{s(P)} = \sum_{P \in \mathcal{P}} s(P) \frac{1}{s(P)} = |\mathcal{P}|.$$

This allowed Knuth to give a good heuristic estimate for $|\mathcal{P}|$ for the 10×10 grid via simulation (in this case, that $|\mathcal{P}| \approx 1.6 \times 10^{24}$), but he didn't expect $\mathbb{E}(1/s(P))$ to be an efficient route to estimate $|\mathcal{P}|$ on larger grids. The problem is that in all likelihood, the *variance* of the random variable $1/s(P)$ is too large for the expectation to be estimated efficiently by drawing samples. In particular, the proposed algorithm is very far from a *uniformly* random sampler for self-avoiding walks in the grid.

Knuth could just as well have asked about partitions of a grid into two contiguous pieces, as the two problems are in natural correspondence; a self-avoiding walk can be seen as the boundary between two contiguous partition classes, and the boundary between two partition classes is a self avoiding walk (as in the figure on the previous page). We know considerably more now about the task of sampling such geometric partitions than we did in 1974, but whether there is an efficient algorithm to uniformly sample partitions of the $n \times n$ grid into two contiguous pieces remains wide open.

The Role of Markov Chains

A fundamental strategy for sampling distributions on very large sets is the use of Markov chains, which are essentially random walks around abstract spaces. More precisely, a Markov chain is a sequence of random variables

$$X_0, X_1, X_2, \ldots$$

on a common domain Ω such that for any $\sigma, \sigma' \in \Omega$ the transition probability

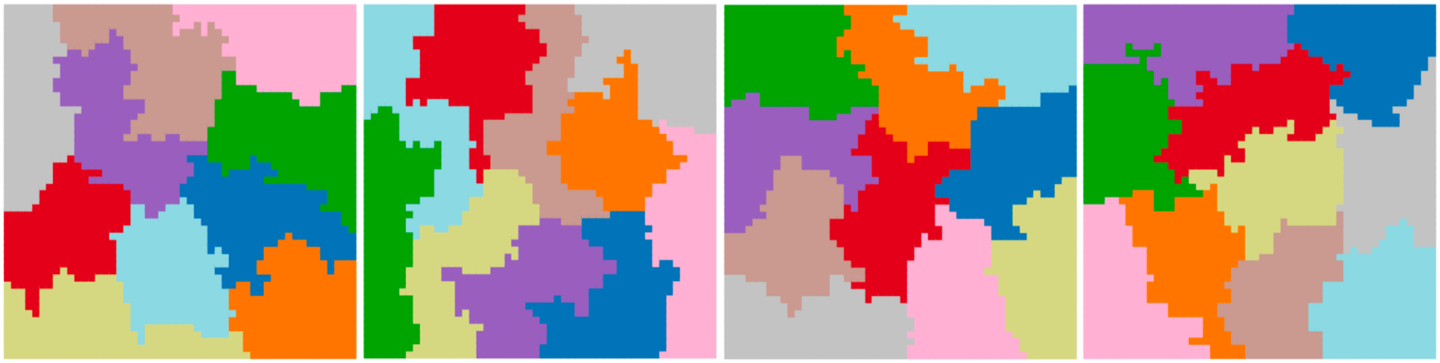
$$\Pr(X_{t+1} = \sigma' \mid X_t = \sigma)$$

depends only on σ and σ' (and is independent of t). A canonical example is a random walk on a graph, where X_t denotes the position of the walk at time t, and the next step of the walk is chosen as a uniformly random neighbor of the current position.

A *stationary* distribution for a Markov chain is a distribution π where $X_0 \sim \pi$ implies that $X_1 \sim \pi$; in this case, we have then that $X_t \sim \pi$ for all t. For example, for a Markov chain given by random walk on an undirected graph, it can be checked that the distribution which selects vertices proportional to their degree is stationary. The power of Markov chains comes from the fact that under mild assumptions (in particular, that the chain is not disconnected into pieces that are mutually unreachable by allowable transitions), the stationary distribution of a Markov chain is unique and can be sampled from (to an arbitrary close approximation) by running the chain from an arbitrary starting point for a sufficiently long time. How long it takes for this approximation to be close is the *mixing time* of the Markov chain; bounding the mixing time of chains of interest is thus a major challenge for the rigorous use of Markov chains. The promise of Markov chains comes from the fact that in the best case, mixing times can be logarithmic in the size of a state space, allowing efficient sampling of spaces that are far too large to enumerate explicitly.

Which Markov Chains?

For a wide class of sampling problems, the space Ω in question is a space of *configurations* $\sigma\colon V \to C$, where each of the (usually finitely many) vertices $v \in V$ is assigned a value C. For example, in the case of statistical physics models like the Ising model, C might be a set of spins; for sampling graph colorings, C might be a set of colors; in our case, for partitioning problems, C would be the set of partition labels. For any interesting problem, it will either be the case that Ω is a proper subset of the set of all possible assignments $\sigma\colon V \to C$, or that we will be trying to sample nonuniformly from the set of all assignments, or both.



Markov chains that favor partitions whose classes have many spanning trees implicitly impose geometric preferences on the sampled partitions (from DeFord–Duchin–Solomon 2021).

Given a target distribution π on such a configuration space, there is a canonical Markov chain, known as the Glauber dynamics, for which transitions on configurations $\sigma \colon V \to C$ are carried out as follows:

(a) Choose a random vertex $v \in V$;

(b) Resample the value $\sigma(v)$ from C, by using the distribution π *conditioned on the values of* σ *at all* $u \neq v$.

Importantly, implementing this chain only requires one to know the *relative* probabilities π assigns to the $|C|$ assignments being considered in part (b) of each step: we just need to be able to compute a weight function $\omega \colon \Omega \to \mathbb{R}^+$ such that

$$\pi(\sigma) \propto \omega(\sigma).$$

When sampling from a uniform distribution, for example, it is enough that we know that all valid assignments have equal probability; we don't need to know the absolute probabilities, which would require knowing the total number of valid configurations.

There are sampling problems where we know the Glauber dynamics is rapidly mixing, cases where we know it isn't, and (most common of all) cases where we still don't know. Most geometric partitioning problems fall in the last class, and advances in our understanding of the mixing times of these types of chains is a major research challenge that also holds real promise for impact on applications.

For the Glauber dynamics, all of our preferences on objects we want to sample from are encoded in the scores $\omega(\sigma)$ to which the desired stationary distribution π is proportional. For example, in applications to districting analysis, the fractal boundaries seen in the figure above don't capture the geometry we expect from political districtings, so we would impose additional constraints, for example, on the perimeter of partition classes, or define ω in such a way as to favor partitions with nicer geometric properties.

But there are also chains that interact differently with the geometry of a space by their very nature. Consider the following way of modifying an existing partition of a graph:

Both of this semester's programs received generous support from the Alfred P. Sloan Foundation.

- Choose two partition classes to merge;
- Choose a random spanning tree of the merged partition classes;
- Remove an edge from the spanning tree to redivide the merged class.

Markov chains based on this type of partition modification have had a dramatic effect on applications to districting analysis, as they frequently appear to exhibit fast mixing behavior on real-world data. The native stationary distribution of these chains is not uniform on contiguous partitions but instead favors partitions whose partition classes have many spanning trees. This means that even without imposing any additional constraints, these chains tend to sample partitions with nice-looking partition classes (see the figure on the previous page). A nascent line of inquiry studies the geometry of these tree-based partition distributions, aiming to better understand how the geometric parameters of a given partitioning of a region influence its weight in the stationary distribution of such a chain, and, conversely, the geometric properties of typical samples from such stationary distributions. Closely related to this is understanding the extent to which such chains can be "Metropolized" to sample from explicitly specified target distributions by introducing appropriately-chosen rejection rules to the chain's transitions.

The Broader Context

Work on these partitioning problems is taking place against a backdrop of major leaps forward on longstanding problems in Markov chain theory. The 30-year-old matroid basis exchange conjecture of Mihail and Vazirani was confirmed in 2019 by Anari, Liu, Gharan, and Vinzant, with immediate implications for an important class of geometric partitioning problems. New approaches to proving rapid mixing developed in just the past few years have delivered breakthrough improvements in mixing time results for classical statistical physics models and graph coloring sampling problems. Against this backdrop, we also have more questions about Markov chains we want answered than ever before, as a new area of applications (the analysis of districtings) has reinvigorated study of probability distributions on geometric partitions.

FOCUS *on the Scientist* Deanna Needell

SIERRA SUTHERLAND

Deanna Needell is a research professor in this semester's program on *Algorithms, Fairness, and Equity*. Deanna is a Professor of Mathematics at UCLA and is also the Dunn Family Endowed Chair in Data Theory and Executive Director of the Institute for Digital Research and Education. Deanna has made significant contributions to the field of mathematics of data, including work in compressed sensing, stochastic optimization, and machine learning. Deanna has also shown a strong commitment to using these methods in the community.

One approach to transparent machine learning is non-negative matrix factorization (NMF), which provides an approximate and interpretable representation of complex data sets in terms of a reduced number of extracted features. Deanna generalized these algorithms to various applications, including an NMF approach with a hierarchical "deep" structure of topics. She also developed a robust tensor CUR decomposition, the first in the tensor setting, that has applications to denoising as well as a modewise measurement scheme for reconstructor large tensor data using practical compression.

The *Algorithms, Fairness, and Equity* program aims to advance the theory of the field and also to ensure that the methods are used for the betterment of society. Deanna has been doing just that for quite some time. Through her work with LymeDisease.org, using a large scale Lyme patient registry, Deanna used her models to help understand the efficacy of antibiotics to treat chronic Lyme disease. Deanna has also worked with the California Innocence Project (CIP), an organization aiming to free wrongfully convicted prisoners, to help process and understand their data sets. She is also doing work on improving the "fairness" of the methods she uses, from an algorithmic perspective.

> *She is also doing work on improving the 'fairness' of the methods she uses, from an algorithmic perspective.*

In 2016 Deanna was awarded the IMA prize in Math and Applications for theoretical work in medical sensing, MRIs, using sparse approximation, signal processing, and stochastic optimization. She became a fellow of the AMS for contributions to mathematics of data in 2022.

Deanna's webpage asserts: "I strive for an inclusive workspace and world. You matter, you are valued." This simple yet profound act of stating that she's an ally to marginalized groups has encouraged her students to see her as an approachable person and a safe space where they can show up as their authentic selves.

When she has to drive down to UCLA from SLMath, she travels with her two "awesome beagles," Tahoe and Sierra, in tow.

— Stephanie Somersille

Call for ***Proposals***

All proposals can be submitted to the Director or Deputy Director or any member of the Scientific Advisory Committee with a copy to proposals@slmath.org. For detailed information, please see the website slmath.org/proposals.

Thematic Programs

The Scientific Advisory Committee (SAC) of the Institute meets in January, May, and November each year to consider letters of intent, pre-proposals, and proposals for programs. The deadlines to submit proposals of any kind for review by the SAC are Mar 1, Oct 1, and Dec 1. Successful proposals are usually developed from the pre-proposal in a collaborative process between the proposers, the Directorate, and the SAC, and may be considered at more than one meeting of the SAC before selection. For complete details, see slmath.org/request-for-proposals.

Hot Topics Workshops

Each year SLMath runs a week-long workshop on some area of intense mathematical activity chosen the previous fall. Proposals should be received by Mar 1, Oct 1, and Dec 1 for review at the upcoming SAC meeting. See slmath.org/proposals-hot-topics-workshops.

Summer Graduate Schools

Every summer SLMath organizes several two-week long summer graduate workshops, both at SLMath and at other locations. Proposals must be submitted by Sep 1 of each year for review at the upcoming SAC meeting. See slmath.org/proposals-summer-graduate-schools.

Graduate Fellows / FALL 2023




PHOTOS AARON FAGERSTROM/JAMIE TUCKER-FOLTZ BY AMY TUCKER

Erin George is the SLMath Doctoral Graduate Fellow in the *Algorithms, Fairness, and Equity* program. They are a fifth-year applied mathematics Ph.D. candidate at the University of California, Los Angeles, advised by Deanna Needell. They received bachelor's degrees in mathematics and computer science at the University of Maryland, College Park. Erin's work focuses on fair machine learning and deep learning theory.

Matthias Oberlechner is the Alfred P. Sloan Foundation supported Graduate Fellow in the *Mathematics and Computer Science of Market and Mechanism Design* program. In 2020, he received his M.S. in Mathematics at the Technical University of Munich and started his Ph.D. in the computer science department under the supervision of Martin Bichler. In his research, Matthias investigates learning dynamics in multi-agent systems with application to economic settings such as auctions and contests. In particular, he is interested in the underlying structures that allow simple learning algorithms to reach the equilibrium strategies in these games.

Shiri Ron is the Kristin E. Lauter Graduate Fellow in the *Mathematics and Computer Science of Market and Mechanism Design* program. She is currently a third-year computer science Ph.D. student in the computer science and applied mathematics department at the Weizmann Institute of Science, advised by Prof. Shahar Dobzinski. She is an Azrieli fellow. In 2019, she received her M.Sc. from the Weizmann Institute of Science, working on communication complexity of payment computation. Before that, she received her bachelor's degree from the Hebrew University of Jerusalem, majoring in computer science and psychology. She is interested in algorithmic mechanism design, and in particular, in communication aspects of auctions.

Jamie Tucker-Foltz is the Alfred P. Sloan Foundation supported Graduate Fellow in the *Algorithms, Fairness, and Equity* program. He is currently a fourth-year Ph.D. student at Harvard, advised by Ariel Procaccia. He earned his bachelor's degree from Amherst College and a master's degree from the University of Cambridge. His research applies techniques from theoretical computer science to improve democratic institutions, such as voting, apportionment, and fair resource allocation. He is particularly interested in algorithms for fair political redistricting and gerrymandering detection. He also has interests in algorithmic game theory, descriptive complexity, computational geometry/topology, and graph theory. Outside of research, Jamie holds the world record for juggling the greatest number of clubs (seven) while riding a unicycle.

*Graduate fellowships support current graduate students to take part in our research programs, thanks to the support of **SLMath individual donors** and **private foundations**. These fellowships allow graduate students to receive financial support so that they can remain in residence at SLMath for the entire semester with their advisor, fully integrated into the semester's research program.*

New Chern Postdoctoral Fellowship

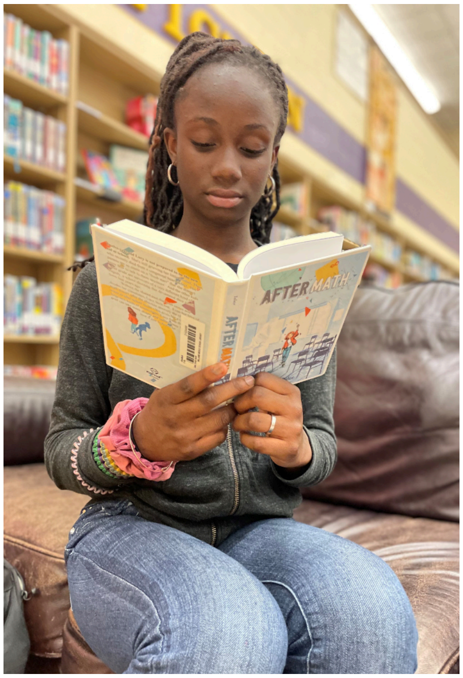
DAVID EISENBUD

The Chern Postdoctoral Fellowship was established in 2022 by the S.S. Chern Foundation for Mathematical Research through the generosity of the family of Shiing-Shen Chern. SLMath is proud to announce that the first fellowship was awarded to Ulrike Schmidt-Kraepelin in this fall's *Algorithms, Fairness, and Equity* program (see page 12).

Shiing-Shen Chern (1911–2004) was an outstanding contributor to research in differential geometry and devised the now-named Chern characteristic classes in fibre spaces. He also gave proof of the famous Gauss–Bonnet formula. Chern received an M.S. degree from Tsinghua University in Beijing and a doctor of sciences degree from the University of Hamburg (Germany).

In 1949, Chern accepted the chair of geometry at the University of Chicago and moved to the University of California, Berkeley, in 1960. He was elected a member of the U.S. National Academy of Sciences a year later. After his retirement from UC Berkeley, Chern was one of the three founders of MSRI and acted as its first director (1981–84). He was awarded the National Medal of Science in 1975 and the Wolf Prize in 1983.

Celebrating a Decade of Outreach Milestones



Mathical books shared by students at U.S. Title I school libraries via SLMath's partnership with School Library Journal

Mathical

Bigger than a Book Prize: Getting Books to Young Readers

Mathical Books launched in 2013–14 aiming to start a quiet avalanche for Pre-K–12 readers through a literary prize awarded to high-quality books with main characters who loved math, storylines woven through with puzzles, and vivid nonfiction highlighting the mathematical patterns behind real-world interests of children.

Mathical

Ten years in, our mission has grown beyond the 100+ titles on the Mathical List to include a nationwide network of educators, librarians, mathematicians, and other partners who help us to distribute the award-winning titles to low-income schools, create educator resources to encourage love of mathematics, and inform and support children's publishers bringing math-inspired titles to tens of millions of youth around the country.

Mathical Books provide much-needed literacy resources around the country. In just the past year:

- 2,400+ Mathical Books were distributed in the San Francisco Bay Area with the assistance of ParentChild+. The organization serves families with free books and in-home facilitation to support reading aloud to young children.
- 32 Title I school libraries around the U.S. received Mathical Book Prize Collection Development Awards of $700 each to purchase Mathical books for their libraries. The program is coordinated by *School Library Journal*.
- 19 low-income (Title I in the U.S.) schools around the U.S. and Canada, selected by the National Council of Teachers of English (NCTE) and the National Council of Teachers of Mathematics (NCTM), received grants of $700 each to purchase Mathical books for their classrooms.

GURU KRUPA Foundation Inc

We are grateful to everyone who has joined us to make Mathical a success. We especially thank the Guru Krupa Foundation, who have supported Mathical book distribution, reaching over 29,000 students and 300+ families in Spring 2023!

We welcome suggestions for future Mathical Honor Books from the community through the Mathical website at www.mathicalbooks.org/suggest.

Numberphile

Quadrupled Subscriptions

Our partnership with video journalist Brady Haran on *Numberphile*, both on YouTube and more recently in audio podcast form, had reached 1 million subscribers and 100 million views in 2014 after our initial partnership began. Now in 2023, *Numberphile* celebrates 4.36 million subscribers and nearly 650 million views, featuring dozens of interviews with visiting researchers in our programs and inspiring a generation of young mathematicians.

Math Lovers Forum

Silicon Valley Math Salons

The Math Lovers Forum salon dinners bring mathematicians to present their work and ideas to curious math lovers especially in California's Silicon Valley. The 10-year celebration in October featured mathematician Manil Suri (University of Maryland, Baltimore County and author of *The Big Bang of Numbers: How to Build the Universe Using Only Math*), hosted by Ashok and Gita Vaish.

Spanning the Globe: Summer 2023 Highlights

Hélène Barcelo, Deputy Director

SLMath played host to a whirlwind of activities during summer 2023. Among the highlights were SLMath's Undergraduate Program (MSRI–UP), ADJOINT, Summer Research in Mathematics (SRiM), eleven Summer Graduate Schools (SGS) that spanned the globe, an in-person reunion for the Fluid Dynamics program, and the launch, in Atlanta, of the Mathematically Advancing Young Undergraduates Program (MAY–UP).

Summer Graduate Schools

SGS are a key benefit of SLMath's 116 Academic Sponsors. Students are nominated by the graduate chairs of their departments and selected on an egalitarian, first-come, first-served basis. We are indebted to the Scientific Advisory Committee for its exceptional stewardship of the popular SGS program. For brevity's sake, I highlight two 2023 schools below.

It's not every day that SLMath makes the *New York Times*: the **Formalization of Mathematics** SGS was highlighted in the article,"A.I. Is Coming for Mathematics, Too." In the article, Siobhan Roberts explored the use of artificial intelligence in mathematics and included interviews and photos taken at SLMath during the SGS, which was organized by **Jeremy Avigad** (Carnegie Mellon University), **Heather Macbeth** (Fordham University), and **Patrick Massot** (Université Paris-Saclay). The students were highly satisfied with their experience, as they reported loudly and clearly in their exit surveys!

Collaborative efforts between research institutions and industry leaders often yield extraordinary results. Such was the case with the joint IBM–SLMath SGS, **Mathematics of Big Data: Sketching and (Multi-) Linear Algebra**, organized by **Kenneth Clarkson** (IBM Research Division), **Lior Horesh** (IBM Thomas J. Watson Research Center), **Misha Kilmer** (Tufts University), **Tamara Kolda** (MathSci.ai), and **Shashanka Ubaru** (IBM Thomas J. Watson Research Center). It is not an exaggeration to say that this SGS was a resounding triumph. Judging from the exit surveys and other testimonials, the knowledge-sharing and mentorships initiated during the school were remarkable. At the students' behest, the lecturers organized a panel on possible careers for mathematics Ph.D. holders, including those outside of academia. The panel was a memorable event! SLMath envisions this partnership with IBM continuing for many years to come.

ADJOINT

There has been an exciting addition to ADJOINT: **Self-ADJOINT**. In 2024, the program will host independent research groups (Self-ADJOINT) concurrently with guided ADJOINT research groups led by **Melody Goodman** (NYU School of Global Public Health) and **Aaron Pollack** (UC San Diego). This enhancement will better serve the unique needs of the ADJOINT community, catalyzing collaborations that have begun either in previous ADJOINT groups or outside SLMath.

SRiM

The response to the SRiM program has remained overwhelmingly positive. We were elated to see interest steadily returning to pre-pandemic levels with 32 groups applying (composed of 124 applicants) and 16 groups (composed of 56 researchers) participating in the program. SRiM's soaring popularity and poignant testimonials highlight the importance of such a program in today's mathematical research landscape.

MAY–UP and MSRI–UP

Two undergraduate research experience (REU) programs are also part of SLMath's continuum of excellence. As mentioned by Tatiana Toro in her Director's Update on page 3, the MAY–UP pilot program, led by **Duane Cooper** (Morehouse College) and **Shelby Wilson** (Johns Hopkins Applied Physics Laboratory), served rising sophomores attending HBCUs in the Atlanta University Center. SLMath's long-running Undergraduate Program (MSRI–UP) on Topological Data Analysis took place at the Institute under **Mercedes Franco** and **José Perea** and was its usual success.

IBM ALMADEN/CHRISTINA HOWELL

Participants in the IBM Almaden 2023 Summer Graduate School

SLMath had yet another outstanding summer in 2023, bringing together diverse researchers at all career stages to enrich the mathematical community's collective knowledge. We are excited about the possibilities presented by new programs and initiatives such as MAY–UP and Self-ADJOINT and look forward to the continued success of programs such as MSRI–UP, SGS, and SRiM.

Named Postdocs / FALL 2023

BERLEKAMP

AARON FAGERSTROM

Ranthony A.C. Edmonds is the Berlekamp Postdoctoral Fellow in the *Algorithms, Fairness, and Equity* program. She earned her Ph.D. from the University of Iowa in 2018 with work in commutative ring theory, studying factorization in polynomial rings with zero divisors. From there, she went to the Ohio State University as a postdoc, where she broadened her horizons through working with the applied algebraic topology group, with added support from an NSF Ascend fellowship. One example of a recent project is a parametrized Gromov–Wasserstein distance, which allows one to describe how similar two metric-measure spaces are; this has many applications in data analysis. Ranthony is forging a new research direction she calls "quantitative justice" — the goal is to turn methods from math, statistics, and data science toward social justice problems like political representation and policing.

The Berlekamp fellowship was established in 2014 by a group of Elwyn Berlekamp's friends, colleagues, and former students whose lives he touched in many ways. He was well known for his algorithms in coding theory, important contributions to game theory, and his love of mathematical puzzles.

ALFRED P. SLOAN SUPPORTED

AARON FAGERSTROM

Paul Gölz is the Alfred P. Sloan Foundation supported Postdoctoral Fellow in the *Algorithms, Fairness, and Equity* program, supported by the Sloan foundation. After studying at Saarland University in Germany, Paul earned his Ph.D. in computer science at Carnegie Mellon University. Before joining SLMath, he was a postdoc at Harvard, and he will join Cornell as an assistant professor of operations research in 2024. Paul studies democratic decision-making and the fair allocation of resources, using tools from algorithms, optimization, and artificial intelligence. Algorithms developed in his work are now deployed to select citizens' assemblies around the world and to allocate refugees for a major U.S. resettlement agency.

The Alfred P. Sloan Foundation is a not-for-profit, mission-driven grantmaking institution dedicated to improving the welfare of all through the advancement of scientific knowledge. Learn more about their mission at sloan.org.

CHERN

AARON FAGERSTROM

Ulrike Schmidt-Kraepelin is the inaugural Chern Postdoctoral Fellow in the *Algorithms, Fairness, and Equity* program this fall, and will start a new tenure-track position in computer science at TU Eindhoven (in the Netherlands) in the spring, where she'll be associated with the algorithms group. Ulrike has wide-ranging interests in social choice and game theory (applications of computing to problems in voting, fair division, and matching). Her past projects have looked at proportional representation in multi-winner elections and fair division, the use of majoritarian devices in single-winner elections, and voting problems in combinatorial domains. In the future, she wants to investigate ways to enhance the explainability of social choice mechanisms and the impact of preference models and ballot design.

The Chern fellowship was established in 2022 by the S.S. Chern Foundation for Mathematical Research through the generosity of S.S. Chern's family. Shiing-Shen Chern was an outstanding contributor to research in differential geometry and was one of the three founders of MSRI, serving as its first director.

Named Postdocs / FALL 2023

ALFRED P. SLOAN SUPPORTED

AARON FAGERSTROM

Tomer Ezra is the Alfred P. Sloan Foundation supported Postdoctoral Fellow in the *Mathematics and Computer Science of Market and Mechanism Design* program. He received his Ph.D. in 2022 from Tel Aviv University, where he was advised by Michal Feldman. After his Ph.D., he was a postdoc at Sapienza University of Rome, hosted by Stefano Leonardi. Tomer's research lies on the border of computer science and economics, focusing on the analysis and design of simple mechanisms in limited information settings. In particular, he studies optimizations of online problems where a decision-maker faces a sequence of interrelated decisions and the information regarding the quality of the decisions is revealed in an online fashion. The optimization problem then becomes finding a tractable decision-making policy that guarantees a good approximation to the optimal sequence of decisions in hindsight.

The Alfred P. Sloan Foundation is a not-for-profit, mission-driven grantmaking institution dedicated to improving the welfare of all through the advancement of scientific knowledge. Learn more about their mission at sloan.org.

GAMELIN

AARON FAGERSTROM

Alireza Fallah is the Gamelin Postdoctoral Fellow in the *Mathematics and Computer Science of Market and Mechanism Design* program. In summer 2023, Alireza completed his Ph.D. in Electrical Engineering and Computer Science at MIT under the supervision of Asu Ozdaglar. Before joining MIT, he obtained his B.Sc. degrees in Electrical Engineering and Mathematics from Sharif University of Technology in Iran. His research primarily focuses on machine learning theory, game theory, algorithmic market design, mechanism design, and optimization. Throughout his graduate studies, Alireza received a number of awards and fellowships, including the Ernst A. Guillemin MIT M.Sc. Thesis Award, the Apple Scholars in AI/ML Ph.D. Fellowship, the MathWorks Engineering Fellowship, and the Siebel Scholarship.

The Gamelin postdoctoral fellowship was created in 2014 by Dr. Ted Gamelin, Emeritus Professor of the UCLA Department of Mathematics. The Gamelin fellowship emphasizes the important role that research mathematicians play in the discourse of K–12 education.

VITERBI

AARON FAGERSTROM

Duygu Sili is the Viterbi Postdoctoral Fellow in the *Mathematics and Computer Science of Market and Mechanism Design* program. She earned a B.S. in Mathematics and an M.A. in economics from Bilkent University before earning a Ph.D. in economics in 2022 under the direction of Özgür Yılmaz at Koç University, where she then worked as a postdoctoral scholar and an instructor last year. Her research interests center around the theoretical and practical aspects of market design, particularly highlighting its application within matching markets. Her research has focused on three main areas: dynamic kidney exchange models, realization of school choice mechanisms in real-world settings, and the evaluation of matching models along with the development of centralized pricing mechanisms for matching customers with service providers for freight transportation (funded by the European Research Council via the Good Mobility Lab at Koç University.

The Viterbi postdoctoral fellowship is funded by a generous endowment from Dr. Andrew Viterbi, well known as the co-inventor of Code Division Multiple Access based digital cellular technology and the Viterbi decoding algorithm, used in many digital communication systems.

Program Article

Mathematics and Computer Science of Market and Mechanism Design

Scott Duke Kominers and Alexander Teytelboym

In recent years, scholars and practitioners have collaborated to organize and improve real-world marketplaces, using economic reasoning to characterize incentive and allocation failures and then applying a mixture of mathematics, computer science, and operations research to design practical solutions. When successful, this can substantially improve the way the world works for both individuals and institutions.

The fields of market and mechanism design use mathematical models of resource allocation to help us better understand how to organize market clearing in theory and practice. These two fields have co-evolved for more than 60 years, but their questions are motivated in somewhat different ways.

Questions in mechanism design typically have a flavor of seeking to characterize a theoretical optimum given realistic constraints on behavior — *What mechanism maximizes the objective of the designer subject to ensuring that rational participants behave optimally, given their beliefs about actions of others, and have an incentive to share their private information?* For example, one might ask: Which auction design maximizes expected revenue in an auction for a single item? (Answer: A second-price auction with a carefully chosen reserve price.)

Questions in market design instead generally build theory around a real-world mechanism and/or the underlying allocative constraints — *Does a given market institution have favorable properties, such as efficient allocation of resources, providing incentives to reveal information, and ensuring equity in outcomes?* For example, one might ask: Is there an mechanism that finds an assignment of students to schools that "eliminates justified envy" in the sense that if a given student i is rejected from a school, then no student with a lower priority than i is admitted to that school? (Answer: Yes, the Gale–Shapley algorithm.)

If forced to provide loose analogies, we might say that mechanism design is a bit similar in spirit to physics, while market design is closer in spirit to engineering: mechanism design is about what is conceptually possible, whereas market design is more framed around what is achievable in practice. The analogy, as crude as it is, does suggest that both fields are deeply intertwined, and rooted in mathematics as well as more recently in computer science (in the same way as it takes physicists, engineers, computer scientists, and mathematicians to send a rocket to space, as our Space Sciences Lab neighbors on top of the hill would no doubt attest — and at least they don't have to deal with the incentives of planets!). It is precisely these fundamental connections that makes SLMath the ideal venue to explore the frontiers of market and mechanism design.

From Theory to Practice and Back to Theory

In the sense just described, economic design is not simply an exercise in applied modeling; rather, formal models are literally projected into the real world through the redesign of economic systems. This approach has been used in a wide range of contexts, including matching systems to allocate junior doctors to hospital residencies, children to nurseries and schools, students to colleges, refugees to local areas, and cadets to branches of military service; allocation systems for social housing, for organ donations to critically ill patients, and for the allocation of food to food banks; auctions to allocate wireless spectrum, fishing rights, liquidity to banks, and government securities; voting/governance systems; and so forth. Private-sector market design applications abound, as well: Web giants like Google and Facebook rely on a mixture of auction theory and machine learning to guide their decisions about which content and advertisements to show to their users. Ride-hailing platforms like Uber and Lyft use matching theory methods to decide which drivers should pick up which riders, and how to set price so as to clear the market efficiently.

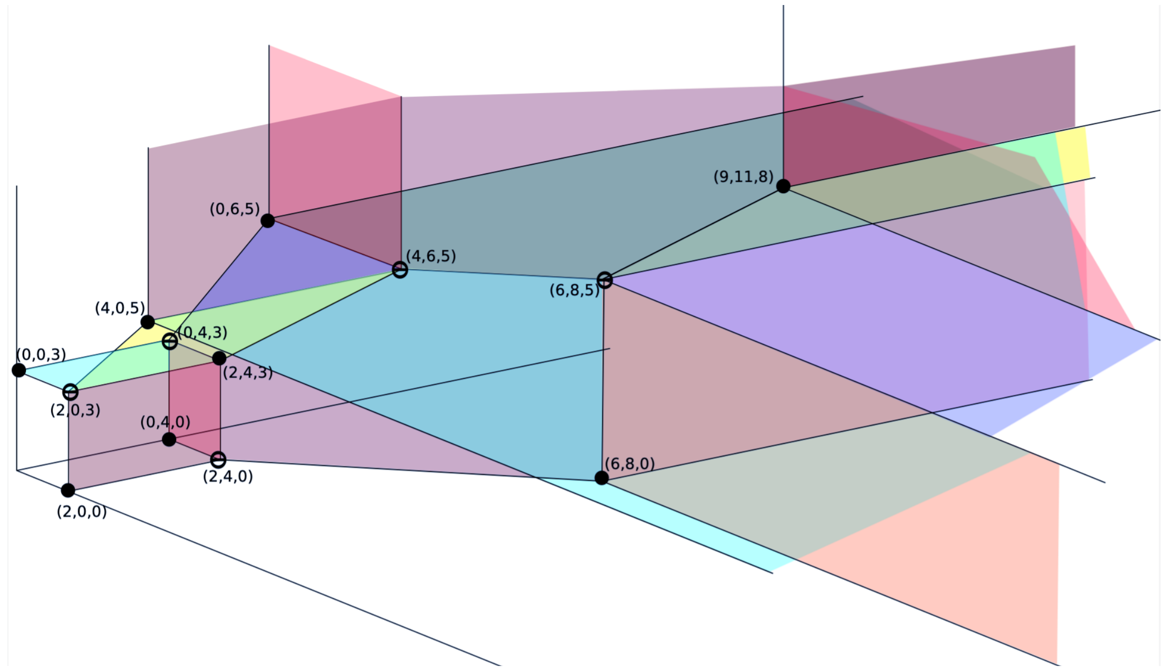
Economic design problems feature a special form of feedback between theory and practice: existing theory and models typically inform initial design strategies — but then practical concerns in real-world applications introduce new wrinkles that lead to new theory.

For example, trying to understand how to reallocate spectrum in the recent "incentive auction" has led to new theoretical insights about property rights and collusion incentives, new results in approximate matroid theory, as well as new models of strategic behavior by unsophisticated market participants.

While it might be impossible to do full justice to the diversity of questions, applications, and methods that the program participants have brought to SLMath, here we sketch four broad themes on the current frontiers of market and mechanism design that seem to be creating a buzz by the blackboards.

Matching with Complex Constraints and Preferences

Matching — that is, solving allocation problems in which it matters who transacts with whom — is one of the most classic applications of market and mechanism design. The standard model is the following. Two sides (for example, students and schools) wish to match. Each side has preferences over the other. The question is whether there exists a "stable" matching in which (1) no one wishes to unilaterally reject their match and (2) no set of agents mutually prefer to match with each other in place of their assigned matches.



Tropical hypersurfaces representing aggregate demand over three indivisible goods. (Image: Elizabeth Baldwin and Paul Klemperer)

In 1962, Gale and Shapley famously showed that in simple settings (for example, one-to-one matching, where each agent receives at most one match partner) a stable matching always exists and can be found by their celebrated "deferred acceptance" algorithm. Subsequently, mathematicians, computer scientists, and economists have deeply investigated the structure of stable matchings and the incentives that stable matching mechanisms create for participants.

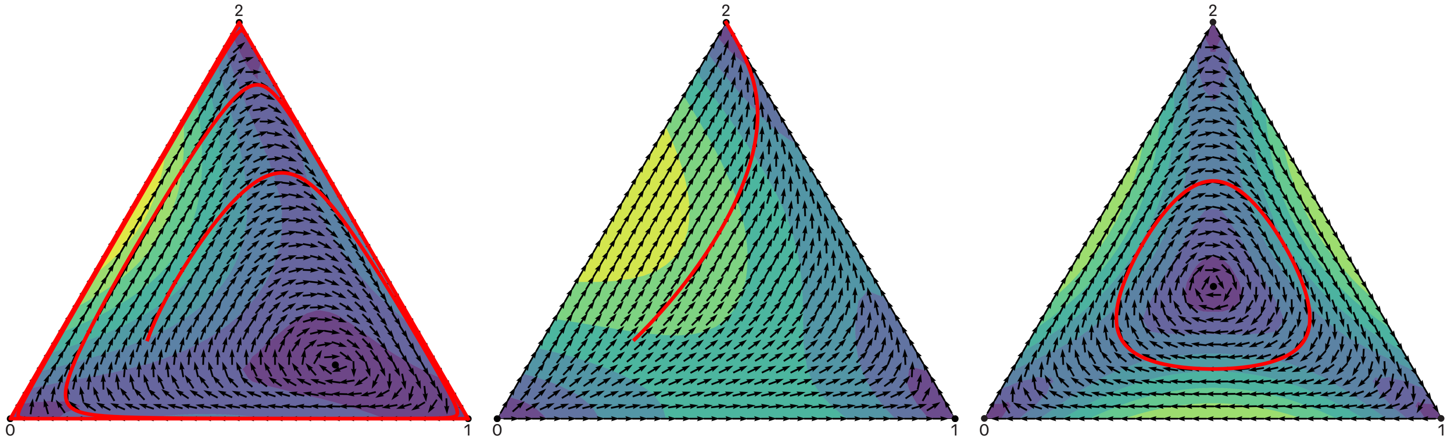
Many of these insights were put into practice after Alvin Roth, one of our program's co-organizers, discovered that the system for assigning junior doctors to residencies in the US had been using a version of the deferred acceptance algorithm for decades. More recently, a wide array of work has shown how to extend the insights from stable matching theory to more complex markets — both to settings where the mechanism determines not just who matches with whom but also terms of exchange, as well as to "multi-sided" markets such as supply chains and trading networks. This has uncovered conceptual links with auction theory and enabled novel applications such as the design of peer-to-peer electricity markets.

At the same time, we have known for decades that the market can unravel in settings even with mild allocation constraints, for example, when two doctors have preferences over hospitals as a couple rather than as separate individuals. More recent applications of matching theory develop solutions for markets with much more complex allocation constraints — settings such as kindergarten matching (in which parents want to place their children in school only on certain days) and refugee resettlement (where refugees match as multi-person families). Advances in integer linear programming and approximation methods have allowed us to systematically study how to achieve stability, efficiency, and robust incentives to reveal preferences in these settings.

Pricing in Markets with Indivisible Goods

When goods are divisible and/or homogeneous, classical economic theory indicates that it is typically possible to find prices that clear multiple markets at once. (Interestingly, this result draws heavily on ideas developed in a previous SLMath program on *Mathematical Economics*, co-organized by Kenneth Arrow, Gerard Debreu, and Andreu Mas-Colell more than 35 years ago.) However, in many application contexts, goods are indivisible and heterogeneous. One example is spectrum auctions: While spectrum is technically divisible, it is typically sold in indivisible "blocks." Another example is wholesale electricity markets: While electricity might appear divisible, supply and demand shifts vary discretely at a second-by-second resolution, at which market clearing under a large number of complex constraints is required.

It has been known for some time that in the presence of these sorts of indivisibilities, market-clearing prices do not always exist. One famous case when you can clear such markets is when goods are substitutes — that is, when increasing the price of one good results in increased demand for other goods. Under substitutability, market-clearing prices can be found by an ascending auction: starting with low prices, the auctioneer can increase prices of over-demanded goods and, due to substitutability, be certain that demand for other goods does not decrease. As a result, prices adjust monotonically to clear all markets. This logic — which, remarkably, turns out to be closely connected to the Gale–Shapley algorithm — was put to work in the pioneering spectrum auction designed by, among others, one of our program's co-organizers — Paul Milgrom (see the profile on page 17) — in the U.S. in 1994. It was applied more recently by Paul Klemperer in the design of the Bank of England liquidity auction, using stunning insights from tropical geometry in joint work with Elizabeth Baldwin (see the figure above).



Replicator dynamics on the components of the smooth Hodge decomposition of a population game. (Image: Davide Legacci)

And more recently, market-clearing algorithms for settings in which goods are nearly substitutes have been developed using methods from matroid theory and combinatorial geometry.

But, in practice, goods are often not substitutes or even close to being substitutes. For example, bidders might have budget constraints or technological constraints such as ramp-up costs, which create complementarities between different purchasing opportunities. One must therefore explore alternatives to exact market clearing, such as looking to nonlinear and/or personalized pricing, as well as approximation methods.

Algorithmic Mechanism Design

The infrastructure for marketplaces often involves both computation and the interaction of algorithmic agents. An exciting research agenda at the intersection of game theory and computer science looks at problems in which algorithmic agents might be computationally constrained to using relatively simple processes to solve problems.

Consider a combinatorial auction problem in which a seller aims to allocate many indivisible goods efficiently, that is, to bidders who value them the most. The auction design that induces bidders to reveal their preferences and produces an efficient allocation is the Vickrey–Clarke–Groves (VCG) mechanism. However, to compute VCG payments, the seller must solve a sequence of integer programs, which is computationally infeasible. An important question is then what computationally feasible auction rules might be approximately efficient. And indeed, payment computation might not be the only practical difficulty in such an auction — for example, bidders might find it nearly impossible to express their preferences over an exponential number of bundles of items. As a result, computationally tractable auctions that are able to elicit bidders' private information and yield high-revenue or high-efficiency outcomes (over restricted preference domains) remain a key area of research and innovation.

Both of this semester's programs received generous support from the Alfred P. Sloan Foundation.

Learning, Decentralization, and Online Market Design

While many questions in market and mechanism design involve centralizing and processing information at once, in many contexts the designer needs to make decisions *online* (that is, irrevocably) or in a decentralized manner. Consider, for example, the following problem: A seller wishes to sell a single item to a set of customers who arrive sequentially and whose valuations for the item are independent. When a customer arrives, the seller makes a take-it-or-leave-it sale offer. What prices should the seller charge to maximize revenue? It turns out that this problem is equivalent to an optimal stopping problem for which a simple algorithm gives a tight 2-approximation known at the "prophet inequality." In recent years this connection between optimal stopping problems and online mechanism design has developed into a rich literature with applications from dynamic pricing to recommender systems.

More broadly, the market and mechanism design community is interested in how decentralized systems might be able to "learn" a predicted outcome, for example, to find an equilibrium of a game. While much of early game theory *assumed* that participants are rational, the current reality is that in many markets participants are rational, at least to some degree, because they are represented by algorithms or artificial intelligence systems. For example, algorithms that choose prices at gas stations in Germany "learned" to collude on higher prices in ways that game theory would suggest.

Learning has important implications for computation, too. It is well known that Nash equilibrium strategies can be computationally challenging to determine. But how can we make a prediction about the bidding strategies of two algorithms in a combinatorial auction? One approach to understanding what types of games allow simple algorithms to find equilibria is to use (smooth) Hodge decomposition techniques (see the figure above). These fascinating intersections of mathematics, computer science, and mechanism design may allow us to make general and powerful predictions about the behavior of large-scale systems, just as the AI revolution really gets under way.

FOCUS *on the Scientist* Paul Robert Milgrom

ANDREW BRODHEAD / STANFORD NEWS SERVICE

Paul Robert Milgrom is one of the organizers of this semester's program on *Mathematics and Computer Science of Market and Mechanism Design*. He is the Shirley and Leonard Ely Professor of Humanities and Sciences at Stanford University and is an expert in economic theory and market design. Paul is perhaps best known for his work on the design of auctions and pricing strategies, for which he received the 2020 Nobel Memorial Prize in Economic Sciences, together with Robert B. Wilson. He has also made foundational contributions to numerous other areas, including organizational and information economics, industrial organization, finance, labor, and mathematical economics.

Paul's work is not only highly respected in academia, but very influential in practice. Together with other economists including Wilson, Preston McAfee, and John McMillan, he played a key role in designing the simultaneous multiple-round auction that was adopted and implemented by the U.S. Federal Communications Commission (FCC) to allocate wireless spectrum. He was also the lead scientist for the design and implementation of the multibillion-dollar U.S. FCC incentive auction in 2016/17, which reallocated spectrum to repurpose it from broadcast television to telecom applications.

The latter is an excellent example of Paul's work using cutting-edge mathematics and advanced algorithms to solve practically relevant economic problems. Underlying the incentive auction was a packing problem: television broadcasters who chose not to sell their licenses had to be assigned channels without creating interference, yet the problem of determining when an interference-free packing exists embeds an NP-complete graph-coloring problem. The auction design challenge was thus not just to choose market rules to govern a fixed set of potential trades but to design an approach that could at once determine the broadcasters' property rights, the goods to be exchanged, and the quantities to be traded — all while being computationally tractable and simple enough for participants to actually use.

Paul's work is not only highly respected in academia, but very influential in practice.

In his current research, Paul continues to bring sophisticated and beautiful mathematics to challenging resource allocation problems such as for water rights, which are increasingly becoming scarce. He is a caring husband, father, grandfather, and Ph.D. supervisor, and passionate about football.

— Martin Bichler and Scott Duke Kominers

Named Positions / FALL 2023

Chern, Della Pietra, and Simons Professors / Alfred P. Sloan Foundation Supported Professors

Péter Biró, KRTK, Eotvos Lorand Research Network
Shahar Dobzinski, The Weizmann Institute
Moon Duchin, Tufts University
Jonathan Mattingly, Duke University
Paul Milgrom, Stanford University
Deanna Needell, University of California, Los Angeles
Sigal Oren, Ben Gurion University of the Negev
Dana Randall, Georgia Institute of Technology

Named Postdoctoral Fellows

Berlekamp: Ranthony Edmonds, Duke University
Chern: Ulrike Schmidt-Krapelin, Universidad de Chile
Gamelin: Alireza Fallah, MIT
Viterbi: Duygu Sili, Koç University

Alfred P. Sloan Foundation Supported Postdoctoral Fellows

Tomer Ezra, SL Math
Paul Gölz, Cornell University

Named Graduate Fellows

Lauter: Shiri Ron, Weizmann Institute of Science
SLMath Doctoral: Erin George, UCLA

Alfred P. Sloan Foundation Supported Graduate Fellows

Matthias Oberlechner, Technical University of Munich
Jamie Tucker-Foltz, Harvard University

SLMath is grateful for the generous support that comes from endowments and annual gifts that support members of its programs each semester.

World Premiere

Journeys of Black Mathematicians

In January 2024, SLMath will debut our newest mathematical documentary film by director George Csicsery (Zala Films). *Journeys of Black Mathematicians* will have its world premiere at the 2024 Joint Mathematics Meetings, which are happily taking place locally in San Francisco. The film is the first of a two part series; the second installment will be released in 2025.

All are invited to attend the film screening and panel discussion held together in partnership with the National Association of Mathematicians (NAM) — see page 20 for the time and location. Additional public screenings will take place in the Bay Area and around the U.S. in Spring 2024 (with further details to be announced).

ZALA FILMS

Zerotti Woods (Johns Hopkins Applied Physics Laboratory) talks to children at a community center in Atlanta.

Call for ***Nominations*** / SUMMER GRADUATE SCHOOLS

Every summer, SLMath organizes summer graduate schools (SGS) held in Berkeley and at partner institutions worldwide. Attending an SGS can be a very motivating and exciting experience for a student; participants have often said that it was the first experience where they felt like real mathematicians, interacting with other students and mathematicians in their field.

The nomination period for the 2024 Summer Graduate Schools begins on **Dec 1, 2023** and will continue until filled or no later than **Feb 1, 2024**. We appreciate your help in identifying students who can benefit from attending these schools. Graduate students from SLMath Academic Sponsoring Institutions or from the mathematics department of any U.S. institution are eligible for nomination by their Director of Graduate Studies. Learn more at slmath.org/summer-schools.

Jun 3–Jun 14, 2024: Séminaire de Mathématiques Supérieures 2024: Flows and Variational Methods in Riemannian and Complex Geometry: Classical and Modern Methods (Montréal, Canada)

Jun 17–28, 2024: Particle Interactive Systems: Analysis and Computational Methods (SLMath)

Jun 17–28, 2024: Special Geometric Structures and Analysis (St. Mary's College, Moraga, CA)

Jun 24–Jul 5, 2024: Introduction to Quantum-Safe Cryptography (IBM, Zurich)

Jul 1–12, 2024: Stochastic Quantization (SLMath)

Jul 1–12, 2024: Koszul Duality in the Local Langlands Program (St. Mary's College, Moraga, CA)

Jul 1–12, 2024: H-principle (Sendai, Japan)

Jul 8–19, 2024: Introduction to the Theory of Algebraic Curves (UC Berkeley)

Jul 21–Aug 2, 2024: Mathematics of General Relativity and Fluids (Crete, Greece)

Jul 29–Aug 9, 2024: Structure and Representation Theory of Reductive p-adic Groups (St. Mary's College, Moraga, CA)

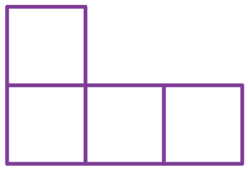
Jul 29–Aug 9, 2024: Analysis of Partial Differential Equations (Okinawa, Japan)

Aug 5–16, 2024: Mathematical Spin Glass Theory (Courant, NY)

The **Puzzles** *Column*

Joe Buhler and Tanya Khovanova

1 Can a 4×2023 grid of squares be tiled by L-shaped pieces of the following form?

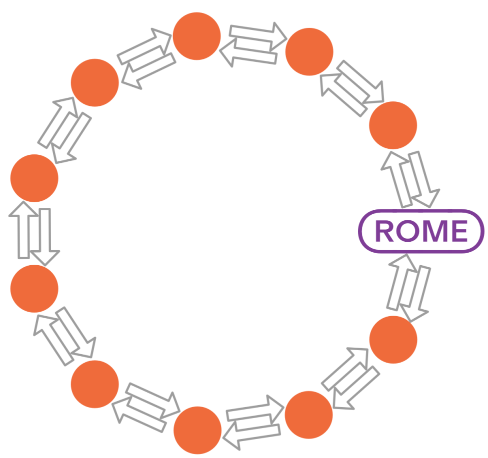


Comment: Problems 1, 3, and 6 are from the MIT PRIMES and Yulia's Dream entrance tests from 2023. Yulia's Dream, an initiative under PRIMES, is a free math enrichment and research program for exceptional high school students (grades 10–11) from Ukraine. Yulia's Dream is dedicated to the memory of Yulia Zdanovska, a gifted 21-year-old graduate of the National University of Kyiv who was killed by a Russian-fired missile in her home city of Kharkiv.

2 Consider eleven cities (one being Rome) in a circle, as shown below, where there are two one-way roads between adjacent cities. Find a coloring of the arrows in two colors (say, red and blue) so that:

(a) The two roads leading out of each city have different colors.

(b) There is a single sequence of colors (such as "red, red, red, blue, blue, red") so that following these instructions from any starting city leaves you in Rome after executing the last instruction.



Comment: This problem is due to Adler and Weiss in 1970 and can be found in, for example, Velleman and Wagon's *Bicycle or Unicycle?*

3 What is the maximum value of $m^2 + n^2$ as m and n range over positive integers that satisfy $(m^2 - mn - n^2)^2 = 1$?

4 Show that if there are 5 points on a sphere, then some 4 of them lie in a hemisphere (where hemispheres are assumed to be closed, that is, they contain their equatorial boundary).

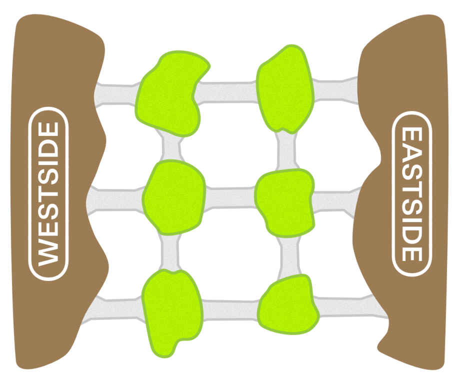
Comment: This question appeared on the 2002 Putnam, and we were reminded of it because of its role in Francis Su's inspiring book from 2020, *Mathematics for Human Flourishing*.

5 Alice and Bob divide a pie. Alice cuts the pie into two pieces. Then Bob cuts one of those pieces into two more pieces. Then Alice cuts one of the three pieces into two pieces. In the end, Alice gets the smallest and the largest piece, while Bob gets the two middle pieces. Given that both want to get the biggest share of the pie, what is Alice's strategy? How much can she get?

Comment: This problem is courtesy of Dick Hess.

6 If z and w are randomly chosen distinct solutions of $x^{2023} = 1$ in the complex plane, what is the probability that $|z + w|^2 \leqslant 2 + \sqrt{3}$?

7 A river has six islands connected by a system of bridges as shown below (islands are green, bridges are gray, river banks are brown). A flood has destroyed some bridges: each bridge is destroyed with probability $\frac{1}{2}$, independent of the others. What is the probability that after the destruction one can cross the river from west to east using the remaining bridges?



Comment: We heard this problem from Stan Wagon; it has appeared in Stack Exchange posts and in the puzzle column on FiveThirtyEight.com, and is apparently due to Jaap Scherphuis.

Send your thoughts to the authors at puzzles@slmath.org Solutions will usually be posted online before the next issue is published.

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MATHEMATICAL
SCIENCES INSTITUTE

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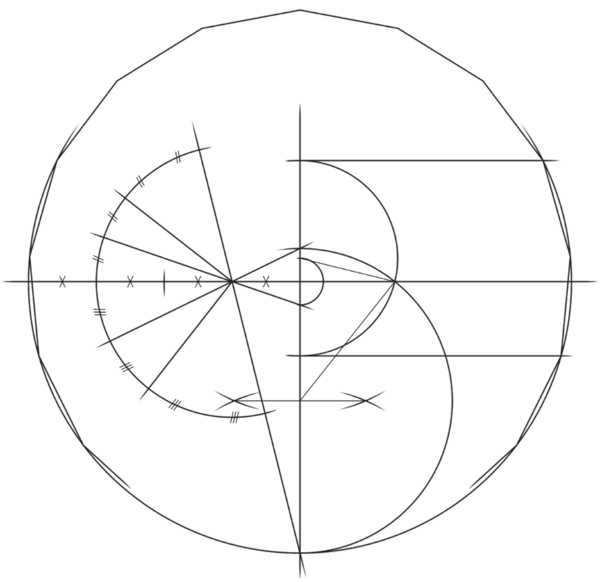

Behind the Name: ***17 Gauss Way***

For many years after SLMath, then MSRI, moved into our current home in the hills above UC Berkeley, its street address was 1000 Centennial Drive — shared with our neighbors, the Space Sciences Laboratory. When the confusion of a shared address became too much, a new road name was selected: Gauss Way, in honor of Carl Friedrich Gauss, significant to both mathematicians and space scientists.

MSRI chose to become 17 Gauss Way in a nod to an early achievement in mathematics by a young Gauss: proving that one can construct a regular 17-gon with a ruler and compass via his proof of a result about "roots of unity" in number theory. It was a natural idea for MSRI to evoke, as one of the Institute's major roles is to train and encourage young mathematicians.

The 17-gon can be found at our entrance in the elegant diagram provided by Silvio Levy (shown above), as well as elsewhere in Chern Hall.

Join Us!

2024 JMM — San Francisco

Three events — No RSVP required

Mathematical Institutes Open House

Thursday, January 4, 2024
6:00–8:00 pm

San Francisco Marriott Marquis, Salons 4–6

SLMath (MSRI) Reception for Current and Future Donors

Friday, January 5, 2024
6:00–7:30pm

San Francisco Marriott Marquis, Pacific C

Journeys of Black Mathematicians

World Premiere
with the National Association of Mathematicians (NAM)

Saturday, January 6, 2024
11:30am–1:00pm

George R. Moscone Convention Center, Room 304

Questions? Contact development@slmath.org

AARON FAGERSTROM

Matthias Oberlechner (Technical University of Munich) and Ata Atay (University of Barcelona), participants in the *Mathematics and Computer Science of Market and Mechanism Design* program, work in the Berlekamp Garden at SLMath.

Forthcoming **Workshops**

Dec 4–8, 2023: Hot Topics: Recent Progress in Deterministic and Stochastic Fluid-Structure Interaction

Jan 18–19, 2024: Connections Workshop: Commutative Algebra

Jan 22–Jan 26, 2024: Introductory Workshop: Commutative Algebra

Feb 1–2, 2024: Connections Workshop: Noncommutative Algebraic Geometry

Feb 5–Feb 9, 2024: Introductory Workshop: Noncommutative Algebraic Geometry

Mar 11–15, 2024: Hot Topics: Artin Groups and Arrangements — Topology, Geometry, and Combinatorics

Apr 8–12, 2024: Recent Developments in Noncommutative Algebraic Geometry

Apr 15–19, 2024: Recent Developments in Commutative Algebra

May 1–3, 2024: Advances in Lie Theory, Representation Theory, and Combinatorics: Inspired by the work of Georgia M. Benkart

2024 Summer Activities

Jun 15–Jul 27, 2024: MSRI-UP 2024: Mathematical Endocrinology

Jun 10–Jul 12, 2024: Summer Research in Mathematics

Jun 24–Jul 5, 2024: ADJOINT

For more information about any of SLMath's scientific activities, please see slmath.org/scientific-activities.

2024 Summer Graduate Schools

See page 18 for a list of all 2024 Summer Graduate School activities and nominations, or see slmath.org/summer-schools.