Institute for Pure and Applied Mathematics, UCLA

Annual Progress Report for 2023 – 2024
Award #1925919
August 7, 2024

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EXECUTIVE SUMMARY

This report covers our activities from June 17, 2023 through June 15, 2024 (which we refer to as the reporting period). This report includes the 2023 summer research programs (RIPS and GRIPS). The 2024 summer programs are underway at the time of reporting and will be included in the next annual report.

IPAM held two long programs in the reporting period:

- Mathematical and Computational Challenges in Quantum Computing (September 11 - December 15, 2023)
  - Workshop I: Quantum Algorithms for Scientific Computation (October 2 - 6, 2023)

  - Workshop II: Mathematical Aspects of Quantum Learning (October 16 - 20, 2023)
  - Workshop III: Many-body Quantum Systems via Classical and Quantum Computation (November 6 - 9, 2023)
  - Workshop IV: Topology, Quantum Error Correction and Quantum Gravity (November 27 - December 1, 2023)
- Geometry, Statistical Mechanics, and Integrability (March 11 - June 14, 2024)
  - Workshop I: Statistical Mechanics and Discrete Geometry (March 25 - 29, 2024
  - Workshop II: Integrability and Algebraic Combinatorics (April 15 - 19, 2024
  - Workshop III: Statistical Mechanics Beyond 2D (May 6 - 10, 2024)
  - Workshop IV: Vertex Models: Algebraic and Probabilistic Aspects of Universality (May 20 - 24, 2024)

IPAM held the following workshops in the reporting period:

- Symmetric Tensor Categories and Representation Theory (January 8 - 12, 2024)
- Mathematical Foundations for Equity in Transportation Systems (January 22 - 26, 2024)
- Tensor Networks (February 5 - 9, 2024)
- Mathematical Approaches for Connectome Analysis (February 12 - 16, 2024)
- EnCORE Workshop on Computational vs Statistical Gaps in Learning and Optimization (February 26 - March 1, 2024)

IPAM held the following Thematic Schools:

- Winter School on Quantum Information Science for Chemistry (February 20-23, 2024), organized in collaboration with the NSF Challenge Institute for Quantum Computation (CIQC) and the Advanced Molecular Architectures for Quantum Information Science (AMAQIS).

Furthermore, the following public lectures were organized during this period:

- Green Family Lecture Series: Peter Shor gave two talks, “Quantum Computing” and “The Development of Quantum Error Correction” (November 27 - 28, 2023)
- Green Family Lecture Series: Hugo Duminil-Copin gave two talks, “From Coffee to Mathematics: Making Connections and Finding Unexpected Links” and “Critical phenomena through the lens of the Ising model” (May 20 - 21, 2024)

During the reporting period, IPAM hosted the following special events and conferences:

- Applied Mathematics skills Improvement for Graduate studies Advancement (AMIGAs) (July 10 - 14, 2023)
- Research Collaboration Workshop, “Women in Data Science and Mathematics” (WiSDM) (August 7 - 11, 2024)
- Research in Industrial Projects for Students (RIPS) Celebration 2023 (August 18, 2023)
- PUNDiT: Practicum for Undergraduates in Number Theory (October 21 - 22, 2023)
- PUMA: Practicum for Undergraduate MAthematicians in Combinatorics (April 13 - 14, 2024)

- International Conference on Multiscale Modeling and Simulation based on Physics and Data (April 25 - 26, 2024)

IPAM typically invites participants from each of our past long programs to two reunion conferences; the first is held a year and a half after the conclusion of the long program, and the second is held one year after the first. During the current reporting period, we were able to bring together several of these cohorts for an opportunity to reconnect and reflect on collaborations that followed since they attended the long programs. These conferences and culminating workshops were held at the UCLA Lake Arrowhead Conference Center.

- Geometry, Statistical Mechanics, and Integrability Culminating Workshop (June 9 - 14, 2024)
- Computational Microscopy Reunion Conference I (June 9 - 14, 2024)
- Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy Reunion Conference II (June 9 - 14, 2024)
- Mathematical and Computational Challenges in Quantum Computing Culminating Workshop (December 10 - 15, 2023)
- Machine Learning for Physics and the Physics of Learning & Advancing Quantum Mechanics with Mathematics and Statistics Reunion Conference I (December 10 - 15, 2023)
- Tensor Methods and Emerging Applications to the Physical and Data Sciences Reunion Conference II (December 10 - 15, 2023)

All RIPS and G-RIPS student research programs were held in-person in summer 2023. This report includes all four programs:

- Research in Industrial Projects for Students at IPAM (RIPS), Los Angeles, CA
- Research in Industrial Projects for Students in Singapore (RIPS-SP)
- Graduate-level RIPS (G-RIPS) in Sendai, Japan
- Graduate-level RIPS (G-RIPS) in Berlin, Germany

A. PARTICIPANT LIST

A list of all participants in IPAM programs will be provided to NSF in electronic form (Excel). The list will include participants for programs whose start dates fall between June 17, 2023 through June 15, 2024.

B. FINANCE SUPPORT LIST

A list of participants that received support from IPAM will be provided to NSF in electronic form (Excel). The list includes all funded participants of programs that occurred between June 1, 2023 through May 31, 2024.

C. INCOME AND EXPENDITURE REPORT

Grant # DMS 1925919:
This table shows appropriations and expenses for June 1, 2023 through May 31, 2024 for grant #1925919.

	A	B	C	D	E	F
			A-B=C		B+D=E	A-E=F
Budget Category	Appropriation Year 4	Actual Expenses	Balance	Encumbered Expenses as of May 2024	Total & Encumbered Expenses as of May 2024	Encumbered Balance as of May 2024
A. Operations Fund	$2,003,333	$1,972,591	$30,742	$368,457	$2,341,048	($337,715)
B. Participant Costs	$1,900,000	$2,070,204	($170,204)	$108,743	$2,178,947	($278,947)
C. Indirect Costs	$1,096,667	$1,055,233	$41,433	$0	$1,055,233	$41,434
Totals	**$5,000,000**	**$5,098,029**	**($98,029)**	**$477,200**	**$5,575,229**	**($575,229)**

During Year 4, Operational Costs (e.g., salaries, benefits, equipment, supplies) were steady at $2,341,048. Participant Support Costs (e.g., stipends, travel, housing, and subsistence for the scientists working on IPAM Programs) were at a healthy level of $2,178,948. Indirect Costs rates are based on current facilities and administrative cost rates negotiated with the Federal government and the University of California. IPAM's work is conducted at an on-campus location which is subject to a 56% facilities and administrative cost rate. Indirect costs are not applied to equipment and participant support costs.

Also, due to the COVID-19 pandemic, a reunion conference planned for the first two years of the grant was moved to Year 4.

Registration fees for NSF-supported conferences are accounted for as program income. IPAM charges modest registration fees primarily to discourage non-serious registrations. Registration fees for workshops are $75 for faculty and government/military participants, $100 for industry participants, $50 for post-doctoral scholars and $25 for graduate students. During this reporting period, the in-person workshop registration fees collected were $29,260 and waived for online programs. All program income collected is spent entirely on participant support expenses.

D. POSTDOCTORAL PLACEMENT LIST

IPAM did not appoint postdoctoral fellows in 2023-24, so we have no data to report in this section.

E. MATH INSTITUTE DIRECTORS' MEETING REPORT

MIDS Meeting 2024

April 27, 2024
Pasadena, CA

Present
Brian Conrey (AIM)
Sergei Gukov (AIM)
Michelle Manes (AIM)
Leslie Hogben (AIM)
David Crombecque (AIM)
Helmut Hofer (IAS)
Brendan Hassett (ICERM)
Ulrica Wilson (ICERM)
Kevin Corlette (IMSI)
Bo Hammer (IMSI)
Selenne Bañuelos (IPAM)
Christian Ratsch (IPAM)
Dima Shlyakhtenko (IPAM)
Hélène Barcelo (SLMath)
Tatiana Toro (SLMath)
David Manderscheid (NSF)
Marian Bocea (NSF)
Stefaan De Winter (NSF)
Joanna Kania-Bartoszynska (NSF)
Stacey Levine (NSF)
Jodi Mead (NSF)
Yong Zeng (NSF)

Agenda
8:30 Refreshments
9:00 Welcome and introductions
9:15 DMS update by the Division Director, David Manderscheid
9:40 NSF Branding policy
9:50 Feedback about PRIMES
10:15 Break
10:30 Updates from the institutes about how collaboration between Institutes works
10:45 Timeline for the Institutes competition
11:00 Update from the Institutes about finances
11:15 Update about mathinstitutes.org
11:30 Other business
12:00 Lunch

Minutes

I. DMS update by the Division Director, David Manderscheid:

DMS Division Director gave an update on recent developments at the NSF Division of Mathematical Sciences.

- **Joanna Kania-Bartoszynska** is now the Science Advisor for DMS.

- **National Institute for Theory and Mathematics in Biology** (NITMB), a collaboration between Northwestern and the University of Chicago supported by NSF and the Simons Foundation, is off to a fantastic start. Ribbon cutting for NITMB will be after the election.

- **NSF budget** is $9.1 billion in FY 2024, down from $9.9 billion last year. Programs do not yet have their final budgets for this year and have been told to be cautious in spending until they do. One likely result is a lower success rate for single-investigator grants. The budget for next year remains uncertain.

- **New Initiatives** include:

    - A lot of activity in mathematical biology including a Program Day with other agencies on "digital twins" and two new solicitations Foundational Aspects of Digital Twins and use of digital twins in biomedical devices.

    - Overall, we see broader federal funding of mathematics, meaning that the percent of mathematics funded by NSF is down.

    - There continues to be momentum behind AI, interactive theorem provers, and the use of tools like DeepMind to make conjectures. The new solicitation AIMing (Artificial Intelligence, Formal Methods, and Mathematical Reasoning) came out in March.

    - Quantum Information Science continues to be supported.

    - The RTG solicitation is under revision. This is one of the longest standing "non core" programs and is undergoing a substantial revision to more closely align with NSF's mission.

A question was raised as to whether NITMB should join the Institutes, for example at MIDS meetings, as part of the Diversity Committee, or on the mathinstitutes.org website. It was noted that NITMB is funded as a cooperative agreement, not as a grant, so the oversight from NSF works differently. Ultimately, this was left up to the Institute Directors to discuss and make a decision.

II. NSF Branding Policy update by Yong Zeng:

NSF has released a new branding policy, and we can anticipate more scrutiny about following the NSF policy. The full policy was described, and three points were highlighted: The new NSF logo in full color should be used, we should be careful about award acknowledgement, and newsletters and other communications should make NSF funding clear and visible.

Several questions were discussed, including whether the Institutes are considered "facilities," which under the new branding policy would require the NSF logo on buildings and structures. Program Officers clarified fine distinctions between "center" and "institute," and clarified that we do not need to make major changes to buildings.

The Institutes requested a concise version of what should be done to be compliant with the award, and POs said they could work on that.

III. Feedback on the PRIMES program by Institutes:

Program Officers set the context by reminding everyone of the overarching goal of the PRIMES program: to increase participation in Institute activities by faculty from Minority Serving Institutions and HBCUs. They pointed out that each Institute that had submissions in the first round had at least one awardee. They

encouraged Institutes to be flexible in accommodating PRIMES awardees, for example by reserving some slots in long programs for PRIMES awardees. They then invited feedback from the Institutes on how the program has been going.

Overall reaction was very positive, including praise for the fast turnaround time on decisions, which is important to work with Institute timelines. In particular, for many PIs, their ability to participate in these programs is contingent on getting the award, so having quick decisions is crucial in their planning.

Other feedback is that having two target dates per year is fantastic, as it allows greater flexibility for PIs applying to participate in either spring or fall programs.

Institutes are working with organizers of their programs to find potential PRIMES applicants. This has become part of the planning for programs. There have been a lot of great outcomes, including PRIMES PIs bringing along students from their institutions to participate in some of the programs.

One point of discussion was the additional workload that Institute staff are shouldering in helping the PIs to get their proposals submitted. This challenge is especially hitting AIM. Since they do not have the filter of a research match with a long program, there are many more potential PIs during each grant cycle, and this involves significant time from Institute staff to coordinate.

III. Update from the Institutes on Collaborations:

Institutes described several areas of collaboration. The Diversity Committee and the MSIDI collaborative grant are an obvious place in which all of the Institutes work together.

Past and current examples of intentional collaboration include the 2013 “Mathematics of Planet Earth” which involved all of the Institutes. Currently the Research Experiences for Undergraduate Faculty is a collaboration between AIM and ICERM. During the workshop, the programs of all of the Institutes are highlighted, and working groups are encouraged to apply for follow-up SQuaRE or Collaborate@ICERM activities.

The mathinstitutes.org website is another area of collaboration in which all of the Institutes contribute highlights, videos, and program listings.

Program Officers asked if there was some mechanism for making sure Institutes are not vying for the same participants or considering programs in very similar areas on similar timelines. The consensus is that the Institutes’ timelines and approval processes are all different, and that sharing proposals prior to approval would be complicated both in terms of timing and in terms of intellectual property concerns. There was concern about sharing of proposals with other Institutes before they are polished, and there is a short timeline between submission and Scientific Board meetings for almost all of the Institutes.

Institutes also pointed out that the extent to which they run similarly-themed programs is a response to the demands of the mathematics community, what is being proposed and where the energy is in terms of new research directions.

Because of a recent experience where the same organizers did propose workshops at multiple Institutes, the Institutes running long programs have included a kind of “current and pending” document as part of their application process to ask what other programs the organizers have applied to. Institute Directors agreed to continue thinking about these questions.

IV. Timeline for the Institutes Competition from DMS Program Officers:

Proposals were submitted on March 14. The panel will meet sometime in early summer, and decisions will be made about declining proposals or recommending them for further review. In early fall, there will be site visits to the Institutes or reverse site visits with Institute teams coming to NSF. It has not yet been determined what kind of visit there will be, but all Institutes still in the competition will have the same kind of visit. Institutes that are recommended for funding will be in budget discussions in the winter, with awards anticipated in Summer 2025.

IV. Update from the Institutes about Finances:

IAS: No significant impact on spending due to COVID since they still funded visitors as expected.

SLMath: Anticipate about $400,000 carryover.

ICERM: Anticipate about $900,000 carryover. They spent less during COVID, but more recently visitors and participants exceed pre-COVID levels.

IPAM: Anticipate a little over $1 million carryover. They ran more summer schools and were generous with reunion conferences. This has caused an uptick in expenses recently.

IMSI: Anticipate about $1 million carryover. They are filling the calendar as much as possible.

AIM: Anticipates spending out the award with no carryover.

Institutes pointed out that some expenses have gone up dramatically: There has been an increase in postdoc stipends, and inflation has hit hotel and transportation rates after a few years of them being quite low. Several Institutes report that underspending has more to do with difficulty recruiting and maintaining staff, while spending on programs is nearly on target.

V. Update about mathinstitutes.org from Brendan Hassett:

The site has seen a lot of activity. Brendan Hassett gave specific numbers including:

- There are currently 19,834 videos indexed on the site, with 117 added in the last 30 days.
- There have been 5,179,156 video “views” with 212,917 in the last 30 days.
- There are currently 1,136 events listed, with 9 added in the last 30 days.
- There have been 141,106 events viewed.
- A total of 151 highlights are on the site, with the most recent added yesterday (two of them).
- Highlights have been viewed 178,857 times, with 6,729 views in the last 30 days.

The website is showcased at the diversity-initiative workshops so that participants know how to find out what’s going on at the Institutes.

VI. Other business:

IAS: “History of Modern Mathematics” will take place at the Institute in September. This is a collaboration with the History department and others, and will include a panel discussion. The idea is to keep track of how ideas develop and how mathematics impacts other areas of science.

SLMath: There is a new workshop series in fundamental topics.

Brendan: The ICM will be in the US in 2026, and there will be satellite conferences throughout North America. The plan is to make 2026 a "year of mathematics," and we will be talking about what that looks like and how to involve outreach activities. DMS POs noted that they expect to spend more on conferences for that Fiscal Year, and that planning is underway to support these satellite conferences and other activities.

Final comment: The MSIs are a large part of the DMS budget. When the program started, they were controversial, but they are now one of the most successful parts of the DMS portfolio.

Next year's MIDS meeting:

The 2025 meeting will be at IAS in Princeton.

--dates: April 25-26, 2025

F. PARTICIPANT SUMMARY

In this report, we are reporting on participants of programs that took place between June 17, 2023 through June 15, 2024. We have included the participants of the reunion conference. This report does not include the participants of our RIPS/G-RIPS 2024 summer programs which will be captured in the next reporting cycle.

We include registered on-line participants as well as in-person participants in all statistical computations. There have been 194 registered remote participants in IPAM events during the reporting period.

Participant Category	In-person Participants	Remote Participants	Total
Faculty	826	53	879
Government/Military	40	6	46
Graduate Student	849	92	941
Industry	181	17	198
Postdoc	334	26	360
Undergraduate Student	195	0	195
Other	5	0	5
Total Participants	**2430**	**194**	**2624**

Also note that we do not collect RSVPs or collect participants data for "Public Lectures".

When self-reporting gender, participants are asked to select one or more of the following options: "Female", "Male", "Nonbinary", "I identify as:", or to select "Prefer to not self-identify". If "I identify as:" is selected, a free-form field is available to enter gender. Three values were supplied: "Homo sapiens sapiens", "They/Them", "Dr. Anand Kumar Yadav". The codes in the table below correspond to various combinations of these possible choices. The code "D" indicates that the participant preferred to not self-identify, and as a result they were excluded

from the report. Otherwise, each choice made corresponds to addition (or omission) of the corresponding letter in the gender code:

- F: “Female”
- M: “Male”
- N: “Nonbinary”
- O: “I identify as…”

This results in 15 possible non-empty combinations, such as “F” (only “Female” is checked), “FM” (both “Female” and “Male” is checked), and so on. Combinations that did not occur this year are not listed.

Table E1: Participant Gender Distribution

Program type	Total Participants	Participant Gender Code									# Reporting
		F	FM	FN	M	MN	MO	N	NO	O	
Board Meetings	43	11			28						39
Long Programs	138	38	1	1	94						134
Reunion Conferences	93	22			64						86
Special Events and Conferences	296	123		1	156	1		2	1	1	285
Student Research Programs	238	63		3	115			1			182
Subworkshops	112	32	1	1	75						109
Workshops	1704	482	8	8	1139	4	2	5			1648
Total	**2624**	**771**	**10**	**14**	**1673**	**5**	**2**	**8**	**1**	**1**	**2485**
Percent of # Reporting (%)		31.03%	0.40%	0.56%	67.32%	0.20%	0.08%	0.32%	0.04%	0.04%	94.63%

Participants were also asked to self-identify as members of certain underrepresented ethnic groups; it was possible to select more than one option.

Table E2: Participant Ethnicity Distribution						
Program type	Total Participants	Underrepresented Ethnic Groups				# Reporting
		Pacific Islander	Amer Indian	Black	Hispanic	
Board Meetings	43	1	0	3	6	37
Long Programs	138	0	1	1	7	122
Reunion Conferences	93	0	0	2	3	72
Special Events and Conferences	296	1	1	26	68	272
Student Research Programs	238	3	0	14	17	179
Subworkshops	112	0	1	0	7	102
Workshops	1704	0	7	21	119	1539
Total	**2624**	**5**	**10**	**67**	**227**	**2323**
Percent of # Reporting (%)		0.22%	0.43%	2.88%	9.77%	88.53%

G. POSTDOCTORAL PROGRAM SUMMARY

A total of 360 postdocs participated in IPAM's programs during the reporting period (June 17, 2023 - June 15, 2024). See tables F1 and F2 below.

Program type	Total Participants	Participant Gender Code				# Reporting
		F	M	MO	N	
Long Programs	23	8	15	0	0	23
Reunion Conferences	25	4	17	0	0	21
Special Events and Conferences	14	4	10	0	0	14
Student Research Programs	12	3	8	0	0	11
Subworkshops	18	8	10	0	0	18
Workshops	268	80	176	1	2	259
Total	**360**	**107**	**236**	**1**	**2**	**346**
Percent of # Reporting (%)		30.92%	68.21%	0.29%	0.58%	96.11%

Table F2: Postdoctoral Ethnicity Distribution						
Program type	Total Participants	Underrepresented Ethnic Groups				# Reporting
		Pacific Islander	Amer Indian	Black	Hispanic	
Long Programs	23	0	0	0	0	19
Reunion Conferences	25	0	0	0	2	17
Special Events and Conferences	14	0	0	1	3	14
Student Research Programs	12	0	0	0	0	11
Subworkshops	18	0	0	0	0	17
Workshop	268	0	0	1	9	235
Total	**360**	**0**	**0**	**2**	**14**	**313**
Percent of # Reporting (%)		0.00%	0.00%	0.64%	4.47%	86.94%

H. GRADUATE STUDENT PROGRAM SUMMARY

As with previous years, a robust number of graduate students participated in IPAM's workshops and long programs during the reporting period, as well as in Graduate-level RIPS. A few participated in RIPS-LA as academic mentors. Graduate students often find a compelling thesis topic at an IPAM program, and also frequently make contacts that lead to their first jobs. See table G or further breakdown.

Table G1: Graduate Student Gender Distribution

Program type	Total Participants	Participant Gender Code								# Reporting
		F	FM	FN	M	MN	MO	N	O	
Long Programs	49	12	1	1	35					49
Reunion Conferences	24	7			17					24
Special Events and Conferences	104	48			51	1	1	1	1	103
Student Research Programs	23	9			13		1			23
Subworkshops	47	11	1	1	34					47
Workshops	694	198	8	7	466		3			682
Total	941	285	10	9	616	1	5	1	1	928
Percent of # Reporting (%)		30.71%	1.08%	0.97%	66.38%	0.11%	0.54%	0.11%	0.11%	98.62%

Table G2: Graduate Student Ethnicity Distribution

Program type	Total Participants	Underrepresented Ethnic Groups			# Reporting
		Amer Indian	Black	Hispanic	
Long Programs	49	0	1	3	44
Reunion Conferences	24	0	1	0	21
Special Events and Conferences	104	1	6	22	96
Student Research Programs	23	0	1	0	23
Subworkshops	47	0	0	3	42
Workshops	694	0	9	60	632
Total	941	**1**	**18**	**88**	**858**
Percent of # Reporting (%)		0.12%	2.10%	10.26%	91.18%

I. UNDERGRADUATE STUDENT PROGRAM SUMMARY

Typically, undergraduate students participate in RIPS-LA, RIPS-Singapore, and RIPS Projects Day. However, we saw a number of undergraduate students attend other programs at IPAM during the reporting period.

Table H1: Undergraduate Student Gender Distribution

Program type	Total Participants	Participant Gender Code				# Reporting
		F	FN	M	N	
Special Events and Conferences	89	37	1	47	1	86
Student Research Programs	106	45	3	52		100
Total	195	82	4	99	1	186
Percent of # Reporting (%)		44.09%	2.15%	53.23%	0.54%	95.38%

Table H2: Undergraduate Student Ethnicity Distribution

Program type	Total Participants	Underrepresented Ethnic Groups			# Reporting
		Amer Indian	Black	Hispanic	
Special Events and Conferences	89	0	9	25	83
Student Research Programs	106	0	9	12	97
Total	**195**	**0**	**18**	**37**	**180**
Percent of # Reporting (%)		0.00%	10.00%	20.56%	92.31%

J. PROGRAM DESCRIPTION

STUDENT RESEARCH PROGRAM

Graduate Research in Industrial Projects for Students (G-RIPS), Berlin, Germany
June 19 - August 11, 2023

Graduate-Level Research in Industrial Projects for Students (G-RIPS) in Berlin offers graduate students in mathematics and related disciplines the opportunity to work on industry-sponsored research problems. Students from the U.S. and Germany work on cross-cultural teams on three research problems designed by the industrial sponsor. The projects are of serious interest to the sponsor and offer a stimulating challenge to students; most involve both analytic and computational work. At the end of the program, the teams present the results of their work and prepare a final report. English is the only language required for participation.

Round-trip travel to Berlin and accommodations in Berlin are included. Students also receive a meal allowance and a stipend of $4,000. (These terms apply to U.S. participants recruited by IPAM.)

Five U.S. students participated in G-RIPS Berlin in 2023 together with four European students. Each team consists of two US students and two European students (one US student worked separately with a research group at MODAL). The students worked on projects that were sponsored by some of the most important companies in Germany. This year, the list of industrial partners included Cray Germany GmbH, Biotronic GmbH/1000shapes GmbH, and FICO and Gurobi Optimization.

2023 INDUSTRY PARTNERS	PROJECT TITLES
Cray Germany/HPE	Evaluating the Compiler Optimization Capabilities on Next-Generation Hardware
1000shapes GmbH	Shape Model Benchmark for Defect Reconstruction
LBW	Electric Bus Scheduling

Cray Germany/HPE Project

Project Title: Evaluating the Compiler Optimization Capabilities on Next-Generation Hardware
Project Description: In 2023, a first generation of non-GPU hardware for data-parallel processing combined with compiler-assisted optimization techniques at runtime become available on the market. For the code developer the question arises, how well this concept works in practice, which kind of kernels are best suited for this hardware, and more important, which optimization steps the compiler and runtime system is applying.

The project goal is a characterization of the compiler/runtime capabilities, the robustness of the toolchain, and the relative performance improvements through the automated mechanisms. For the later, a suitable metric is defined within the project.

1000shapes GmbH Project

Project Title: Non-rigid registration of 3D shape priors to sparse or incomplete data
Project Description:
Motivation- Shape models (including Statistical Shape Models – SSMs) play a crucial role in various applications, such as defect completion, 3D shape estimation from sparse measurement data, or general statistical analysis. A Statistical Shape Model can be regarded as a population based deformable shape prior that can been generated from many observations. Such a prior does represent the average shape of such an observation including anatomical variation in shape. Using SSMs for a match to given individual data became increasingly popular, e.g., in orthopedics where normally shaped anatomical priors are compared to pathological anatomy of individual patients in order to assess deviations between the two states or to propose corrections that lead to more normal/healthy states. Therefore, SSMs may provide a suitable shape prior to assess anomalies and to guide patient specific surgical reconstruction or individualized implant designs. The driving question is “How much information does a pathological, maybe incomplete anatomical structure give us in view of its unknown native state?”. This is an ill-posed inverse problem which can be solved by using shape priors.

Traditional methodologies have shown great success but also some limitations. Novel methods that utilize non-linear shape spaces or neural network techniques, however, are mathematically and computationally challenging and subject of current research. Your task in this project will be to explore where and how those new approaches can make some impact in the above-mentioned applications.

Task - Within this project we aim to reconstruct patient specific native anatomical regions which are unknown due to pathologies or incomplete data with the help of SSMs. Several SSMs can be investigated for an estimation of a native anatomical approximation by mathematical optimization of a shape fitting process. Therefore, a comparison of different shape modeling frameworks and an evaluation of the respective fitting accuracies need to be undertaken. Besides standard affine registration approaches such as variants of iterative closest points (ICP) or coherent point drift (CPD), we are primarily interested in non-rigid registration such as non-rigid ICP or Gaussian process morphable models, and particularly in SSM-based approaches. The following frameworks are potentially suitable for comparison:

- ZIB/1000shapes SSMs
- Statismo and Scalismo
- ShapeWorks
- Mesh Monk
- FlowwSSM
- Deformetrica
- Morphomatics

Data - Different approaches can be tested on a large variety of anatomical shapes, such as pelvic bones, jaw bones, knee bones and many more that have been derived and geometrically reconstructed from tomographic image data. In addition, we can also provide facial surface data that have been captured with stereophotogrametry.

Aims - A team of 4 G-RIPS students will collaborate on this topic, however, with a challenging aspect of competition.

Besides a common general understanding of SSMs, each student shall make him- or herself familiar with a different approach, where at least one (better two) student(s) shall evaluate neural flow SSMs. The different approaches and the respective results will then be compared and presented. The best approach will be awarded.

LBW

Project Title: Electric Bus Scheduling
Project Description: Electric busses are used in more and more public transit companies in order to provide emission free public transport. Their operation, however, poses several challenges, in particular, limited range, long charging times, limits on the total amount of energy that is available for charging at any time, and energy prices that fluctuate and/or are related to the peak load.

What is the best strategy to deploy ebusses? Should one prefer large over small batteries, is depot charging better than opportunity charging, and what is a good charging strategy? Such questions can be assessed by using mathematical optimization methods. In fact, the electric bus scheduling problem can be seen as a multicommodity flow problem with additional side constraints on the state of charge of the batteries and the loading facilities.

In this G-RIPS project, we want to work on mathematical optimization approaches to electric bus scheduling. Analyzing and visualizing data, setting up mathematical models, designing and implementing solution approaches, and doing scenario analyses will be the main task in a collaborative work.

The project is supported by LBW Optimization GmbH, a leading supplier of optimization technology for public transit companies, whose solvers are used by hundreds of companies all over the world.

STUDENT RESEARCH PROGRAM

Graduate Research in Industrial Projects for Students (G-RIPS), Sendai, Japan
June 19 - August 8, 2023

Graduate-Level Research in Industrial Projects for Students (G-RIPS) in Japan offers graduate students in mathematics and related disciplines the opportunity to work on industry-sponsored research problems in Sendai, Japan. Students from the U.S. and Japan work on cross-cultural teams on research problems designed by industrial sponsors. The projects are of serious interest to the sponsor and offer a stimulating challenge to students; most involve both analytic and computational work. At the end of the program, the teams present the results of their work and prepare a final report. IPAM encourages the U.S. students to publish and/or present their research at conferences in the year following the program. English is the only language required for participation.

Round-trip travel to Sendai and accommodations in Sendai are included. Students also receive a meal allowance and a stipend of $4,000, and conference support to present their research. (These terms apply to U.S. participants recruited by IPAM.)

Ten U.S. students participated in G-RIPS Sendai in 2023 together with ten Japanese students. Each team consisted of two US students and two Japanese students. The students worked on projects that were sponsored by some of the most important companies in Japan. This year, the list of industrial partners included Mitsubishi, Fujitsu, IHI, and NEC.

2023 INDUSTRY PARTNERS	PROJECT TITLES
Mitsubishi	Construction of metrics for map matching between travel trajectories and map graphs (Project A)
	Novel technique to estimate wave spectra using ocean HF radar for environmental monitoring (Project B)
Fijitsu	Enhancing explainability of modern AI.

IHI	Mathematics for trajectory extrapolation using vehicle and human traffic data toward zero traffic fatalities.
NEC	Automated negotiation for supply chain management

Mitsubishi Projects A and B

Project A Title: Construction of metrics for map matching between travel trajectories and map graphs
Project A Description: In this project, students will formulate a new map-matching algorithm based on an analysis of previous studies using hidden Markov models. Some basic knowledge of elementary geometry, probability, statistics, and graph theory is desirable.

Project B Title: Novel technique to estimate wave spectra using ocean HF radar for environmental monitoring.
Project B Description: In this project, students will develop new methods to estimate the wave spectra of ocean waves based on high-frequency radar measurements. Such models are important for a number of applications ranging from disaster prevention to improving the efficiency of marine transport and the fishing industry, and more generally for environmental monitoring of the oceans.

Fijitsu

Project title: Enhancing explainability of modern AI.
Project description: Fujitsu has developed "Wide Learning": explainable AI (XAI) that combines discovery science and machine learning. In this project, students will develop an enhanced view of explanations of Wide Learning assisted by mathematics.

IHI Project

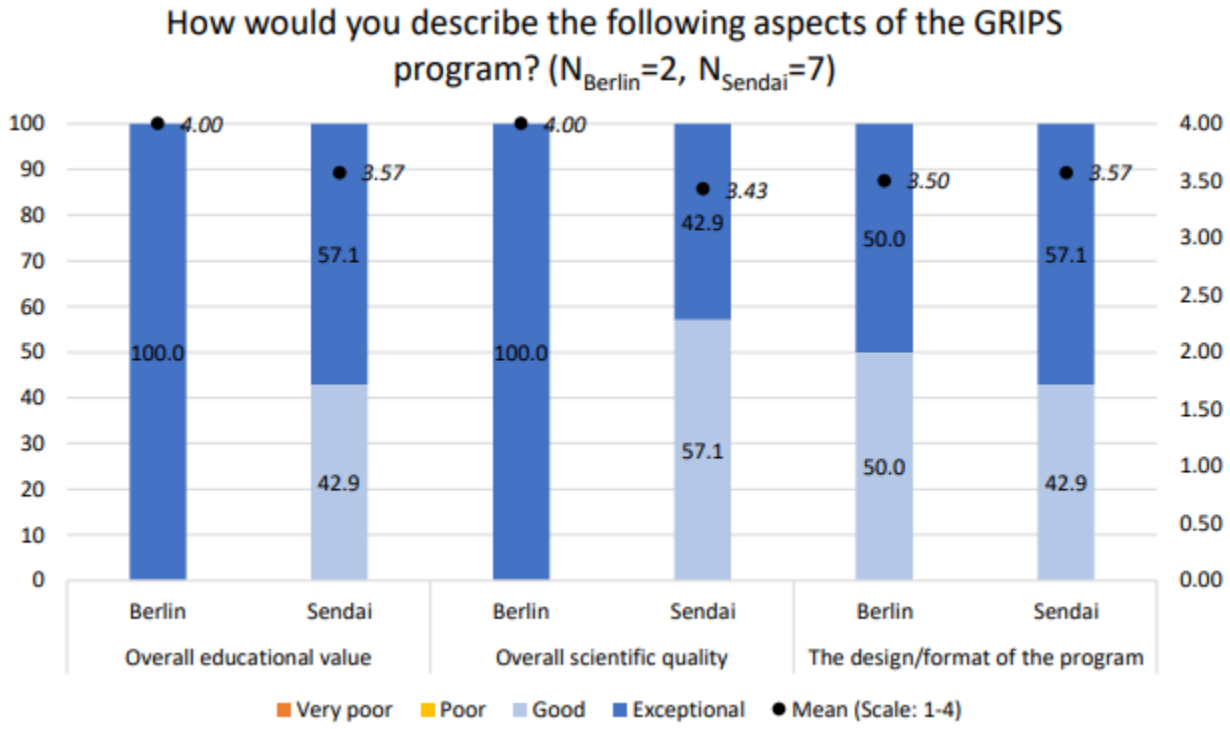
Project title: Mathematics for trajectory extrapolation using vehicle and human traffic data toward zero traffic fatalities.
Project description: IHI has developed a unique LiDAR sensor (3D Laser Radar) to support automation of industrial machinery in harsh environments with poor visibility. In this project, students will use LIDAR data to analyze and predict vehicle trajectories with the goal of improving the safety of traffic systems.

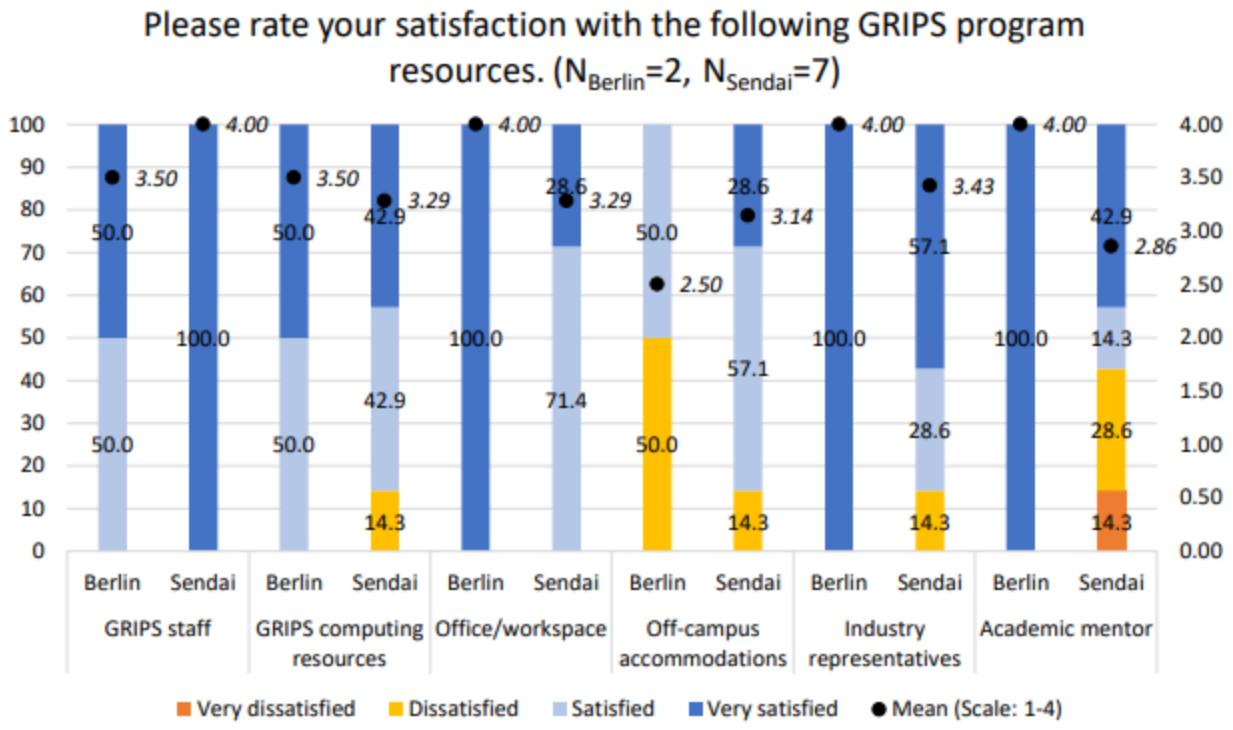
NEC Project

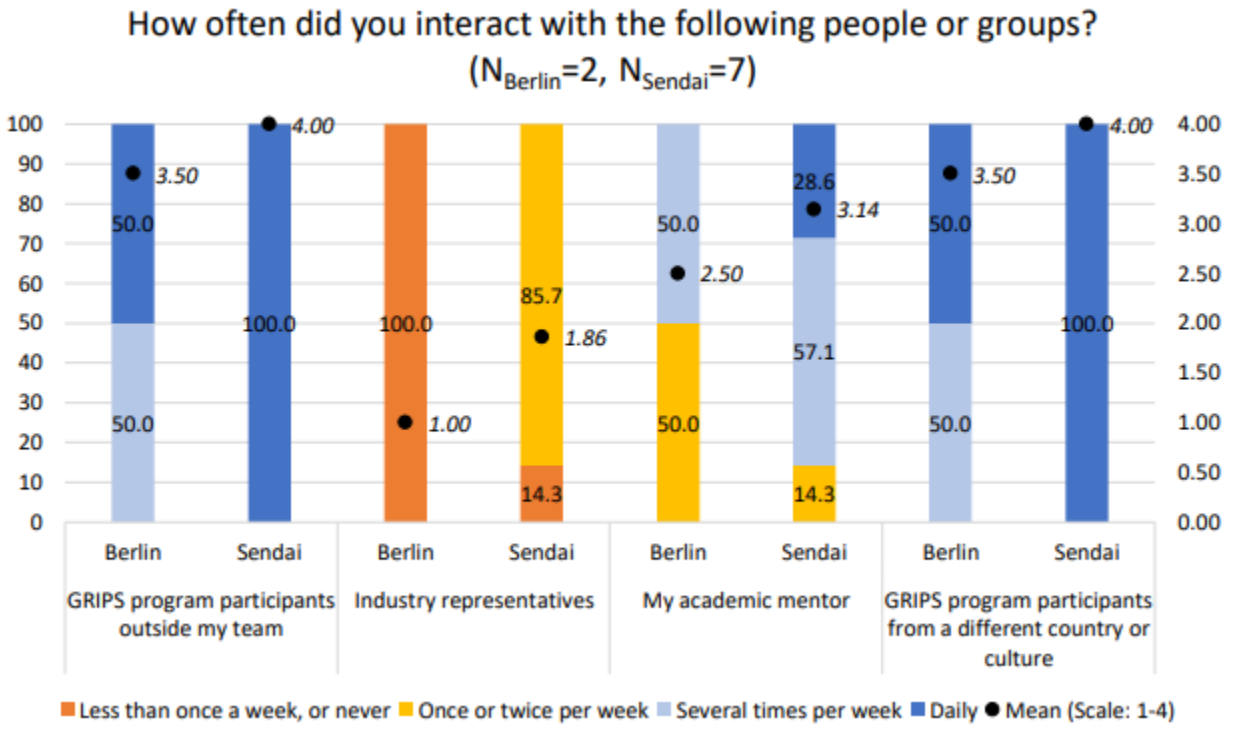
Project title: Automated negotiation for supply chain management
Project description: Supply Chain Management (SCM) is one of the most important industrial activities without which production cannot proceed. The goal of SCM is to make sure all required supplies are available when needed where they are needed at an appropriate cost. The goal of this project is to design, build and evaluate negotiation strategies to optimize supply chain management in a business-like simulation environment.

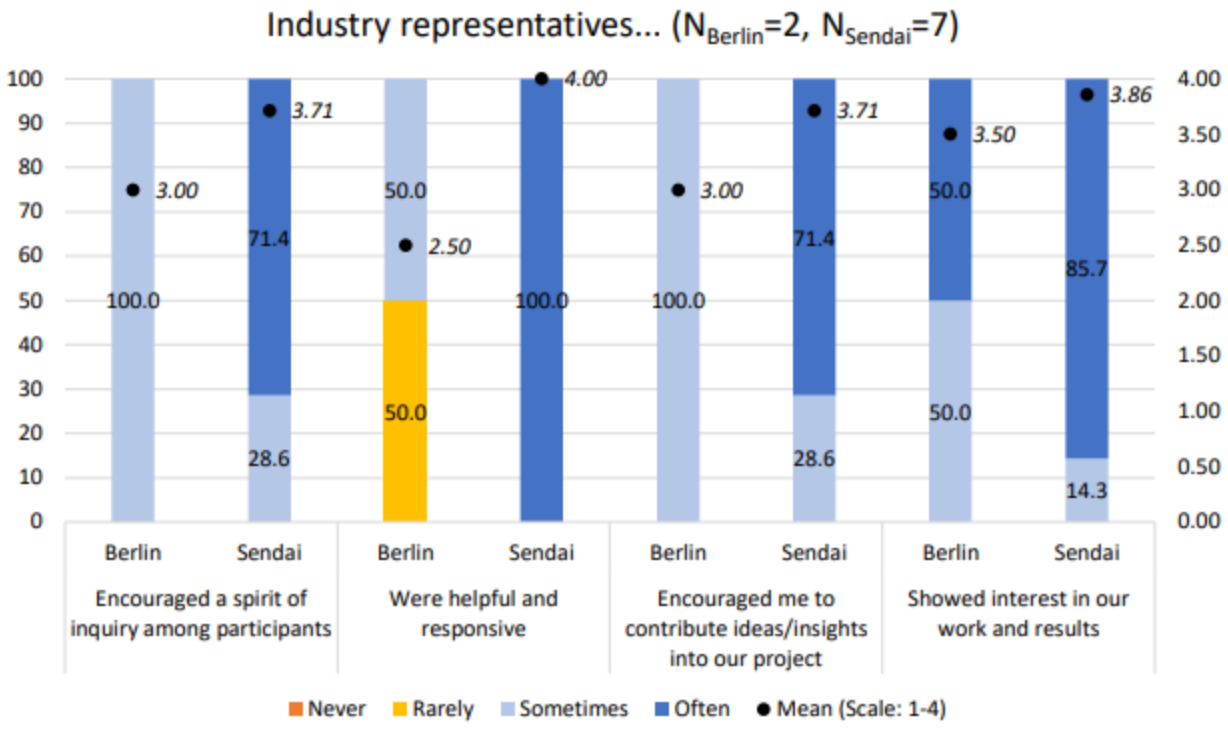
G-RIPS 2023 Participant Survey Results

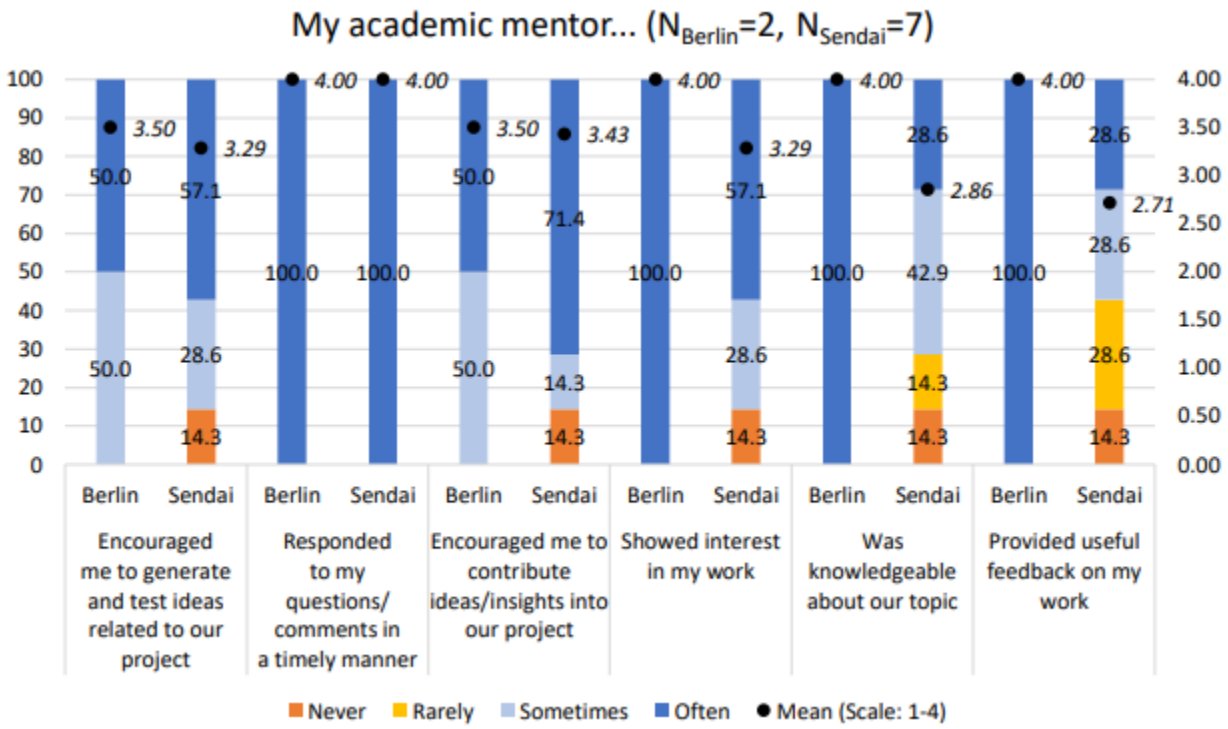
IPAM surveys G-RIPS participants (both Berlin and Sendai) both pre- and post-participation. They surveys are designed to elicit feedback from participants as well as to gauge the effectiveness of the program. A total of 11 Berlin and Sendai G-RIPS participants responded to surveys (10 pre-program, 9 post-program), with 8 completing both the pre- and post-program surveys. Chart data are disaggregated by campus and summarize their respective response frequencies and mean response scores.

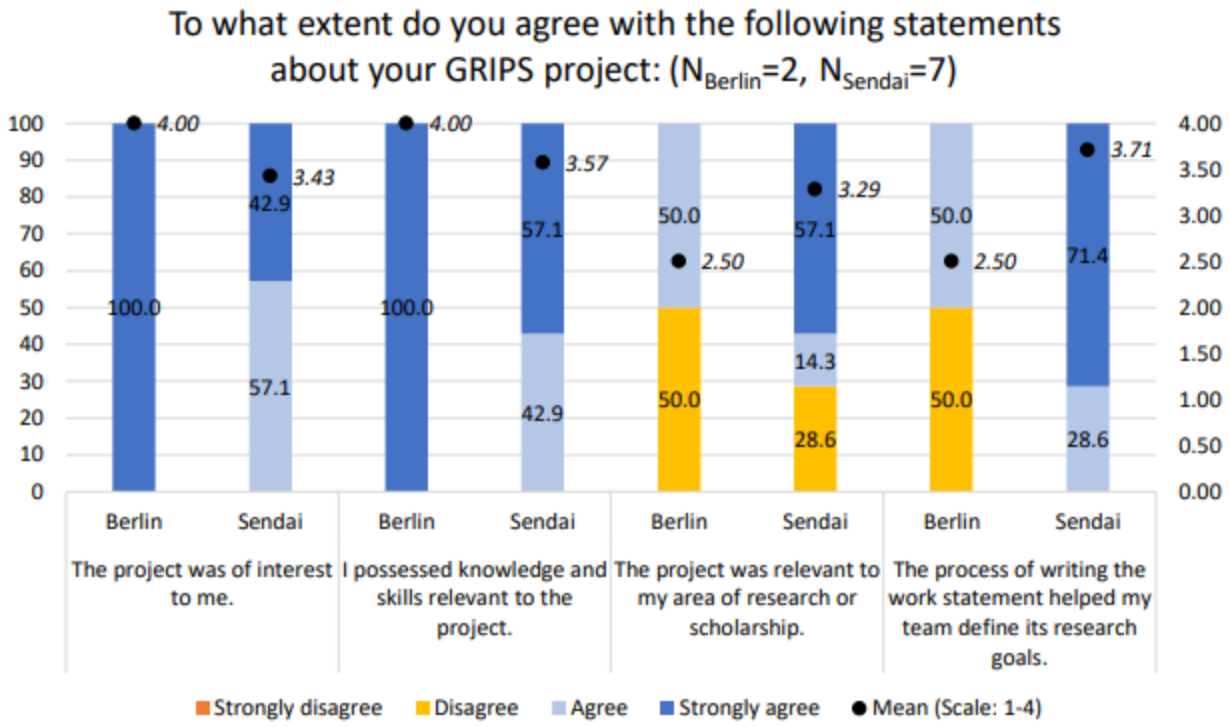


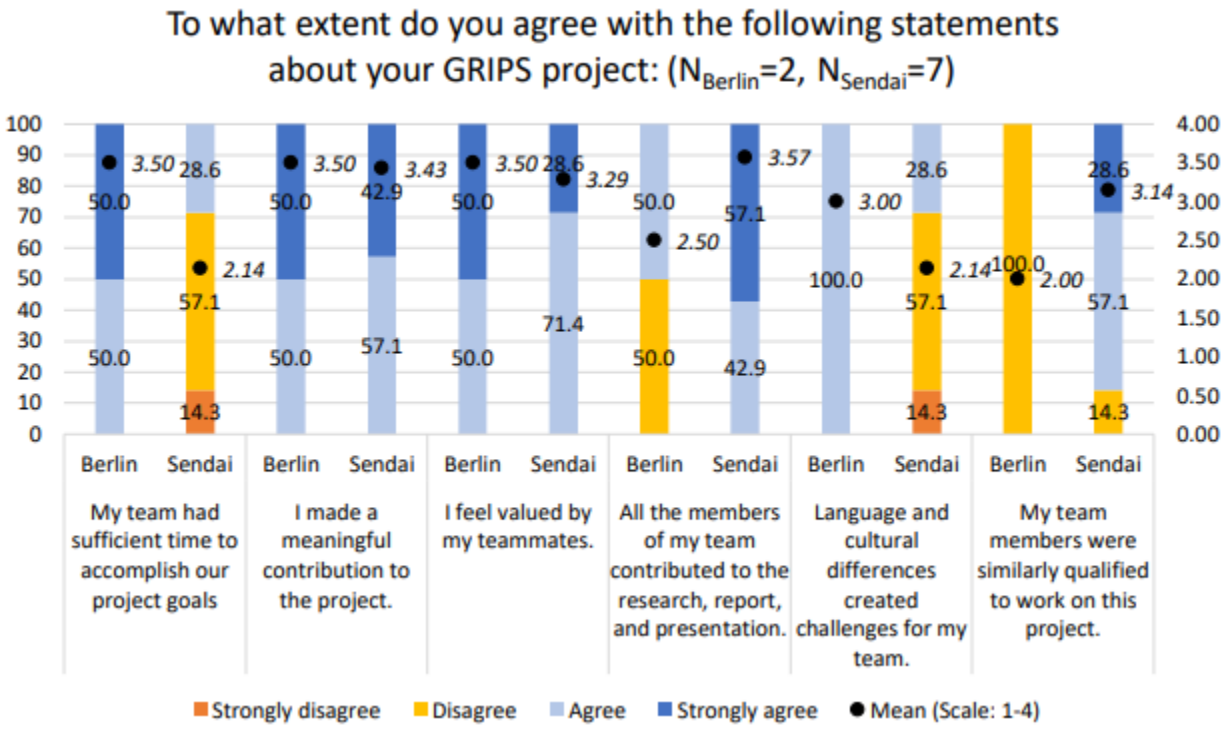

Please rate your satisfaction with the following GRIPS program resources. (N_Berlin=2, N_Sendai=7)
GRIPS staff
GRIPS computing resources
Office/workspace
Off-campus accommodations
Industry representatives
Academic mentor
Berlin
Sendai
Very dissatisfied
Dissatisfied
Satisfied
Very satisfied
Mean (Scale: 1-4)

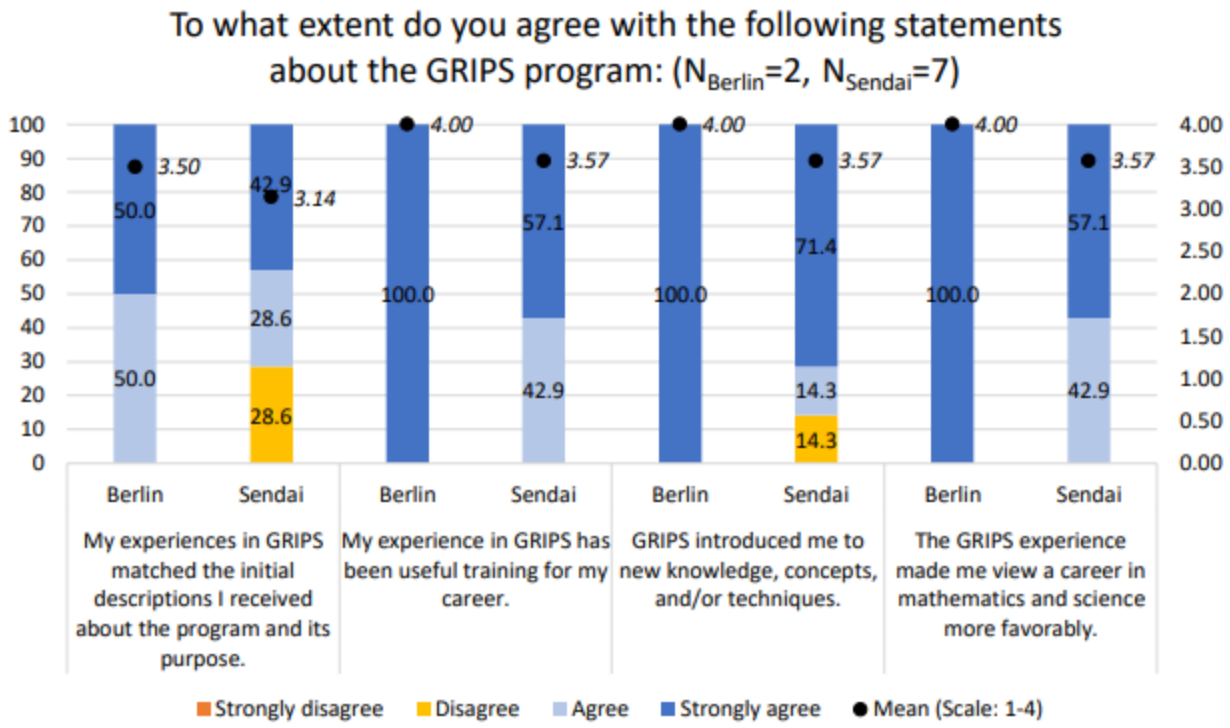

How often did you interact with the following people or groups? (N_Berlin=2, N_Sendai=7)
GRIPS program participants outside my team
Industry representatives
My academic mentor
GRIPS program participants from a different country or culture
Berlin
Sendai
Less than once a week, or never
Once or twice per week
Several times per week
Daily
Mean (Scale: 1-4)

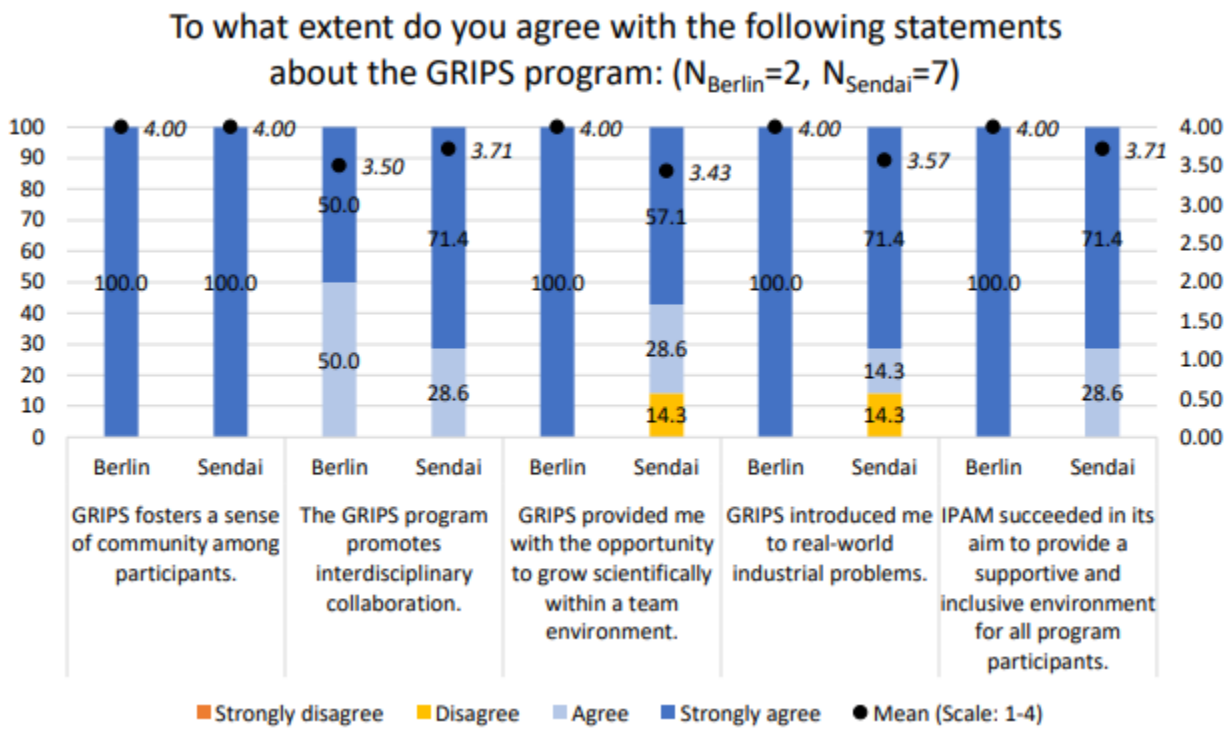

Industry representatives... (N Berlin=2, N Sendai=7)
Berlin
Sendai
Encouraged a spirit of inquiry among participants
Were helpful and responsive
Encouraged me to contribute ideas/insights into our project
Showed interest in our work and results
Never
Rarely
Sometimes
Often
Mean (Scale: 1-4)

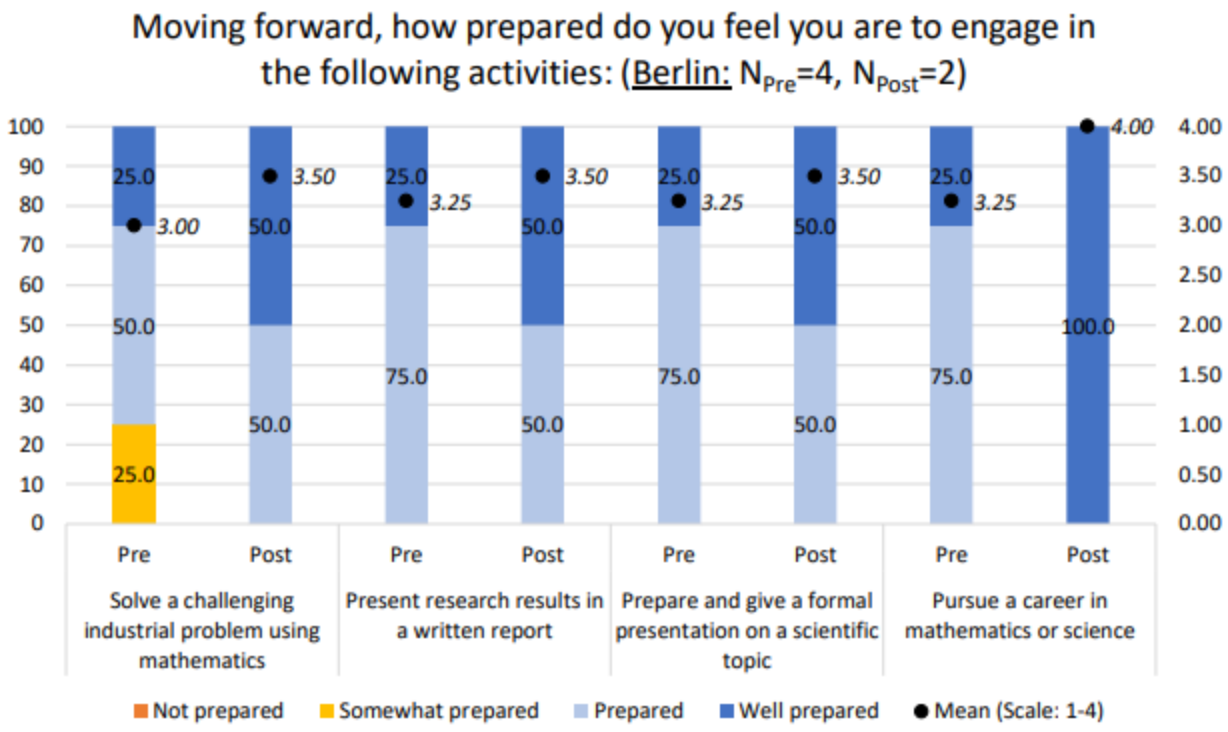

My academic mentor... (N Berlin=2, N Sendai=7)
Berlin
Sendai
Encouraged me to generate and test ideas related to our project
Responded to my questions/ comments in a timely manner
Encouraged me to contribute ideas/insights into our project
Showed interest in my work
Was knowledgeable about our topic
Provided useful feedback on my work
Never
Rarely
Sometimes
Often
Mean (Scale: 1-4)

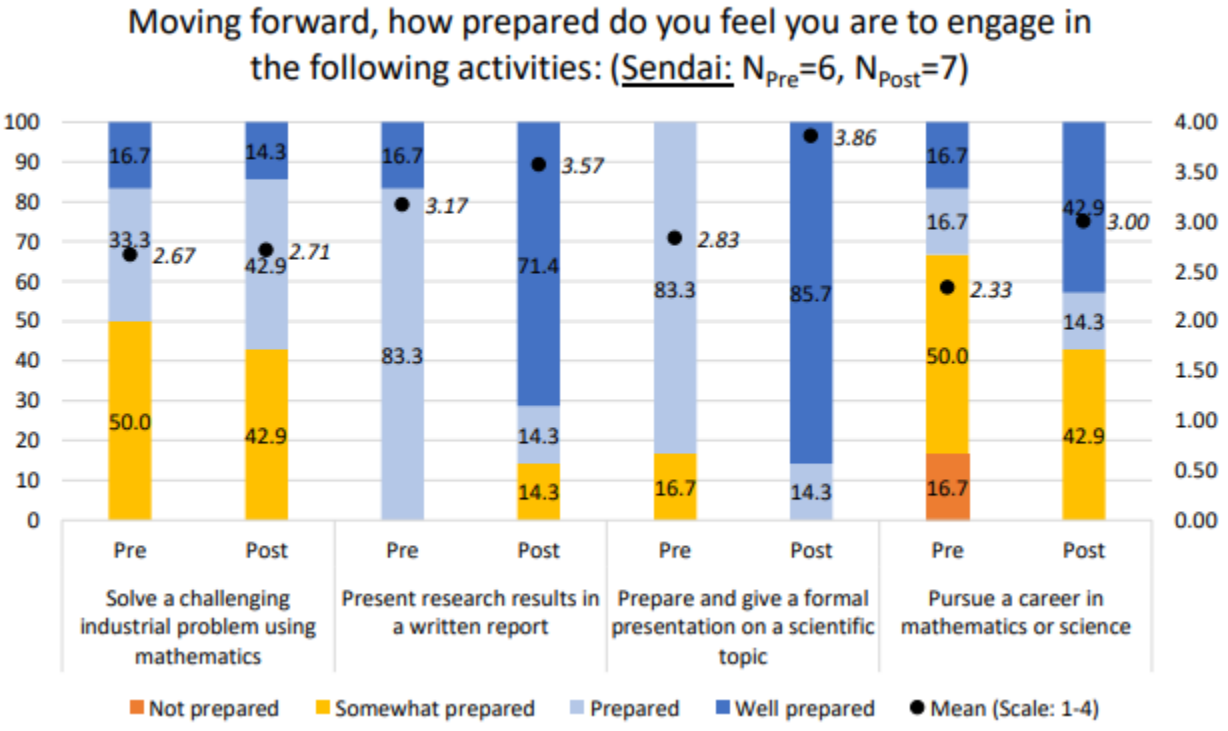

To what extent do you agree with the following statements about your GRIPS project: (N_{Berlin}=2, N_{Sendai}=7)
Berlin
Sendai
The project was of interest to me.
I possessed knowledge and skills relevant to the project.
The project was relevant to my area of research or scholarship.
The process of writing the work statement helped my team define its research goals.
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)

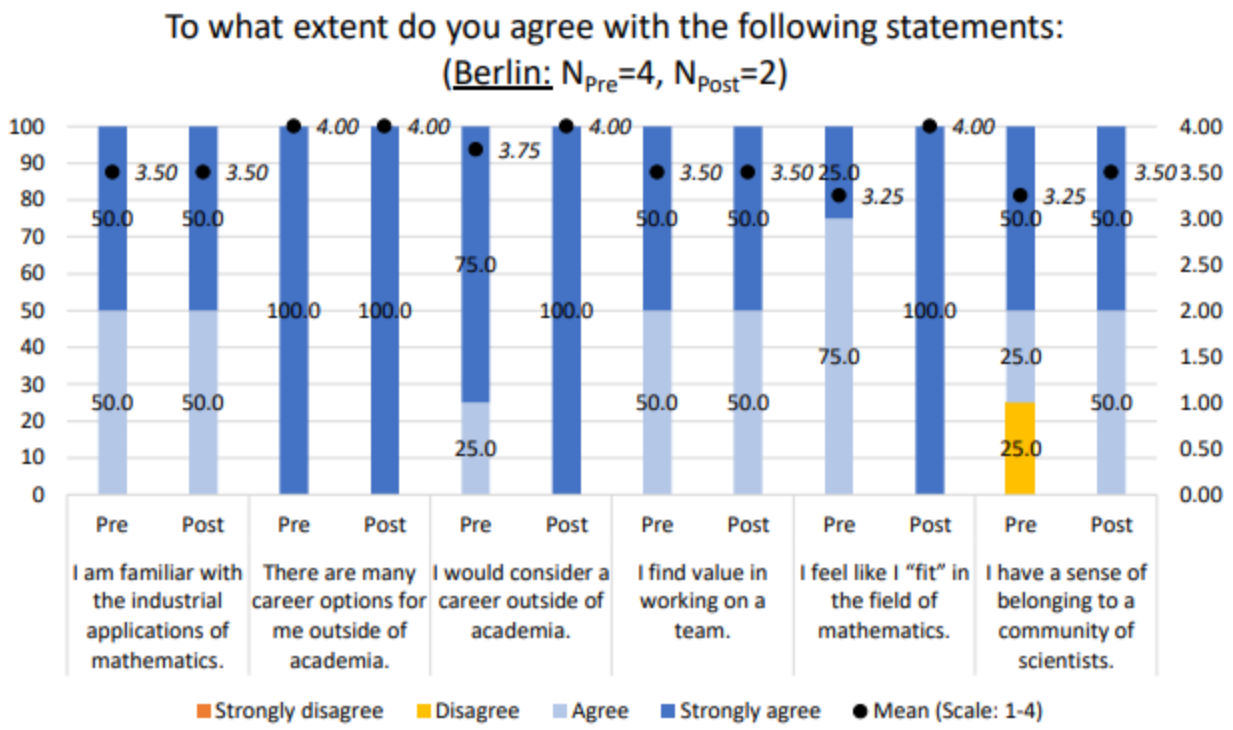

To what extent do you agree with the following statements about your GRIPS project: (N_{Berlin}=2, N_{Sendai}=7)
Berlin
Sendai
My team had sufficient time to accomplish our project goals
I made a meaningful contribution to the project.
I feel valued by my teammates.
All the members of my team contributed to the research, report, and presentation.
Language and cultural differences created challenges for my team.
My team members were similarly qualified to work on this project.
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)

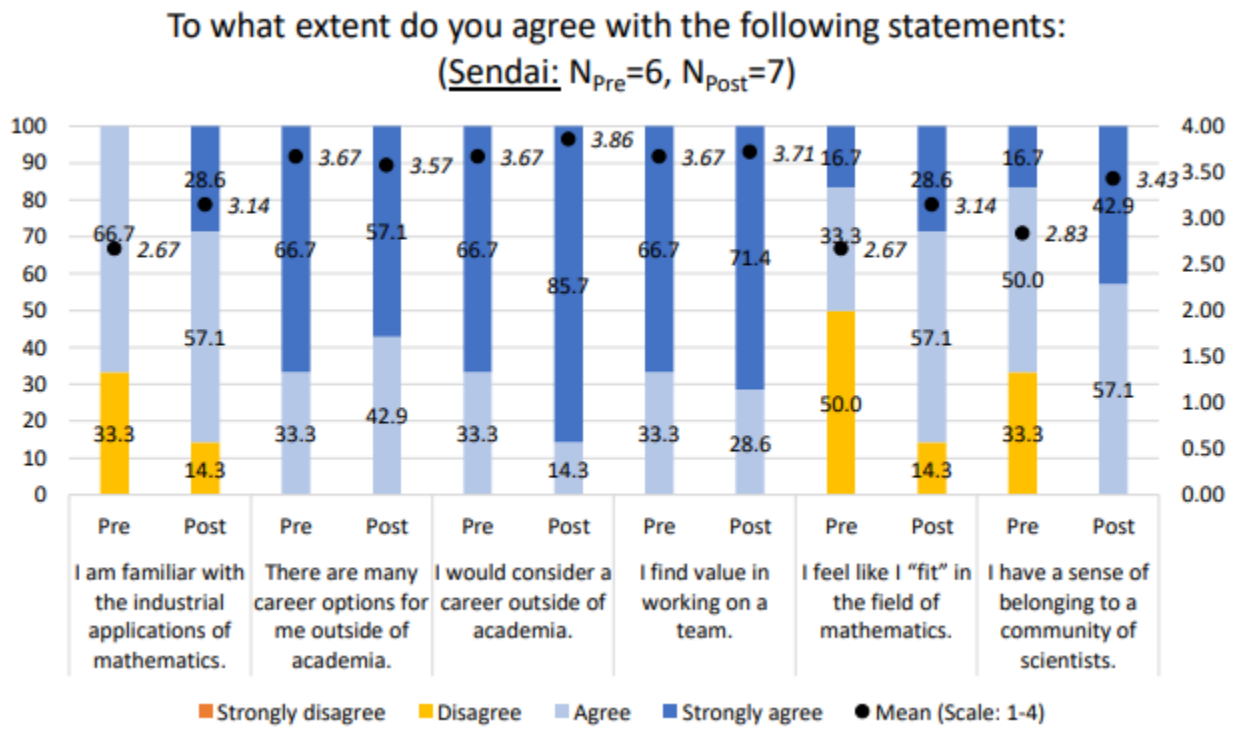

To what extent do you agree with the following statements about the GRIPS program: (N_{Berlin}=2, N_{Sendai}=7)
My experiences in GRIPS matched the initial descriptions I received about the program and its purpose.
My experience in GRIPS has been useful training for my career.
GRIPS introduced me to new knowledge, concepts, and/or techniques.
The GRIPS experience made me view a career in mathematics and science more favorably.
Berlin
Sendai
3.50
3.14
4.00
3.57
4.00
3.57
4.00
3.57
50.0
50.0
42.9
28.6
28.6
100.0
57.1
42.9
100.0
71.4
14.3
14.3
100.0
57.1
42.9
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)

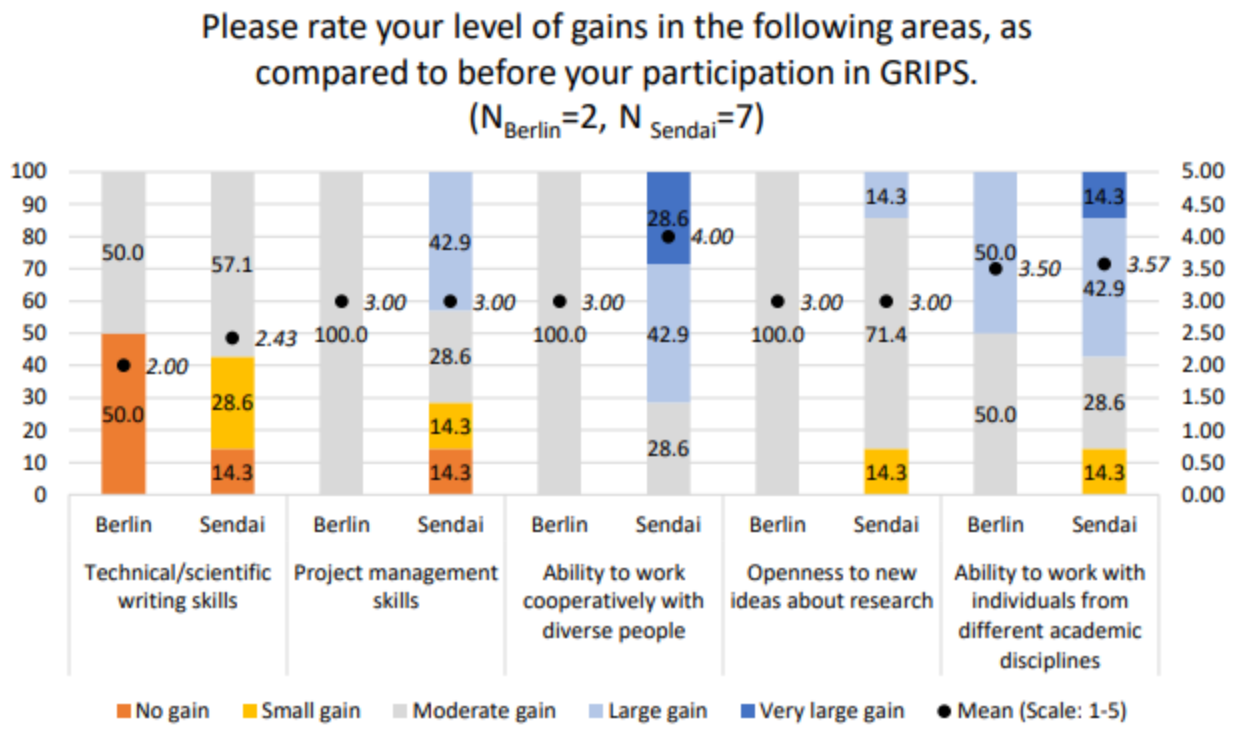

To what extent do you agree with the following statements about the GRIPS program: (N_{Berlin}=2, N_{Sendai}=7)
GRIPS fosters a sense of community among participants.
The GRIPS program promotes interdisciplinary collaboration.
GRIPS provided me with the opportunity to grow scientifically within a team environment.
GRIPS introduced me to real-world industrial problems.
IPAM succeeded in its aim to provide a supportive and inclusive environment for all program participants.
Berlin
Sendai
4.00
4.00
3.50
3.71
4.00
3.43
4.00
3.57
4.00
3.71
100.0
100.0
50.0
50.0
71.4
28.6
100.0
57.1
28.6
14.3
100.0
71.4
14.3
14.3
100.0
71.4
28.6
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)


Moving forward, how prepared do you feel you are to engage in the following activities: (Berlin: N_Pre=4, N_Post=2)
Pre
Post
Solve a challenging industrial problem using mathematics
Present research results in a written report
Prepare and give a formal presentation on a scientific topic
Pursue a career in mathematics or science
Not prepared
Somewhat prepared
Prepared
Well prepared
Mean (Scale: 1-4)


Moving forward, how prepared do you feel you are to engage in the following activities: (Sendai: N_Pre=6, N_Post=7)
Pre
Post
Solve a challenging industrial problem using mathematics
Present research results in a written report
Prepare and give a formal presentation on a scientific topic
Pursue a career in mathematics or science
Not prepared
Somewhat prepared
Prepared
Well prepared
Mean (Scale: 1-4)


To what extent do you agree with the following statements:
(Berlin: N_Pre=4, N_Post=2)
I am familiar with the industrial applications of mathematics.
There are many career options for me outside of academia.
I would consider a career outside of academia.
I find value in working on a team.
I feel like I "fit" in the field of mathematics.
I have a sense of belonging to a community of scientists.
Pre
Post
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)


To what extent do you agree with the following statements:
(Sendai: N_Pre=6, N_Post=7)
I am familiar with the industrial applications of mathematics.
There are many career options for me outside of academia.
I would consider a career outside of academia.
I find value in working on a team.
I feel like I "fit" in the field of mathematics.
I have a sense of belonging to a community of scientists.
Pre
Post
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)



Comments from our Student survey:

- I learned how to code in python, work in a team, collaborate with people from foreign countries, and create an excellent presentation and written report. These will all help me in the future, no matter what I do!
- The opportunity to work abroad in a foreign country, and engage with a completely new community of researchers and subject matter experts from such diverse backgrounds was really fantastic. Furthermore, despite the fact that my specialization is computational techniques, the materials science curriculum in my PhD program has very little attention given to computer science. I've generally had to self-teach myself these skills "on the side," as it were (which is difficult because the engineering classes I do have to take don't leave a lot of time left over for "on the side" learning). The best part about participating in this program was finally having a chunk of time carved out that allowed me to focus on a project solely on the computer science side. I'm really quite grateful to G-RIPS for creating the environment that supported this.
- I hope that if [industry partner] sponsor us again that they not only communicate more frequently but give us actual goals to work towards instead of just providing feedback on our progress. I also hope that [our supervisor] will be more hands on and communicative.
- The hardest part of my project was that I was alone on a team, and not provided with much clear direction on what I ought to be creating. I think I wasted a lot of time trying to learn content that ended up not being helpful to what the industry sponsor wanted. I only got to speak one-on-one with the industry sponsor on the last day of the program, after all the presentations. Everyone was very supportive, and I am grateful to the individuals who took the time to assist me in my project, but I cannot help but feel like I didn't really contribute anything meaningful, aside from a bit of personal self-growth. I wish I had

been a part of a team. But even though the program could have been a better experience in a variety of ways, I'm genuinely thankful that I had the opportunity to participate in it. I believe that it is a valuable program

STUDENT RESEARCH PROGRAM

Research in Industrial Projects for Students (RIPS), Los Angeles, California
June 20 - August 18, 2023

The Research in Industrial Projects for Students (RIPS) Program provides an opportunity for talented undergraduates studying math, computer science, and related disciplines to work in teams on a real-world research project proposed by sponsors from industry or the public sector. The student team, with support from their academic mentor and industry mentor, will research the problem and present their results, both orally and in writing, at the end of the program. The REU program is nine weeks. IPAM provides each undergraduate student with a stipend of $4,000.

Round-trip travel and accommodations costs are covered by IPAM. Students also receive a meal allowance and a stipend, and conference support to present their research. These terms apply to U.S. participants recruited by IPAM. A total of 36 students participated in the RIPS Los Angeles program.

2023 INDUSTRY PARTNERS	PROJECT TITLES
Aerospace Corp.	Gauss-Markov Modeling of GPS Ephemeris and Clock Error
Air Force Research Laboratory	Multifidelity Modeling for Rarefied Gas Kinetics
Advanced Micro Devices, Inc.	Surrogate Modeling Investigation of Scientific Applications with Neural Networks
Artificial Genius, Inc.	Particle-Type Methods for Stochastic Nonlinear Control and Intelligent Game-Playing
IBM	Benchmarking Quantum Chemistry Circuit Costs for Near Term Quantum Computers
LLNL	Parallel Algebraic Multigrid for Fusion and Higher-Order PDEs
Relay Therapeutics	Evaluation of Large Language Models on QSAR Datasets
SAP	Applying Computer Vision for Product Pricing and Out-of-stock Detection in Retail Stores
Toyota	A Physics-Informed Model Predicting Cycle Life of Lithium-ion Batteries

Aerospace Corp

Project Title: Gauss-Markov Modeling of GPS Ephemeris and Clock Error
Project Description: The Global Positioning System (GPS) is a Global Navigation Satellite System (GNSS) that consists of a constellation of satellites which broadcast signals to users so that they may compute estimates of their positioning, navigation, and timing (PNT).

Additionally, GPS has a ground control segment that monitors the real-time position, velocity, and clocks of the satellites themselves. The real-time estimates of GPS satellite ephemeris and clock obtained from the control segment play a crucial role in determining the accuracy of GPS user PNT solutions. In this project, we will develop a Gauss-Markov model of the broadcast ephemeris and clock error. This statistical error model will be generated from and validated against real errors of broadcast GPS ephemeris and clock information. The model will then be used for uncertainty quantification of user PNT.

Air Force Research Laboratory

Project Title: Multifidelity Modeling for Rarefied Gas Kinetics
Project Description: In a Hall-Effect Thruster (HET) device, propellant gas is bombarded by electrons through ionization collisions, forming plasma in the discharge channel. Ions in the plasma are accelerated to high velocities through the applied electric field. A high-fidelity model for a HET kinetically solves both ions and electrons, and due to the large-scale separation between the two species, such simulations require large computational resources and are not always practical. A particle-in-cell (PIC) model is widely used to treat kinetic species, but this method suffers from computational noise originating from discrete particles. A medium-fidelity model for a HET uses a hybrid approach, solving ions kinetically and treating electrons as a fluid. Even with simplified assumptions, this type of model has separate computational challenges. There are lower-fidelity models for a HET that are not based on physics equations but are formulated from data. Even with all of these models, the community still lacks predictive capabilities of thruster behavior and life both in ground facilities and on orbit. The ultimate goal is to fuse the models of different fidelity to predict thruster behavior and lifetime as accurately as the high-fidelity model but faster. Another goal is to use all of these models in the multifidelity framework to perform applications like uncertainty propagation, sensitivity analysis, and optimization. However, instead of modeling a plasma, this project involves the simpler problem of a rarefied gas flow through a converging channel to study the multifidelity model.

Advanced Micro Devices, Inc. (AMD)

Project Title: Surrogate Modeling Investigation of Scientific Applications with Neural Networks
Project Description: In machine learning, neural networks (NNs) are very effective at performing cognitive tasks. However, we are in the early days of using NNs to solve the most challenging problems in science – drug discovery, assessing weather extremes from climate change, etc. Applications like these strain our computational capabilities and would greatly benefit from the dramatic performance improvements that NNs might enable. NNs use hardware accelerators, such as Graphics Processing Units, more efficiently compared to traditional computational models. Thus, enabling the use of NNs for a broader range of scientific applications may increase the adoption rate of these accelerators and will decrease the environmental impact of those computations. In this project, we will explore the development and performance characterizations of fast surrogate models for predicting the solution of a set of partial differential equations where both time and space are fixed. We will consider solution of the two-dimensional acoustic wave equation and will assess the network's ability to interpolate between training points using a driving forcing function that varies in space and functional form.

Artificial Genius

Project Title: Particle-Type Methods for Stochastic Nonlinear Control and Intelligent Game-Playing
Project Description: The essence of human intelligence is creativity—the ability to produce novel solutions to problems, based on relatively limited knowledge, training and abilities. In contrast, the currently fashionable approaches to AI amount to sophisticated "interpolation" of massive amounts of training data. While the current paradigm can produce useful presentations of existing knowledge, it is not truly creative. To automate creativity itself, new approaches to AI are needed that can produce novel, detailed strategies to achieve high level goals, without massive training data. This project will explore a new class of algorithms that can practically realize creative problem solving in various concrete problem domains—such as in virtual worlds as are used in video games, in "digital twin" models of real-world systems, or in other areas as diverse as AI for drug design or power grid management. The new approach is based on a series of patented algorithms which take this intractable problem and provides new means to massively reduce the computational burden.

IBM

Project Title: Benchmarking Quantum Chemistry Circuit Costs for Near Term Quantum Computers
Project Description: Quantifying the performance of a quantum device is a critical component of quantum computing research. The results from these tests are expressed using metrics that measure features and behaviors of quantum computing systems such as speed and accuracy. For example, one- and two- qubit gates are characterized by randomized benchmarking, whereas the quality of a device when executing multi-qubit circuits is often measured via Quantum Volume. Unfortunately, most of the times these metrics are not sufficient to get an insight into real-world application-level performance. As such, benchmarks for application-specific metrics to evaluate the efficiency and applicability of the near-term quantum computers are desired. Chemistry is one of the most promising applications of quantum computing. Computational resources needed for chemistry simulations scale exponentially with the system size and complexity, which makes such simulations hard on classical computers but "natural" on quantum computers. To assess the capabilities and efficiency of the current devices to simulate chemistry problems, this study will focus on benchmarking present day quantum devices with quantum chemistry circuits.

Lawrence Livermore National Laboratory (LLNL)

Project Title: Parallel Algebraic Multigrid for Fusion and Higher-Order PDEs
Project Description: This project develops algebraic multigrid (AMG) techniques for solving higher-order partial differential equations (PDEs) such as those that arise in tokamak edge plasma simulations (a tokamak is a machine that confines a plasma using magnetic fields and is believed to be the leading plasma confinement concept for future fusion power plants). Multigrid methods play a key role in large-scale scientific simulation, because they are among the fastest and most scalable approaches for solving the underlying sparse linear systems of equations that arise. AMG is a special type of multigrid method that depends only on the description of the linear system, giving it better portability and broader applicability than geometric multigrid. Even though these methods are widely used today, there are still applications where further development is needed. This project will focus on PDEs with higher-order terms (e.g., fourth

order), concentrating first on a PDE that arises in tokamak edge plasma simulations. Standard AMG methods struggle with these higher-order PDEs and this project will investigate several techniques for extending the method to this important class of problems. Surrogate model problems will be used to test algorithmic ideas. Initial code will be provided to get the project started.

Relay Therapeutics

Project Title: Evaluation of Large Language Models on QSAR Datasets
Project Description: Large language models (LLMs) have become a significant factor in several fields including text generation, protein structure prediction, and protein design. More recently, a few groups have been applying LLMs in drug discovery. Instead of employing the traditional method of training an LLM on a large corpus of text, these groups are training their models on billions of chemical structures. One promising avenue for this research involves the application of LLMs to predictive modeling. The main purpose of this project is the implementation, evaluation, and possibly fine-tuning of one open-source LLM trained on chemical structures. This will be done on datasets designed to realistically represent challenges normally encountered in drug discovery projects.

SAP

Project Title: Applying Computer Vision for Product Pricing and Out-of-stock Detection in Retail Stores
Project Description: Consumer product manufacturers today have a difficult time finding out whether their promotions are being executed in retail stores as agreed with the retailers. Moreover, manufacturers have little insights into what their competitors are doing in terms of discounts and promotions. Hence, this project aims at applying computer vision to analyze images of retail store shelves in order to extract data from price tags such as prices, minimum quantity constraints, original retail prices, and promotional statements. Additionally, this data needs to be matched with the appropriate products on the shelf.

Our primary objective is to develop a comprehensive solution that utilizes computer vision to track the on-shelf availability of different items and match their corresponding price tags. We aim to identify instances of empty inventory or out-of-stock (OOS) items by reporting their absence and associated price tags. The proposed approach can potentially notify the retailers about what specific items are unavailable in their competitors' stores. With this knowledge, retailers can devise various short-term strategies to capitalize on the situation.

Toyota

Project Title: A Physics-Informed Model Predicting Cycle Life of Lithium-ion Batteries
Project Description: The market share of electric vehicles (EVs) has grown exponentially in recent years. The principal part of an EV is the energy storage system, which is usually the batteries. Thus, the accurate estimation of the remaining useful life (RUL) of the batteries, for an optimal health management and a decision-making policy, is of importance, but still remains a challenge for automakers. Recently, many data-driven methods have been applied for the prediction of battery life. These models directly learn models for battery lifetime prediction from

data, but ignore the physical processes that occur within the batteries. The goal of this project is to develop a hybrid approach that employs the support vector regression (SVR) to identify the battery capacity fading, using robust features associated with battery aging. These features are extracted from the data using feature extraction methods such as incremental capacity analysis. A relevant advantage of this hybrid model is that it can be adapted to different settings. For battery cells tested, we will show that our hybrid model built upon the data from one single cell is able to predict the capacity fading of other cells.

STUDENT RESEARCH PROGRAM

Research in Industrial Projects for Students (RIPS), Singapore
June 20 - August 18, 2023

The Los Angeles program is complemented by a satellite program in Singapore. Similar to the Los Angeles program, RIPS provides an opportunity for talented undergraduates studying math, computer science, and related disciplines to work in teams on a real-world research project proposed by sponsors from industry or the public sector. The student team, with support from their academic mentor and industry mentor, will research the problem and present their results, both orally and in writing, at the end of the program. The REU program is nine weeks. IPAM provides each undergraduate student with a stipend of $4,000.

Round-trip travel and accommodations costs are covered by IPAM. Students also receive a meal allowance and a stipend, and conference support to present their research. These terms apply to U.S. participants recruited by IPAM. A total of 4 students participated in the RIPS Singapore program.

2023 INDUSTRY PARTNERS	PROJECT TITLES
Cubist Systematic Strategies	A Review of NLP on the Form 10-K for Systematic Trading
Google	Document Understanding by On-Device ML
Ministry of Health Office for Healthcare Transformation (MOHT)	Predicting adverse events in schizophrenia from digital phenotyping data
Proctor and Gamble	Repeated Measures Design in Skin and Scalp Care

Cubist Systematic Strategies

Project Title: A Review of NLP on the Form 10-K for Systematic Trading
Project Description: Natural Language Processing (NLP) has gained significant traction in the financial sector, providing powerful analytical tools for processing and extracting valuable insights from financial documents, such as the Form 10-K. This paper presents a comprehensive review of NLP methodologies applied to the Form 10-K and their implications for systematic trading. By synthesising research from both accounting and computer science disciplines, this review offers a balanced perspective that combines domain expertise with technical advancements. The study explores the feature extraction methods commonly employed on Form 10-K data, encompassing a range of techniques from lexicons and statistical approaches to state-of-the-art deep learning methods. These methods facilitate the transformation of textual

information into numerical representations, which are essential for systematic trading. Moreover, this paper critically analyses existing literature in four research subdomains, replicates and validates previous findings, and enhances them through the utilisation of modern NLP techniques. This review serves as an introduction to the application of NLP on the Form 10-K for trading and holds implications for practitioners and researchers interested in leveraging NLP on long-form financial documents like the Form 10-K.

Google

Project Title: Document Understanding by On-Device ML
Project Description: The proliferation of smartphones in everyday life has led to many sensitive and useful documents being stored as images on them. Information on these documents may need to be accessed repeatedly, leading to frustration among users. In recent years, advances in document understanding models have shown promise in extracting important information from documents. However, these models are extremely memory and compute expensive, making them impractical to run on-device. However, running these models on device is imperative for security purposes, necessitating model compression. Recognising the similarity between Layout Models and Language Models, we attempt to apply various techniques of model compression for Language Models to Layout Models. We present a compute-efficient scheme of model compression, preserving roughly 90% of performance across a wide variety tasks, while reducing parameter count by 48%.

MOHT

Project Title: Predicting adverse events in schizophrenia from digital phenotyping data
Project Description: Schizophrenia is a devastating mental disorder affecting 1.5% of the world population and the illness affects all aspects of a patient's life. A common problem in the medical community is predicting patients' adverse events (an adverse event signifies a worsening of symptoms) and intervening early. To tackle this problem, the Ministry of Health Office for Healthcare Transformation (MOHT) conducted a study collecting data from the daily activities of schizophrenia patients. Some of these include the number of hours spent, time in REM sleep, and GPS activity. The goal is to predict adverse events using these features, a technique known as digital phenotyping. It has been noted in previous studies by Cohen et al., Barnet et al., and Henson et al. that outliers in these features are useful in predicting relapses.

While the original model in Barnet et al. did not work well, slight modifications were able to give good results. In particular, we found that the rate of behavioral anomalies is 125% higher in two-week windows before an adverse event compared to normal two-week windows. In addition, we found several behavioral features that were strong predictors of relapses. These included the expected factors such as sleep patterns and the subject's level of sociability. However, we also discovered some unexpected behavioral features that turned out to be strong predictors, namely the amount of time spent on games/entertainment apps and the duration of missing GPS signal. 4

Proctor and Gamble

Project Title: Repeated Measures Design in Skin and Scalp Care

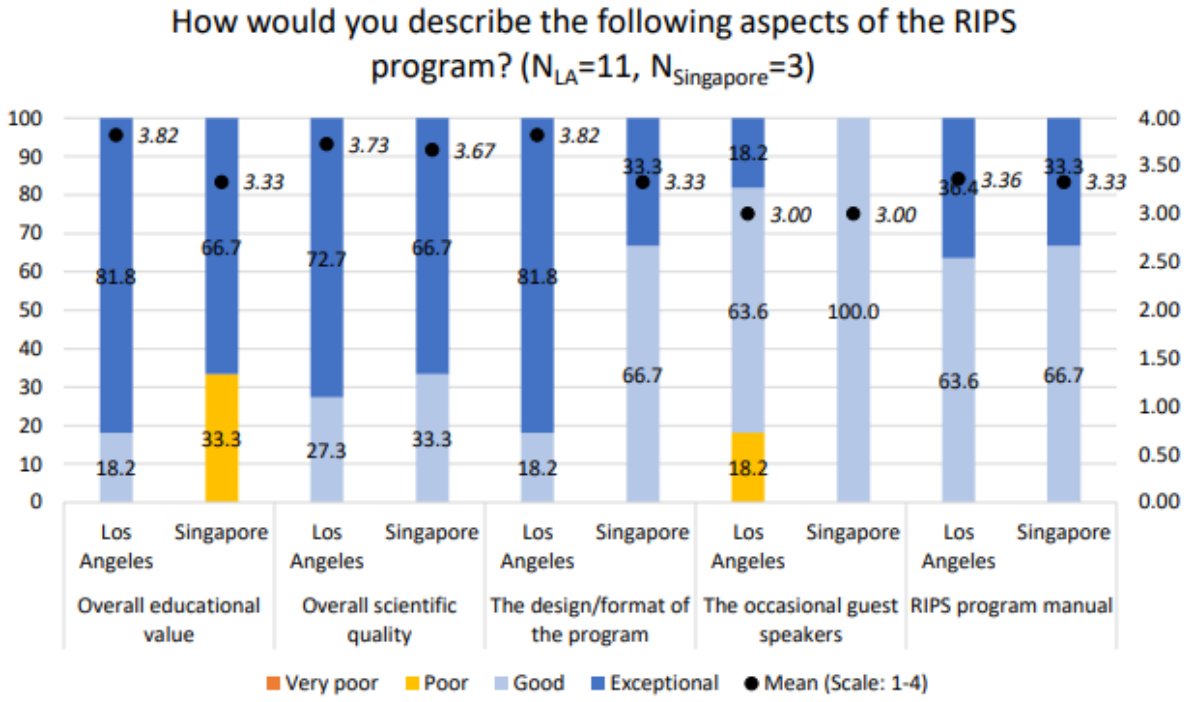
Project Descriptions: Repeated measurement studies are commonly used to analyze the results of clinical trials. For the first project, Procter and Gamble provided data regarding the effect of two products on six indicators of an individual's skin health across eight visits: Relative Humidity (RH), Stratum Corneum Hydration (SCH), Trans-Epidermal Water Loss (TEWL), Temperature (measured by two different instruments), and skin pH. Since SCH, TEWL, and pH are more important variables in the context of skin care, we decided to only use these three measurements when creating response variables. Instead of working with the raw measurements, we decided to use Change from Baseline (CFB) measurements as response variables because we wanted to assess the differences between existing products and newly-developed products; for which, we came up with a reasonable baseline by doing moving averages comparisons across different window lengths, in order for CFB to make sense. We also introduced our own covariate involving the stability of an individual's skin, as we hypothesized that one's skin stability may potentially influence the model as a fixed effect. The presence of several response variables, or measurements, of interest presents an interesting challenge, as traditional statistical methods only permit analysis of a single response variable. Furthermore, given the repeated measurement design, a (three-level) linear mixed model is appropriate. Following the approach of Wright (1998), we stacked our three response variables of interest into a single dependent variable. We hence built 3-level linear mixed models for this composite dependent variable. We started with a base 3-level linear mixed model that includes a simple G matrix (only a random intercept) and a UN $\otimes$ AR(1) R matrix, as well as a preliminary fixed effect structure with only the main effects for the covariates of interest— each individual's baseline measurements, skin stability, and test leg, along with variables that refer to the conditions of each measurement (Visit Number and Time of Day)—and interaction terms between the type of measurement and these covariates. We then considered more complicated G matrices (i.e., assigning random slopes) and decided to add random effects for the slopes of measurement type and time of day. We employed a forward selection-like approach based on the Bayesian Information Criterion to select the final fixed effect structure and decided to add three interaction terms involving time of day and each of the individual-specific covariates. This final linear mixed model yielded an interesting finding: holding all other variables constant, respondents with unstable skin are expected to have lower CFB measurements in the morning than those with stable skin; moreover, the difference is greater for evening measurements.

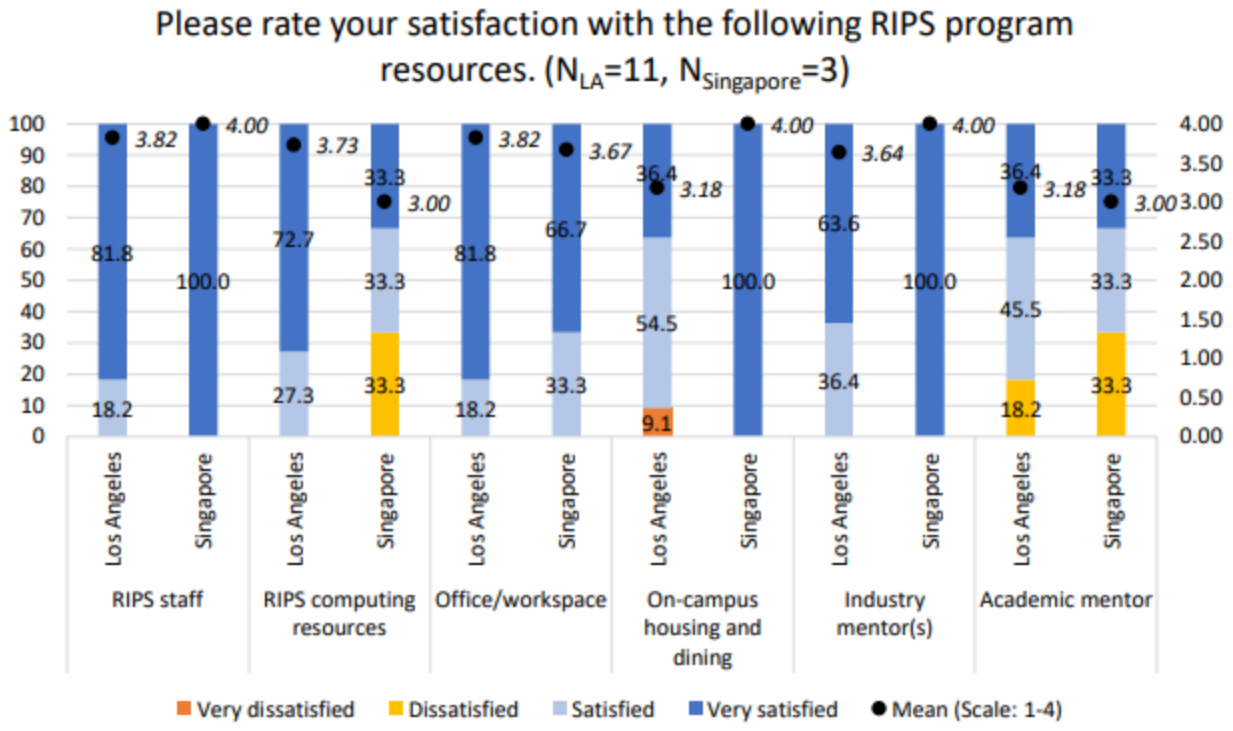
For the second project, Procter and Gamble provided data regarding the effect of two scalp care products on 47 indicators of 100 individuals' scalp health across seven visits over four weeks; the sheer number of indicators is difficult to handle, thus for simplicity, three important scalp indicators (or objective measurements) were picked: AsfsTotal, Histamine, and IL1raIL1aRatio. This was conducted in a reversed clinical study fashion; that means participants were first administered the anti-dandruff shampoo for two weeks, before they were split into two treatment groups A and B: group A remained on the anti-dandruff shampoo, while group B was shifted to use a cosmetic shampoo. The first task in this project aimed to find the visit number from which the objective measurements for the two treatment groups differ significantly in terms of their progressions of the three objective measurements. Applying both objective analysis via a linear mixed model approach similar to that of Project 1 and subjective analysis via plots of CFB measurements for each objective measurement over time, we found that the significant difference kicked in at Visit 4 (Day 11) for Histamine, Visit 6 (Day 22) for AsfsTotal, and Visit 7 (Day 29) for IL1raIL1aRatio. For the second and third tasks of this project, we were interested

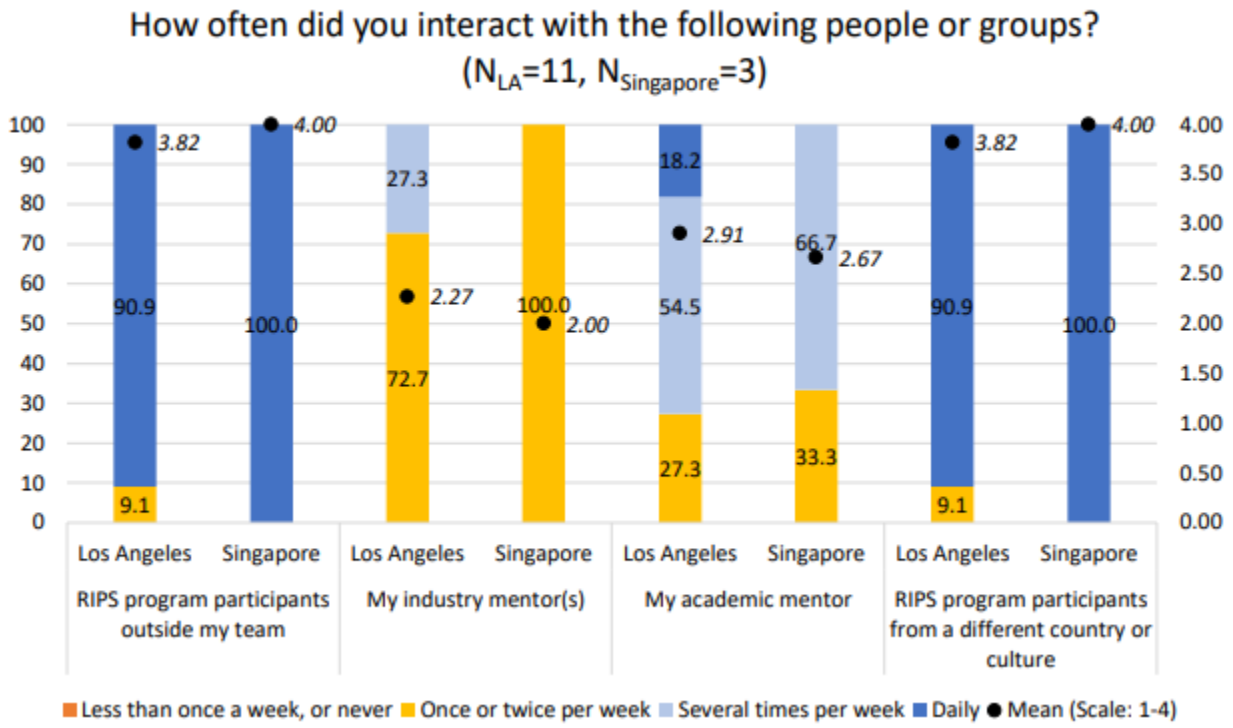
in figuring out the relationship between breakout measurements (i.e., the individuals' self-assessment of their own scalp conditions pre-experimentation) and the objective measurements. For Task 2, a multivariate multinomial logistic regression model was employed to study the relationship between the four breakout measurements of interest—all of which relate to the severity of a particular scalp attribute—and the three objective measurements. A logistic model was chosen since the breakout measurements were measured on a discrete scale. Detailed results in terms of log-odds ratios are then presented in greater detail. For the third and final task of this project, an endeavour was made to use known clustering methods to draw links between the objective measurements and breakout measurements. This task leveraged Group-Based Trajectory Modeling to unveil inherent clusters among subjects according to longitudinal objective measurements. We identified three distinct clusters, each manifesting to a certain extent unique demographic composition and breakout measurements. The findings revealed notable variation in scalp health conditions and hair treatment habits across clusters, providing valuable insights into how individual characteristics might influence the long-term effectiveness of anti-dandruff shampoos.

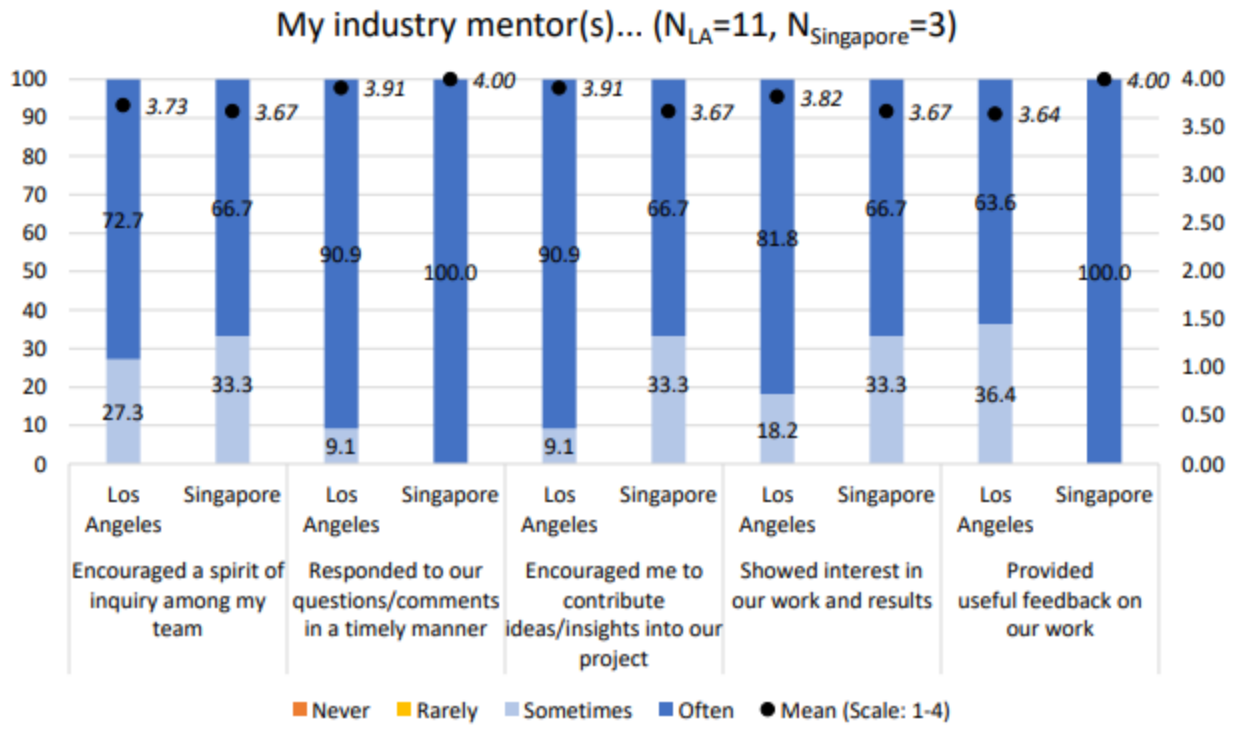
RIPS 2023 Participant Survey Results

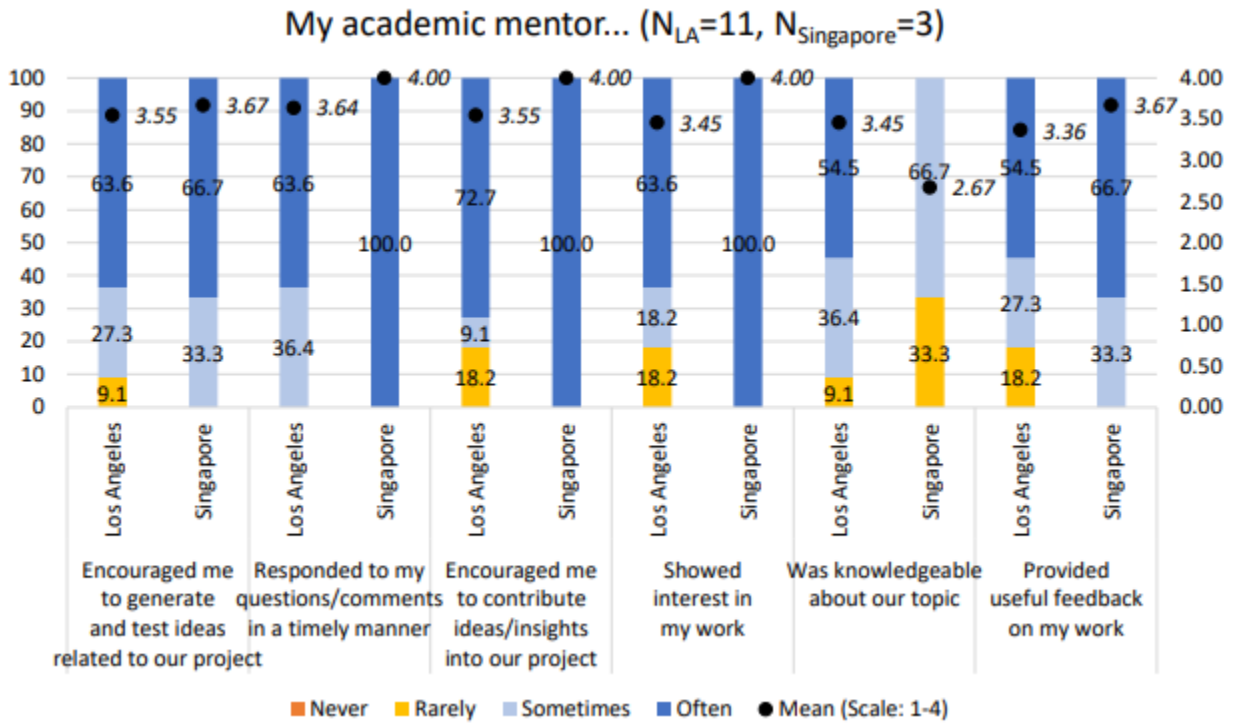
IPAM surveys RIPS participants (both LA and Singapore) both pre- and post-participation. They surveys are designed to elicit feedback from participants as well as to gauge the effectiveness of the program. A total of 35 Los Angeles and Singapore RIPS participants responded to surveys (32 pre-program, 14 post-program), with 11 completing both the pre- and post-program surveys. Chart data are disaggregated by campus and summarize their respective response frequencies and mean response scores.

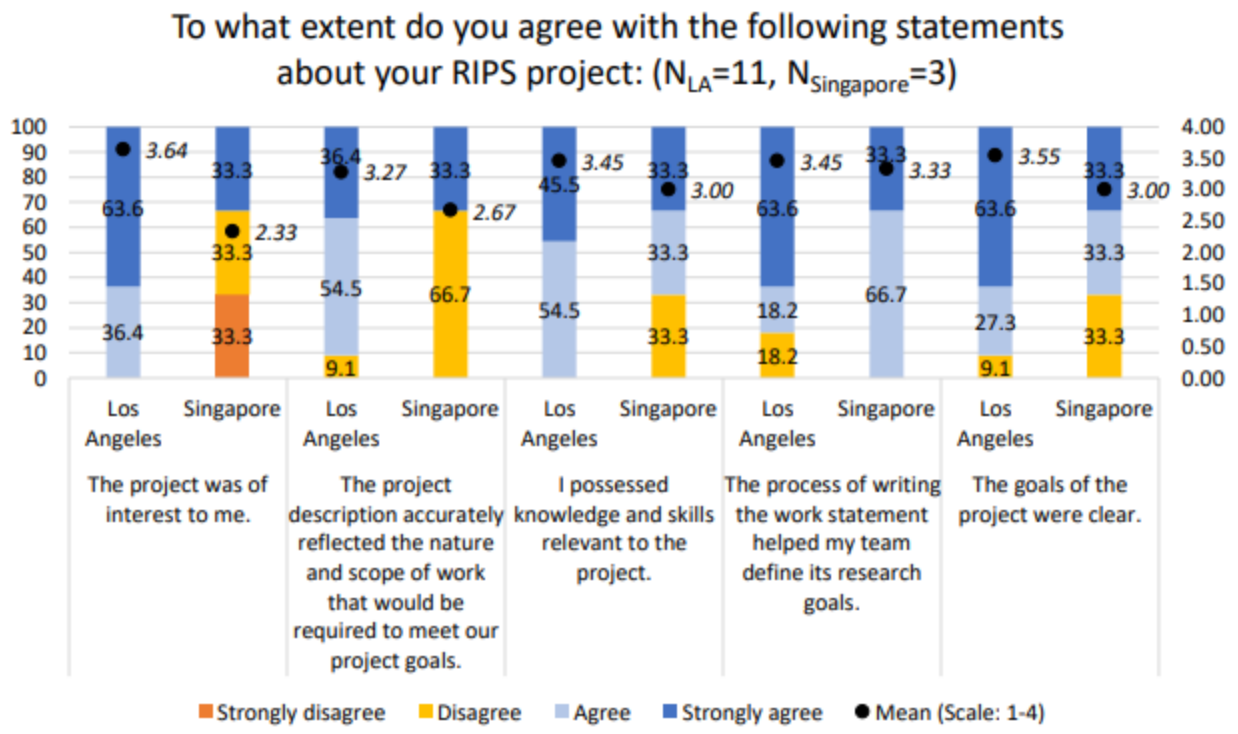


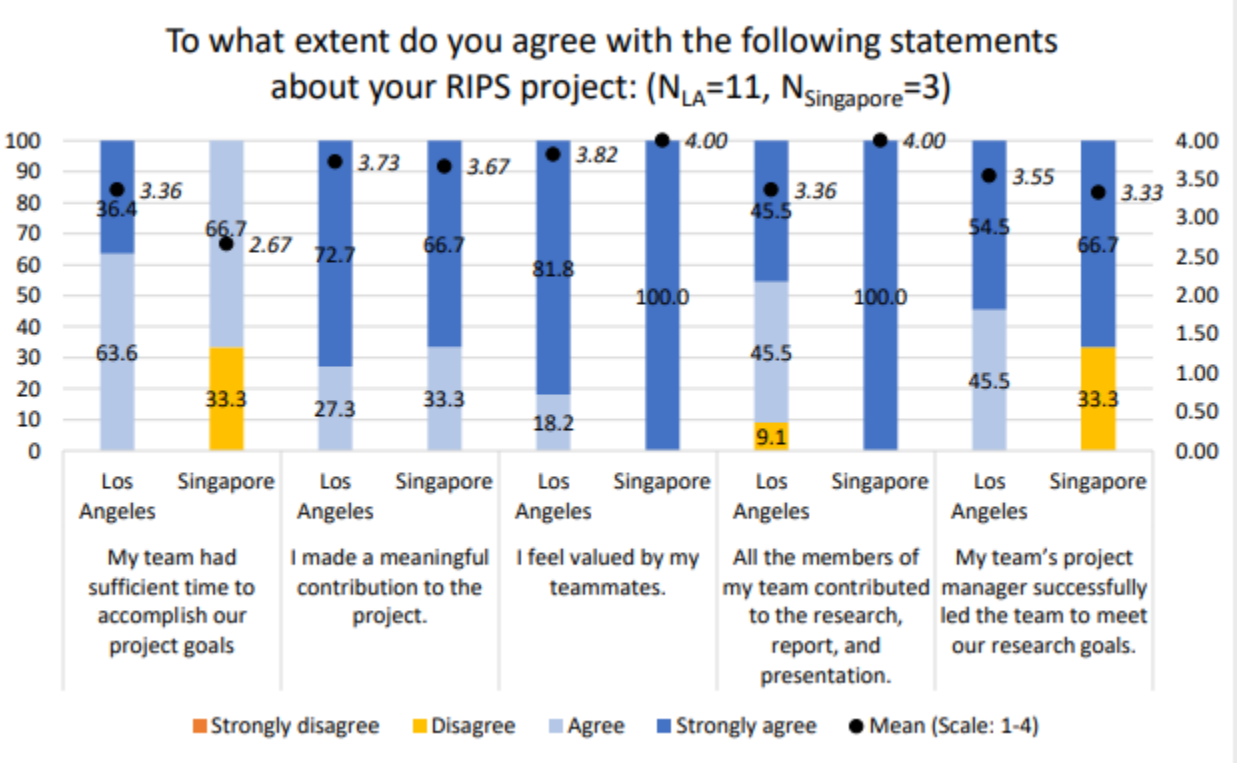

Please rate your satisfaction with the following RIPS program resources. (N_{LA}=11, $N_{Singapore}$=3)
RIPS staff
RIPS computing resources
Office/workspace
On-campus housing and dining
Industry mentor(s)
Academic mentor
Los Angeles
Singapore
Very dissatisfied
Dissatisfied
Satisfied
Very satisfied
Mean (Scale: 1-4)

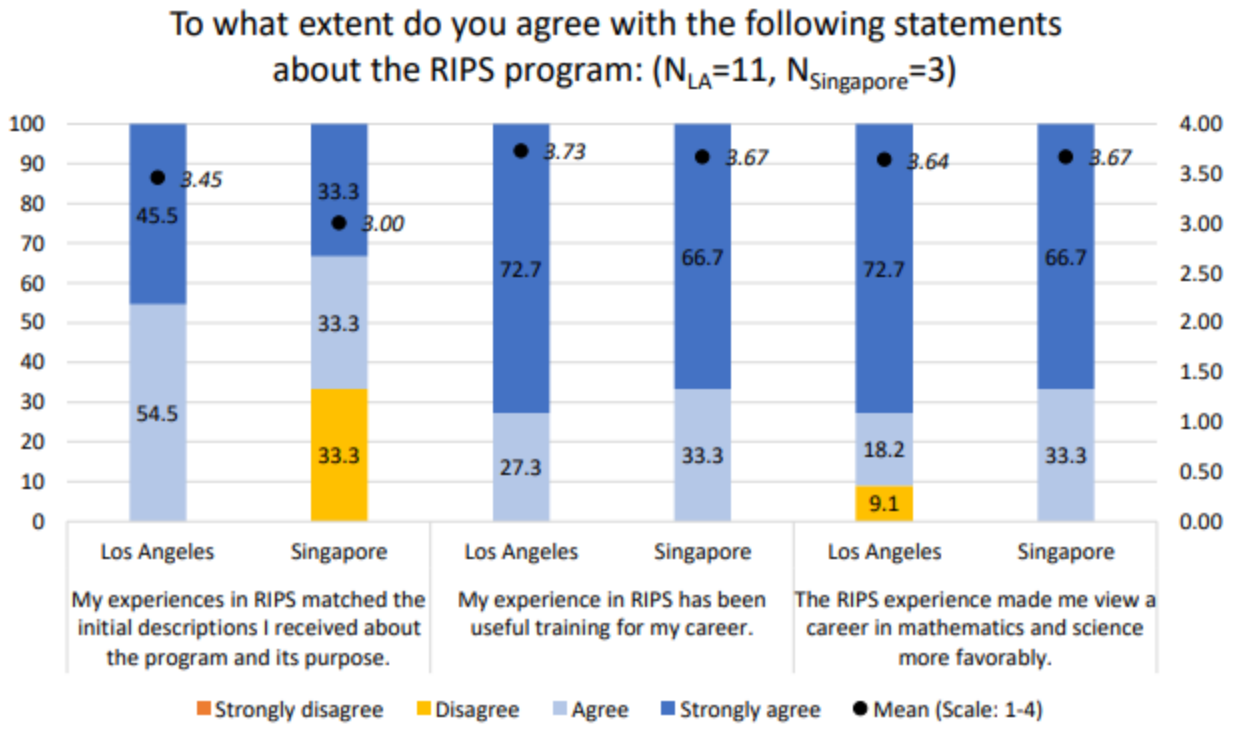

How often did you interact with the following people or groups? (N_{LA}=11, $N_{Singapore}$=3)
RIPS program participants outside my team
My industry mentor(s)
My academic mentor
RIPS program participants from a different country or culture
Los Angeles
Singapore
Less than once a week, or never
Once or twice per week
Several times per week
Daily
Mean (Scale: 1-4)

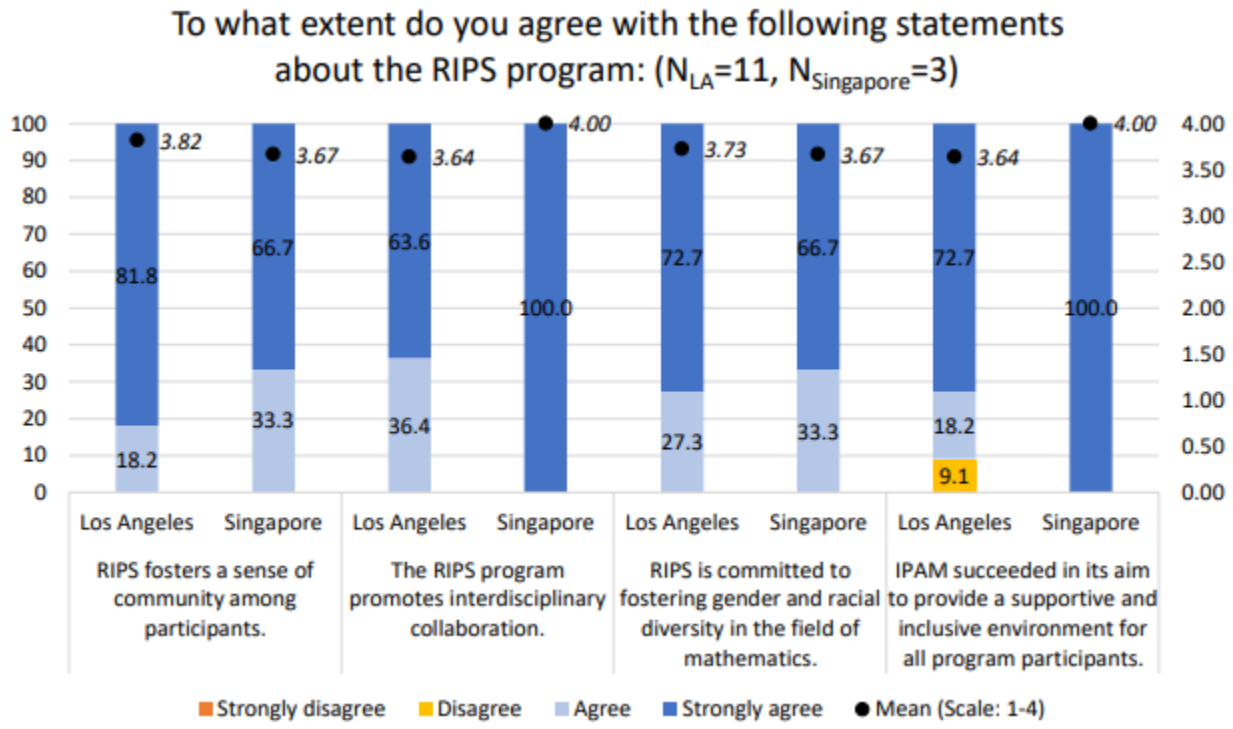

My industry mentor(s)... (N_{LA}=11, $N_{Singapore}$=3)
Encouraged a spirit of inquiry among my team
Responded to our questions/comments in a timely manner
Encouraged me to contribute ideas/insights into our project
Showed interest in our work and results
Provided useful feedback on our work
Los Angeles
Singapore
3.73
3.67
3.91
4.00
3.91
3.67
3.82
3.67
3.64
4.00
72.7
27.3
66.7
33.3
90.9
9.1
100.0
90.9
9.1
66.7
33.3
81.8
18.2
66.7
33.3
63.6
36.4
100.0
Never
Rarely
Sometimes
Often
Mean (Scale: 1-4)


My academic mentor... (N_{LA}=11, $N_{Singapore}$=3)
Encouraged me to generate and test ideas related to our project
Responded to my questions/comments in a timely manner
Encouraged me to contribute ideas/insights into our project
Showed interest in my work
Was knowledgeable about our topic
Provided useful feedback on my work
Los Angeles
Singapore
3.55
3.67
3.64
4.00
3.55
4.00
3.45
4.00
3.45
2.67
3.36
3.67
63.6
27.3
9.1
66.7
33.3
63.6
36.4
100.0
72.7
9.1
18.2
100.0
63.6
18.2
18.2
100.0
54.5
36.4
9.1
66.7
33.3
54.5
27.3
18.2
66.7
33.3
Never
Rarely
Sometimes
Often
Mean (Scale: 1-4)


To what extent do you agree with the following statements about your RIPS project: (N_{LA}=11, $N_{Singapore}$=3)
100
90
80
70
60
50
40
30
20
10
0
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
3.64
63.6
36.4
33.3
2.33
33.3
33.3
3.27
36.4
54.5
9.1
2.67
33.3
66.7
3.45
45.5
54.5
3.00
33.3
33.3
33.3
3.45
63.6
18.2
18.2
3.33
33.3
66.7
3.55
63.6
27.3
9.1
3.00
33.3
33.3
33.3
Los Angeles
Singapore
The project was of interest to me.
The project description accurately reflected the nature and scope of work that would be required to meet our project goals.
I possessed knowledge and skills relevant to the project.
The process of writing the work statement helped my team define its research goals.
The goals of the project were clear.
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)


To what extent do you agree with the following statements about your RIPS project: (N_{LA}=11, $N_{Singapore}$=3)
100
90
80
70
60
50
40
30
20
10
0
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
3.36
36.4
63.6
66.7
2.67
33.3
3.73
72.7
27.3
3.67
66.7
33.3
3.82
81.8
18.2
4.00
100.0
3.36
45.5
45.5
9.1
4.00
100.0
3.55
54.5
45.5
3.33
66.7
33.3
Los Angeles
Singapore
My team had sufficient time to accomplish our project goals
I made a meaningful contribution to the project.
I feel valued by my teammates.
All the members of my team contributed to the research, report, and presentation.
My team's project manager successfully led the team to meet our research goals.
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)





The surveys rated the Los Angeles program very highly. Both Los Angeles and Singapore programs have shown significant positive impact on student attitudes towards viewing

mathematics as a viable career path (in and out of academia), and their desire to obtain an advanced degree. We are working with our Singapore partners to address student feedback related to ensuring a supportive an inclusive environment, as well as providing good academic mentorship. The RIPS Director visited Singapore (including coming for the 2024 opening day) to discuss these issues.

Student comments:

- For one, we needed stronger computing resources and my team wasted 1-2 weeks trying to find workarounds for our computing limitation. I think we spent a lot of time not focused on our main task because we didn't have the resources necessary for data storage and model training. Secondly, I think it might also be better if the academic mentor has experiences that are more aligned with the project. Our academic mentor helped us as much as he possibly could, but I think we could've gotten some more pointers or insight.
- I think there needs to be student input when determining project assignments. Several students were dissatisfied with their project and would've preferred to switch to another. I also think that there should be organized lectures for RIPS as opposed to leaving the door open for all IMS conference/workshop talks since they are quite advanced. The academic mentors were kind of out-of-place. They were CS postdocs and physics postdocs, so they didn't have too much background info on our topics. I think the academic mentors should have some experience related to the project.
- It was very nice to be involved with a diverse group of students, and to see projects from many different companies in industry. I felt that the IPAM staff was very supportive and invested in the success of our project. I also think that defining the problem in depth with the problem statement at the beginning was instrumental to the success of our project. I noticed that the involvement of academic mentors was not equal across all teams and so some groups received more guidance than others.
- Thank you for the incredible summer! The RIPS program greatly exceeded my already high expectations. The IPAM staff is the best!
- The community aspect of it is very great. Also, many people have a preconceived idea that every project will publish which I found to be not great if some doesn't.

SPECIAL EVENTS AND CONFERENCES

Applied Mathematics skills Improvement for Graduate student Advancement (AMIGAs)
July 10 – 14, 2023

Organizing Committee:
Erika Tatiana Camacho (Arizona State University)
Keisha Cook (Clemson University)
Malena Espanol (Arizona State University)
Alicia Prieto Langarica (Youngstown State University)
Nancy Rodriguez (University of Colorado Boulder)

AMIGAs was a week-long summer program for incoming second- or third-year students in graduate programs in the USA, designed to support and train a new generation of mathematical scientists in applied and computational mathematics, with a special emphasis on increasing the

number of women, particularly those from historically excluded racial groups, in both academia and industry.

Applied mathematics research is rapidly shifting from classical applied mathematics, which focuses mainly on physical applications, to one that is more heavily driven by data and technology. In this Big Data era, students need to be suitably trained in computational skills such as statistics, optimization, and machine learning.

AMIGAs seeks to provide participants with the initial skills and the confidence to transition smoothly to the next stage of their graduate program through tutorials, professional development activities, and research talks related to the mathematics of data science and its applications. Tutorials will focus on skills such as computer programming, mathematical modeling, and data management and computing. In addition, AMIGAs will provide participants with a network of women interested and/or thriving in industrial careers.

Data on the number of women doctorates and underrepresented minority groups in mathematics and applied mathematics are well known. The steps after graduate course work can be even more difficult for students from these historically excluded groups, as few graduate programs have targeted mentoring support and guidance. Therefore, another important component of this program was networking, building a sense of community among peers, and professional development sessions.

Comments from our participant survey:

- It was an eye opening event for me, I now know many challenges Ive been through are common among latin American students in the US. The organizers are awesome people that wants to help you and they are very real and honest, which I really appreciate.
- The only thing I wish we had more time for is more allotted time to engage with other participants and faculty. Maybe one evening of an optional group activity in the program would have helped with this!
- I think it might be nice to incorporate more breaks and/or free-time in someway. I felt that the week was so packed, that it was hard for me to absorb everything, especially being so exhausted. Due to the schedule, it was hard to find time to connect with other participants outside the program in a more natural and relaxed setting.
- In terms of program's technical logistics, I wonder if it might have been helpful to use Github more (instead of google, creating a fork and working on there). I'm not sure how many participants here are familiar with using Github and version control, but that might be a good skill to teach and practice using, as I don't know people who use Colab for their own work, nor did we take advantage of having multiple people working on a Colab notebook.
- I feel some of the lectures could have been a bit clearer in their purposes. For example, Dr. Cook's talk spent a lot of time going through formula derivations; for me it was very easy to get lost in those weeds. The order was also unhelpful at times, ie talking about MCMC before defining a Markov Chain. I think a practical, big picture/themes approach with a few deep dives might have been more helpful. The working sections timing was a bit off: some activities took 5 minutes, while other required a lot more scaffolding besides copy and pasting previous code.

- The entire program was super exciting. Favorite part of the program mine was professional development session. It would be really helpful if you can share the process of internship applications and some sample interview processes.
- Including a Spanish language class for non-Spanish speakers should be a fun way to learn more about other cultures.
- 1. My first suggestion is just have sessions of 2 hours, sometimes 3 hours become very exhaustive. 2. I would like to suggest one session where women talk about their experiences in their jobs and studies. Try to talk about how women feel about talking in a classroom, how they have feel that in some way they have to effort more than men to be part of the academia, talk about controversial topics. I would like to have a space where women could talk about their experiences and how they have feel discriminated or abuse at some point of their professional life. I suggested this because during the event you have the opportunity to talk with another women that have been through difficult situations. So, for me it is very important feel that we are not alone and that as women we could also be very successful.
- I think it would be nice to leave on a Sunday instead of Saturday. This would allow more time to spend time together as a group.
- If there are written content in the activity, it would help being able to read through it the day before (especially if it is mathematical). It was hard for me to pay attention to the lecture and read simultaneously.
- I would look into for future workshops to provide recipients with a bag or stickers with the AMIGAS logo and motto (a motto would be cute)
- Perhaps in the future as the program grows larger, one idea could be to hold a few different workshop topics at the same time and letting participants to choose which workshops to attend based on what aligns closest with their research.

SPECIAL EVENTS AND CONFERENCES

Women in Data Science and Mathematics (WiSDM)
August 7 - 11, 2023

Organizing Committee:
Andrea Bertozzi (University of California, Los Angeles (UCLA))
Kathryn Leonard (Occidental College)
Deanna Needell (University of California, Los Angeles (UCLA))
Linda Ness (Rutgers University)

The third research collaboration workshop, “Women in Data Science and Mathematics” WiSDM 2023 built on successes from WiSDM 2017 and 2019.

The recent burgeoning of processing speed and sources of data have created a tremendous demand for mathematically-founded approaches to modeling data for exploration, understanding, and prediction. Relevant mathematical tools span the full discipline, from algebraic geometry used for existence and uniqueness proofs of low rank approximations for tensor data, to category theory used for natural language processing applications, to approximation and optimization frameworks developed for convergence and robustness guarantees for deep neural networks. These research problems are inherently interdisciplinary, requiring mathematics, computer

science, and data domain expertise. Many of these problems also have immediate applications in industry and government.

This one-week workshop consisted primarily of time spent in small research groups actively working to solve problems in data science. Participants typically range from senior researchers to early graduate students, collaborating as equals and building relationships centered on shared research interests and complementary research skills. Our previous two workshops have produced follow-on sessions at national mathematics conferences and two volumes of early research results in the AWM-Springer series 2017 and 2019.

Comments from our participant survey are below. Please note that due to the unique requirements of many small rooms, a number of the working groups were accommodated at Kaplan Hall rather than IPAM.

- The leaders for the program should be arranged more vigilantly who are willing to participate and assign each candidate to the group with similar academic profiles.
- This workshop was so friendly and so welcoming. This was my first time participating in a research workshop as opposed to going to conferences and listening to talks, and I had a lot of anxiety regarding imposter syndrome and feeling like I wasn't good enough to be here. All of the participants I met were SO kind and so welcoming, and I think this reflects the values set in place by the WiSDM organizers and IPAM staff. Thank you all so much for working so hard to create such a joy filled event.
- Everything were well organized and specially staff were so friendly and helpful. Only thing need give attention is the server access more smooth.
- I loved attending this workshop and have a few comments for future iterations: 1. It would be great to have a shared space for participants to gather throughout the day to e.g., grab a coffee and chat about each other's projects. 2. I'm torn about the midweek presentations. On the one hand, I really liked hearing what others were working on and was able to use this information to reach out to other groups for questions during the week. On the other hand, I felt that with roughly one day's worth of work, we didn't have much yet to say, and it took away from precious working time together. Off the top of my head, this might be addressed by (a) no presentations, just chat during coffee or (b) making shorter, more informal updates: 1-2 slides tops, 10 minutes, talk about the problem, the goal, the approach. 3. I personally had no issues with my roommate, but I was very uncomfortable sharing a room. It would have be nice to be more notice (I only realized a week before and had I known sooner I would have explored alternative accommodations) and/or an option to request another participant as a roommate. That being said, the accommodations themselves were *very* nice and I enjoyed my stay!
- I submitted a form with feedback regarding sharing a room and suggested that this be told to participants ahead of time. I wanted to submit this form again to say I completely missed the repeated mentions of the double occupancy room well before the workshop. I'm very sorry about missing this, and thank you for communicating it. Please disregard my previous feedback. Sorry again and thank you!

- Thank you so much for hosting the WiSDM workshop, providing breakfast and lunch and funding our stay at the Luskin. This made the workshop very very pleasant. It would have been nice to also have a very simple tea in the afternoon and to have more support for and easier access to the computing resources. The rooms in Kaplan were also a bit cold. Experienced IPAM visitors knew how to reserve the best work spots in the IPAM facility. Perhaps they should have been rotated among the groups. The staff on site were very helpful and friendly.
- Classrooms as co-working spaces are pretty hard to use. Also, having afternoon tea (like in other workshops) would have been great to facilitate conversations between research groups!

SPECIAL EVENTS AND CONFERENCES

Research in Industrial Projects for Students (RIPS) Celebration 2023
August 18, 2023

On August 18, 2023 IPAM celebrated 20 years of the immensely successful annual Research in Industrial Projects for Students (RIPS) summer program. This event was scheduled for the summer of 2021, but was delayed until the summer of 2023 due to the COVID pandemic. More than 700 students have come to IPAM since the inception of RIPS in 2001, and many of the program alumni came to UCLA to participate in this celebration.

The program included key note talks by two long-term supporters of RIPS and IPAM Alan Lee, Chief Technologist, Analog Devices, Inc., and Nancy Potok, CEO of NAPx Consulting. The program also included three panel sessions where RIPS alumni shared experiences about their careers in industry**,** academia, and other opportunities afforded to them since their participation in the program.

The event was capped off with a celebration banquet and testimonials from former RIPS students, sponsors, and mentors about their experience during their time in the program and how it affected their career path and life. A limited number of small travel grants were available for a small number of people under special circumstances.

LONG PROGRAM

Mathematical and Computational Challenges in Quantum Computing
September 11-December 15, 2023

Organizing Committee:
Di Fang (Duke University)
Eric Hudson (University of California, Los Angeles (UCLA))
Lin Lin (University of California, Berkeley (UC Berkeley))
Jarrod McClean (Google)
Prineha Narang (University of California, Los Angeles (UCLA))
Richard Ross (University of California, Los Angeles (UCLA))
Dan Stamper-Kurn (University of California, Berkeley (UC Berkeley))
Konstantina Trivisa (University of Maryland)

The aim of this program was to empower mathematics to change quantum information science, and to explore the rich overlap between pure and applied mathematical sciences and quantum information science. The broad goal was to cultivate and amplify the impact of mathematical sciences on quantum information science, and, conversely, to grow the impact of quantum information science on mathematics. With this broad goal in mind, the program convened many sub-communities of mathematics together with many sub-communities within quantum science (both theoretical and experimental) so as to encourage cross fertilization of ideas and the creative emergence of discoveries and new communities.

The program had the dual objective to explore how pure mathematics, applied mathematics, and data science can be applied to define and understand new concepts that arise in quantum information science and the quantum description of complex phenomena, and also how pure and applied mathematics may be advanced by the concepts and applications of quantum information science generally and quantum computing in particular. Among the important challenges addressed in this program was the effort to understand fully what are the new capabilities that quantum models for computation offer beyond classical models. Another important challenge was that of describing the structure and dynamics of complex quantum systems. Descriptions of few-body quantum systems are relatively well at hand and understood, even though surprises continue to arise. For larger systems, scientific progress has relied on various effective mathematical treatments. The drive to control large-scale quantum systems and use them to realize quantum computation challenges is to extend our treatments and obtain a deeper understanding of their structure and limitations. A third challenge was understanding where quantum information science can address current limitations in applied mathematics, data science, and numerical simulation.

This program brought together mathematicians, physicists, computer scientists, and others interested in pushing the boundaries of quantum computing.

Long Program Tutorials Workshop

Mathematical and Computational Challenges in Quantum Computing
September 12 – 15, 2023

The workshop had the same organizing committee as the long program; the vast majority of participants were from the long program core. The goal is to build a foundation for the participants of this program who have diverse scientific backgrounds.

Long Program Workshop I

Quantum Algorithms for Scientific Computation
October 2 – 6, 2023

Organizing Committee:
Dominic Berry (Macquarie University)
Di Fang (Duke University)
Lin Lin (University of California, Berkeley (UC Berkeley))
Konstantina Trivisa (University of Maryland)

The recent development of quantum algorithms has significantly pushed forward the frontier of using quantum computers for performing a wide range of scientific computing problems. This includes solving numerical linear algebra tasks for very large matrices, such as solving linear systems, eigenvalue and singular value transformation, matrix function evaluation, trace estimation, topological data analysis, etc., as well as solving certain high dimensional linear and nonlinear differential equations.

This workshop aims to bring together leading experts across different disciplines, including experts in solving related tasks using classical computers that can potentially inspire the development of new quantum algorithms; discuss recent progress made in the development of quantum algorithms for scientific computation, and the advances in classical algorithms; foster the discussion and pave the path towards identifying and overcoming challenging problems in science and engineering and for various industrial and technological applications.

Comments from our Participant Surveys:

- Include a few longer breaks for in-depth technical conversations!
- I wanted to commend you all for putting together an excellent workshop. The organizers and staff did an amazing job, and I look forward to coming to visit again.

Long Program Workshop II

Mathematical Aspects of Quantum Learning
October 16 – 20, 2023

Organizing Committee:
Srinivasan Arunachalam (IBM Research - Almaden)
Jens Eisert (Freie Universität Berlin)
Marika (Maria) Kieferova (University of Technology, Sydney)
Jarrod McClean (Google)
Nathan Wiebe (University of Toronto)

Recent results have hinted at the role quantum computing and technology may play in the future of machine learning, but much remains to be understood. For example, it has been shown that quantum computers can offer exponential improvements in learning from quantum data that comes from the physical world, and that compact quantum models can allow us to sample from probability distributions that seem inaccessible to traditional computing devices. In addition, general purpose quantum algorithms exist to dramatically speed up a number of subroutines that are pivotal in existing machine learning systems, but come with challenging caveats or have led to novel classical algorithm counterparts that challenge the advantage provided by quantum systems. However, fully grasping these results and connecting them to problems of interest today remains challenging for many reasons.

In this workshop, we hope to bring together experts from mathematics, quantum algorithms, and machine learning to better understand this intersection and reach the full potential of quantum computing and machine learning. This includes, but is not limited to, the ways in which quantum computers can accelerate existing machine learning algorithms, how we process

inherently quantum data with either classical or quantum computers, and ways in which machine learning can change how we operate quantum devices. We hope to identify a number of open questions of interest in each area, and draw strong connections to the mathematical foundations of both quantum computing and machine learning.

Comments from our Participant Surveys:

- Thanks for the opportunity to participate in this event! It's one of the best workshops I have been this year.
- I really enjoyed the workshop, which I thought was truly excellent - thank you!
- Give the possibility to the African people to participe physically
- One of the best organized conferences I've ever attended.

SPECIAL EVENTS AND CONFERENCES

PUNDiT: Practicum for Undergraduates in Number Theory
October 21 – 22, 2023

Organizing Committee:
Edray Goins (Pomona College)
Haydee Lindo (Harvey Mudd College)

"PUNDiT: (P)racticum for (Und)ergraduates (i)n Number (T)heory" is a 2-day intensive program which will showcase number theory broadly interpreted at the introductory level. A goal of this program is to expose Southern California students traditionally underrepresented in number theory (such as women and historically marginalized minorities) to the beauty of the subject.

The Practicum is introductory in nature and no prior number theory coursework will be assumed. Students should be familiar with Calculus and Linear Algebra, although this is not required. The Practicum is designed for students who have completed minimal coursework in upper-division mathematics courses.

PUNDiT will take place at **IPAM in UCLA**, and will feature:

- **Tutorials**: Two faculty members will rotate to give three lectures over two days to introduce topics in Number Theory.
- **Problem Sessions**: Two graduate students will coordinate a series of three hour-long group-work sessions where students will work on problems meant to supplement the tutorials.
- **Expository Talks**: Four experts in number theory will give one-hour introductory presentations on various topics.
- **Professional Development:** The organizers will lead two workshops on REUs, CVs, asking for letters of recommendation, *etc.*

Long Program Workshop III

Many-body Quantum Systems via Classical and Quantum Computation

November 6 – 9, 2023

Organizing Committee:
Soonwon Choi (Massachusetts Institute of Technology)
Sophia Economou (Virginia Tech)
Lloyd Hollenberg (University of Melbourne)
Prineha Narang (University of California, Los Angeles (UCLA))
Richard Ross (University of California, Los Angeles (UCLA))

The ability to coherently manipulate complex quantum many-body states offers the potential for dramatic improvements in a wide range of applications such as fast computation, enhanced sensing, and secure communications. However, understanding and ultimately controlling the dynamics of such entangled quantum states pose a number of challenges in mathematics and physics. In particular, the description of such complex quantum states often lies beyond the standard approach used in different areas of physics owing to their rich complexity.

This workshop is devoted to the related questions of how quantum and classical computers can be used to address important problems in quantum many-body physics, ranging from simulating quantum chemistry to understanding information dynamics in quantum circuits. While the faithful representation of full many-particle Hilbert spaces on a classical computer is exponentially costly, efficient approximate descriptions for specific purposes have been developed such as tensor network representations or mapping random circuits to statistical mechanics models. Also, recent advances of quantum technologies enable the empirical investigation of previously unexplored regimes of physics with high complexity, demanding new approaches to robustly controlling and utilizing near-term quantum devices for scientific discoveries and practical applications. This workshop will report the status quo of these developments and facilitate discussions for future research directions.

Comments from our Participant Surveys:

- It was really great, and I wish I have applied for the long program instead of the one-week workshop.
- This particular combination - quantum many-body physics and quantum chemistry - is a little odd and I felt that there were two disjoint communities
- Overall experience was pretty good. I think the opportunity to ask questions during the talk was super important to keep the audience engaged, and that is why I didn't find the lectures tiring although there were many topics new to me. Another thing I appreciated the most was the opportunity to mix with senior graduate students, post-doctorates, early career researchers, and professors. It was an encouraging environment in the vicinity of the beautiful campus and LA mountains.
- Some speakers only appeared for their talks and did not attend any of the remaining talks/activities. It would be good to get a sense of commitment in the future when speakers are invited.

Long Program Workshop IV

Topology, Quantum Error Correction and Quantum Gravity
November 27 – December 1, 2023

Organizing Committee:
Anurag Anshu (Harvard University)
Colleen Delaney (University of California, Berkeley (UC Berkeley))
Marius Junge (University of Illinois at Urbana-Champaign)
Roman Lutchyn (Microsoft Research)
Zhenghan Wang (Microsoft Research)
John Wright (University of California, Berkeley (UC Berkeley))

Quantum error correction has deep implications beyond quantum computing—two examples being its connections to topological phases of matter and quantum gravity. Recent exciting developments in these directions include the discovery of optimal quantum LDPC codes, progress towards the quantum PCP conjecture such as the proof of the NTLS conjecture, and the invention of Floquet codes. The workshop will focus on such new developments with the goal of finding better quantum error correction codes and new applications to open problems in quantum complexity theory, topological phases of matter, and quantum gravity. Error correction is also crucial in black hole physics. This workshop will explore (not necessarily unital) coding and complexity problems emerging from the information paradox.

Comments from our Participant Surveys:

- In the interest of inclusivity, you might consider having pronoun stickers available for participants to add to their attendee badges. This would help trans and non-binary participants feel more included.
- Eventually IPAM will want to make sure to provide a substantial (protein-ful) vegan option at breakfast to accommodate the growing number of participants with plant-based diets. Also, since the Luskin conference center rooms do not include refrigerators the IPAM reimbursements should include a modest per diem for early-career researchers to offset the high cost of eating out.
- You did a great job, and I greatly appreciate the opportunity to come!
- This workshop was amazing! One of the best weeks of my life.

GREEN FAMILY LECTURE SERIES

Lectures by Peter Shor: "Quantum Computing" and "The Development of Quantum Error Correction" delivered on November 27, 2023 and November 28, 2023, respectively.

IPAM does not keep track of public lecture participants.

LONG PROGRAM CULMINATING WORKSHOP AND REUNION CONFERNCES

UCLA Lake Arrowhead Conference Center
December 10-15, 2023

IPAM long programs end with a culminating workshop for long-term ("core") participants. Additionally, participants from past IPAM long programs are usually invited to two reunion conferences, which take place 1.5 and 2.5 years following the completion of their long programs.

Thus, normally, there are three groups at the IPAM Lake Arrowhead event: the core participants from the recently completed program (attending the culminating workshop), and the first and second reunions of two past long programs.

These co-located culminating and reunion conferences allow IPAM to track evolution of ideas we helped incubate, and plant seeds for future scientific directions. The 5-day conferences allow participants to present the research results and publications initiated by the long program but take a year or two to mature, and to further develop collaborations. The reunion conferences also help IPAM assess its success at building a successful and vital research community.

Culminating Workshop

December 10-15, 2023

IPAM long programs end with a culminating workshop for long-term ("core") participants. The workshop is held at the UCLA Lake Arrowhead Conference Center. The organizing committee is the same as for the long program itself. The purpose of the workshop is to summarize what is learned during the program. Working groups that formed during the long program give reports about their progress. Additionally, all participants collaborate to produce a White Paper, which serves to both capture developments discussed during the program itself and to map out potential future developments. The white paper is available at the IPAM web site, https://www.ipam.ucla.edu/reports/white-paper-mathematical-and-computational-challenges-in-quantum-computing/

Comments from our Participant Surveys:

- It was a great opportunitiy and I enjoyed the stay scientifically very much!

Reunion Conference

Tensor Methods and Emerging Applications to the Physical and Data Sciences
Reunion Conference II
December 10 – 15, 2023

This reunion occurred on-time, 2.5 years after the completion of the program. An alumni survey of the program was performed after this reunion, since this was the last activity associated with the long program. Our exit survey gathered 34 responses. A majority of the participants indicated that their involvement in the long program at IPAM had a positive impact on their research, collaborations, and career. Participants were asked to indicate their agreement by checking the corresponding boxes for the statements that applied to them.

At the completion of the program, we also performed several bibliographic analyses of the program. The results can be found in section K.

Comments from our Participant Surveys:

- Thank you so much for the wonderful opportunity! The event provided excellent opportunities to network with mathematicians and scientists from across the field,

exposed me to other areas of the field, and fostered excellent multidisciplinary connections, for which I am very grateful.

Reunion Conference

Machine Learning for Physics and the Physics of Learning
Reunion Conference II
December 10 – 15, 2023

This reunion occurred 4 years after the completion of the program and was held in combination with the Reunion Conference I from Advancing Quantum Mechanics with Mathematics and Statistics due to the overlap in participants. An alumni survey of the program was performed after this reunion, since this was the last activity associated with the long program. However, the survey also included the Advancing Quantum Mechanics with Mathematics participants. Our exit survey gathered 10 responses. A majority of the participants indicated that their involvement in the long program at IPAM had a positive impact on their research, collaborations, and career. Participants were asked to indicate their agreement by checking the corresponding boxes for the statements that applied to them.

At the completion of the program, we also performed several bibliographic analyses of the program. The results can be found in section K.

Reunion Conference

Advancing Quantum Mechanics with Mathematics and Statistics
Reunion Conference I
December 10 – 15, 2023

This reunion occurred 1.5 years the completion of the program and an alumni survey of the program was performed after this reunion. At the end of the 3-month long program, our exit survey gathered 24 responses. About 71% of those who responded self-identified as recent PhDs (5 years or less from PhD), and 29% identified as having received a PhD more than 5 years before the program. About one third of those responding identified as a mathematician or a statistician (46%), followed by computer scientists (12%), Physical Sciences (38%) and Chemistry (4%).

The table below summarizes responses to the question on the value of program activities. Generally, participants rated all program components highly.

	1-POOR	2	3	4-EXCELLENT	N/A	TOTAL
Value of Opening Day activities.	0.00% 0	0.00% 0	20.83% 5	45.83% 11	33.33% 8	24
Quality or usefulness of the series of workshops.	0.00% 0	4.17% 1	50.00% 12	45.83% 11	0.00% 0	24
Quality or usefulness of the activities between workshops.	0.00% 0	8.33% 2	12.50% 3	70.83% 17	8.33% 2	24

Value of the Culminating Workshop.	0.00% 0	4.17% 1	4.17% 1	58.33% 14	33.33% 8	24
Overall merit or quality of the long program.	0.00% 0	4.17% 1	16.67% 4	79.17% 19	0.00% 0	24

Overall, most participants were very satisfied with IPAM resources. The table below summarizes responses:

	1-POOR	2	3	4-EXCELLENT	N/A	TOTAL
Value of Opening Day activities.	0.00% 0	0.00% 0	20.83% 5	45.83% 11	33.33% 8	24
Quality or usefulness of the series of workshops.	0.00% 0	4.17% 1	50.00% 12	45.83% 11	0.00% 0	24
Quality or usefulness of the activities between workshops.	0.00% 0	8.33% 2	12.50% 3	70.83% 17	8.33% 2	24
Value of the Culminating Workshop.	0.00% 0	4.17% 1	4.17% 1	58.33% 14	33.33% 8	24
Overall merit or quality of the long program.	0.00% 0	4.17% 1	16.67% 4	79.17% 19	0.00% 0	24

Comments included positive comments such as "*The time in between workshops was the most unique and valuable part of the program, but the workshops were also quite informative*", as well as some critical comments, such as "*Paper checks are quite a hassle for overseas visitors. Opening a US bank account even only temporarily would create annual extra paperwork at home e.g. for people with economic ties to Switzerland. Personally, I'd be happy pay for the banking fees if it just means reimbursement would happen as international wire transfer*."

The majority of participants liked collaborative opportunities they had at IPAM. The table below summarizes their responses:

	NONE	LOW	MEDIUM	HIGH	TOTAL
Collaboration within your discipline or sub-discipline.	4.17% 1	8.33% 2	25.00% 6	62.50% 15	24
Collaboration outside your discipline or sub-discipline.	0.00% 0	4.17% 1	20.83% 5	75.00% 18	24
Collaboration between junior and senior participants.	0.00% 0	12.50% 3	29.17% 7	58.33% 14	24

More than 63% rated the possibility to collaborate outside one's discipline or sub-discipline as "high", which illustrates the highly interdisciplinary nature of this program. Almost 60% of

participants responded that the possibility of collaboration between a junior and senior participant was “high”.
Most participants agreed when presented with statements about the program meeting their expectations and being of help with furthering their career and research goals. The table below summarizes these responses:

	1 - STRONGLY DISAGREE	2	3	4 - STRONGLY AGREE	TOTAL
The IPAM long program met my expectations.	0.00% 0	8.33% 2	12.50% 3	79.17% 19	24
The long program will have a positive impact on my research and career.	0.00% 0	12.50% 3	12.50% 3	75.00% 18	24
The long program was a valuable mentoring opportunity for the "junior" participants.	0.00% 0	12.50% 3	37.50% 9	50.00% 12	24
I formed new collaborations that will lead to publications or other outcomes.	0.00% 0	16.67% 4	25.00% 6	58.33% 14	24
I would participate in another IPAM long program.	0.00% 0	12.50% 3	8.33% 2	79.17% 19	24

One of the respondents commented that *“I formed a collaboration with an awesome chemist and I’m excited to be working on a paper together with them!”*

At the completion of the program, we also performed several bibliographic analyses of the program. The results can be found in section K.

Comments from our Participant Survey after the reunion conference:

- Revisiting the white paper we wrote after the long program; Requiring PIs to stay through the end of the program, or dispersing the talks throughout Tues and Thurs afternoon so as to leave Friday morning open; Having topical discussion sections organized around areas from the white paper; Having a discussion regarding development of future IPAM long programs around topical areas of interest within the group
- Reimbursement could be made easier for European attendees

WINTER WORKSHOP

Symmetric Tensor Categories and Representation Theory
January 8 – 12, 2024

Organizing Committee:
Iván Angiono (FaMAF, Universidad Nacional de Cordoba)
Pavel Etingof (Massachusetts Institute of Technology)
Cris Negron (University of Southern California (USC))

Julia Plavnik (Indiana University)
Guillermo Sanmarco (University of Washington)

A tensor category is symmetric if it comes equipped with a braided structure that squares to the identity. A prototypical example is the category of finite dimensional representations of an affine group scheme, where the braiding is the usual swap. These categories provide a natural habitat for any kind of algebraic structure, which should, in principle, differ at a fundamental level from the usual structures defined over the category of vector spaces. In characteristic zero, a celebrated theorem by Deligne establishes that a symmetric tensor category has moderate growth if and only if it is equivalent to the category of super representations of an affine supergroup scheme. But as usual, the story in positive characteristic differs due to additional symmetries. This was first shown in the early 90's, where Verlinde categories, certain symmetric fusion categories with non-integral dimension, were built as a quotient of the tilting categories of some classical groups.

Symmetric tensor categories in positive characteristic have garnered significant attention in recent years, following a breakthrough initiated by the quest of providing substitutes for Deligne's theorem. Among others, the theory has applications to the study of modular representations of finite groups, and to Lie superalgebras in positive characteristic. On the other hand, the theory has encouraged the study of algebraic structures in certain symmetric categories, preeminently commutative algebras, affine group schemes and Lie algebras. This last direction also includes categories of super-exponential growth, which are thought of as representation categories of classical groups in non-integral rank, and play a fundamental role in stability questions.

The workshop aims to bring together researchers whose work involves the exploration of symmetric categorical structures in different contexts such as Hopf algebras, tensor categories, Lie superalgebras, homological algebra, and representation theory. The meeting will promote an exchange of ideas within researchers at different stages of their careers, and we hope to leave ample time for open-ended conversation and collaborative discussion.

Comments from our Participant Surveys:

- This workshop was extremely well organized! One idea of the organizers which worked very well was to devote separate days to various topics; I think this might be useful for some other workshops as well.
- Only comment: more vegan / vegetarian options when food is offered!
- I believe the workshop was a very useful and enjoying experience for all those who participated in person.
- Many of the lectures had significant overlap in material. Moreover, I would've enjoyed a winter school prior to the workshop and/or some introductory lectures during morning sessions. This could've prevented this overlap since speakers did not know the level of the audience.
- Poster session should have been announced in advance.
- I thought everything worked out beautifully, and I was very happy with how the conference went.

WINTER WORKSHOP

Mathematical Foundations for Equity in Transportation Systems
January 22 – 26, 2024

Organizing Committee:
Chad Higdon-Topaz (Williams College)
Hani Mahmassani (Northwestern University)
Juan Carlos Martinez Mori (Cornell University)
Samitha Samaranayake (Cornell University)
Anita Schöbel (Fraunhofer Institute for Industrial Mathematics ITWM)
David Shmoys (Cornell University)
Amanda Stathopoulos (Northwestern University)

Affordable and convenient transportation is a fundamental societal right—one with broad implications for personal well-being, environmental health, economic mobility, and access to education and health services. The past decade or so has seen significant innovations in transportation; powered by advances in artificial intelligence, mobile phone adoption, the internet-of-things, and new business models. However, one key concern is whether these changes are leading us toward a transportation future that is more equitable, especially given the historical injustices faced by marginalized segments of the population.

As the planning and operation of modern transportation systems become more and more data and computation driven, their societal impact becomes directly tied to the mathematical models and algorithms supporting their deployment. The fundamental goal of this workshop is to understand how modeling and computation in the planning and operation of transportation infrastructure impacts the equitable utilization of public resources. While the focus of this workshop will be on transportation, we believe it has the potential to more broadly contribute to understanding equitable public decision-making for all kinds of networked infrastructure systems, including but not limited to transportation.

Comments from our Participant Surveys:

- I very much enjoyed the workshop. I do not have suggestions.
- Excellent all around! Thank you!
- Having half a day without scientific talks (maybe even with some social program) would be great.
- Also, some (optional) joint activities in the evenings would be nice.
- I am so grateful to IPAM's wonderful staff for their support, and to IPAM leadership for their thoughtful processes.
- Very well organized & great initiative!
- I would like a primer to speakers on how to frame presentation and who was in the audience, otherwise it was great to have it be quite open-ended so talks were quite diverse
- I truly enjoyed the event because of the high-caliber of participants and the small number
- A social event (some excursion, can be done by participants themselves) would have be nice.

WINTER WORKSHOP

Tensor Networks
February 5 – 9, 2024

Organizing Committee:
Alessandra Bernardi (Università di Trento)
Joseph Landsberg (Texas A&M University - College Station)
Lek-Heng Lim (University of Chicago)
Jianfeng Lu (Duke University)

Many-body quantum mechanical systems are described by tensors. If a system has n particles, its state is an element of H1⊗···⊗Hn, where Hj is a Hilbert space associated to the j-th particle. Due to the exponential growth of the dimension of H1⊗···⊗Hn with n, any naive method of representing these tensors is intractable on a computer. However, most tensors are unlikely to appear as quantum states. Tensor network states were defined to reduce the complexity of the spaces involved by restricting to a subset of tensors that is physically reasonable. States of physical interest seem to be well parameterized as tensor networks with a small number of parameters. The construction essentially consists of a decorated graph, and the structure of the graph determines which tensors can be constructed from the configuration. This leads to questions regarding the best (still tractable) structures for graphs. Approximating a state in terms of a tensor network makes the entanglement nature of the state itself apparent, which is not visible when approximating the state in a physical coordinate system. Recently a tensor network on a classical computer apparently was more effective than Google's quantum computer. In this workshop we will compare the computational advantages of quantum computing vs tensor networks. It is important to investigate this question both practically and theoretically. Beyond tensor networks, the workshop will explore additional classes of tensors useful for many-body physics and quantum information theory and their utility in areas such as high dimensional probability.

Comments from our Participant Surveys:

- It was a pleasure to participate in this interesting Workshop at IPAM. Nice points: 1. Long sessions (50mins) mixed between blackboard and presentations, 2. long breaks to discuss 3.the open problem session, which in the beginning did not seem very appealing, resulted in a very interesting open discussion session. Many thanks to Joseph Landsberg, who acted as mediator posing many questions and uniting an audience from a diverse spectrum ranging Maths and Physics. To consider: Coming from Physics, sometimes the Math seminars seemed to me a bit far from the main question: classical tensor networks vs. quantum computation. To improve: Breakfasts. I would suggest adding some oats or cereal to the menu--it is simpler, and healthier. Thank you again for this nice Workshop.
- It would be great if we have some short tutorial sessions before the workshop so that people from different fields can understand each other's notations and problems they care about.
- Looking forward to come back :)

- It was a fantastic workshop! Only potential improvement: label food with vegan/vegetarian/gluten free/.. labels
- It is a bit radical, but I am tempted to ban slide talks from the next workshop I organize. Independent of theme, the board talks were far superior to the slide talks that tended to be too much information to follow (with a few exceptions).

WINTER WORKSHOP

Mathematical Approaches for Connectome Analysis
February 12 - 16, 2024

Organizing Committee:
Gwyneth Card (Columbia University)
Moo K. Chung (University of Wisconsin-Madison)
Marta Costa (University of Cambridge)
Vivek Jayaraman (Janelia Research Campus)
Ashok Litwin-Kumar (Columbia University)
Marcella Noorman (Janelia Research Campus)
Mason A. Porter (University of California, Los Angeles (UCLA))
Sandro Romani (Janelia Research Campus)
Eli Shlizerman (University of Washington)

In the past few years, the scale of data sets of the wiring of neural systems ("connectomes") has increased significantly. There are now near-complete connectomes of the central brains of *Drosophila* larvae and adults, volumes of mouse and human cerebral cortex, and data sets from several other species. With this increasing scale comes a need for quantitative methods to identify structure in large connectivity maps and relate it to the function of nervous systems.

The purpose of this workshop is to bring together neuroscientists who collect and study these data sets with mathematicians and other theorists who develop techniques to model and analyze networks, network dynamics, and dynamical processes on networks. We expect that crossing disciplinary boundaries will greatly facilitate progress, as neuroscientists working in connectomics often lack exposure to recent mathematical developments, while the biological and technical details that underlie connectomic data may not be familiar to mathematicians. This workshop will help define directions of future work in connectomics, with deep links to neuroscience, mathematics, and data science.

Comments from our Participant Surveys:

- I appreciate the variety of perspectives that were included in the meeting and the positive, inclusive atmosphere that the organizers helped to create. Would have been nice to have the TDA tutorial at the start of the week, though. Building off of this meeting, it would be fun to attend a workshop on dynamics on graphs (or on networks).
- This was an outstanding workshop. Well done.

SPECIAL EVENTS AND CONFERENCES

Winter School: Winter School on Quantum Information Science for Chemistry

February 20 – 23, 2024

Organizing Committee:
Anastassia Alexandrova (University of California, Los Angeles (UCLA))
Eric Hudson (University of California, Los Angeles (UCLA))
Anna Krylov (University of Southern California (USC))
Richard Ross (University of California, Los Angeles (UCLA))

The Challenge Institute for Quantum Computation (CIQC), the Advanced Molecular Architectures for Quantum Information Science (AMAQIS), and IPAM are pleased to present the fourth annual Winter School in Quantum Information Science. This year's school will turn its focus to Quantum Information Science for Chemistry and will provide both in-depth primers and surveys of current areas of active research in atomic, molecular, and materials systems for quantum information science applications, as well as quantum algorithms alongside methods of "usual" quantum chemistry. Topics that will be included in this winter school include:

- Introduction to Quantum Information
- Classical Quantum Chemistry and QIS applications
- Optical Cycling Centers
- Quantum Algorithms for Chemistry
- Molecular Spin Qubits

The school is aimed at early career participants, including graduate students, experimentalists, computational scientists, and theorists working in quantum information science and related disciplines. We aim to convene a multidisciplinary group of students and researchers who will disseminate and accelerate developments in the field, and to draw on their own research to help inspire new approaches and application domains. Applications are now being accepted. Financial support will be offered to young researchers subject to demonstrated need and availability.

Comments from our Participant Surveys:

- It would be nice to have more inclusive food options for dietary restrictions.
- I enjoyed the problem sessions. Solutions would be helpful, too!

WINTER WORKSHOP

EnCORE Workshop on Computational vs Statistical Gaps in Learning and Optimization
February 26 - March 1, 2024

Organizing Committee:
Arya Mazumdar (University of California, San Diego (UCSD))
Raghu Meka (University of California, Los Angeles (UCLA))
Rachel Ward (University of Texas at Austin)

In this workshop, we will explore the statistical and computational requirements for solving various learning problems. The statistical limit is the minimum number of samples needed to solve a learning problem. In contrast, the computational limit is the minimum number of samples required for the problem to be solvable by an efficient algorithm. There is much research on the

statistical requirements for many important learning problems, but the computational requirements are less well-understood. We often have large gaps between the two for several important problems (e.g., sparse linear regression). In addition, there are also gaps in our understanding of the costs of various constraints on learning, such as privacy, fairness, interpretability, robustness, and parallelization. This workshop will provide a forum to discuss the latest research and develop new ideas on the above questions. It will help build bridges between different disciplines, such as applied mathematics, statistics, optimization, and theoretical computer science, which will lead to more effective solutions to challenges in statistical inference.

Comments from our Participant Surveys:

- Great workshop, thanks for organizing!
- The breaks between talks can be a little too long, especially the afternoon one which has 40 minutes.

LONG PROGRAM

Geometry, Statistical Mechanics, and Integrability
March 11-June 14, 2024

Organizing Committee:
Dmitry Chelkak (University of Michigan)
Jan de Gier (University of Melbourne)
Vadim Gorin (University of California, Berkeley (UC Berkeley))
Richard Kenyon (Yale University)
Greta Panova (University of Southern California (USC))
Sanjay Ramassamy (Centre National de la Recherche Scientifique (CNRS))
Marianna Russkikh (University of Notre Dame)
In the last 20-30 years probability theory and statistical mechanics have been revitalized with the introduction of tools from geometry, notably conformal geometry and discrete analyticity, but also algebraic geometry and integrable systems.

Recent connections between classical and discrete geometric structures on surfaces, and combinatorial models such as the dimer model, Ising model and the Tutte polynomial reveal a significant connection with geometry, notably hyperbolic geometry and polyhedra. Other recent work on the dimer model has led to connections with knot theory, Lorentzian geometry, and symplectic geometry. From another direction, the combinatorics of the totally nonnegative Grassmannian has connections with the dimer model. Likewise, the isotropic Grassmannian and orthogonal Grassmannian have connections with spanning trees and the Ising model.

Finally, there are well-known connections between some statistical mechanics models and representation theory, such as Young diagrams, Gelfand-Tsetlin patterns, Knutson-Tao puzzles and Littlewood-Richardson coefficients and their generalizations. The Bethe Ansatz and the Yang-Baxter equation were developed for the 6-vertex model but are now fundamental tools in combinatorial representation theory.

This program will bring together researchers in this somewhat disparate realm of ideas, united by the underlying themes of geometry and statistical mechanics.

Long Program Tutorials Workshop

Geometry, Statistical Mechanics, and Integrability
March 12-15, 2023

The workshop had the same organizing committee as the long program; the vast majority of participants were from the long program core. The goal is to build a foundation for the participants of this program who have diverse scientific backgrounds.

Long Program Workshop I

Statistical Mechanics and Discrete Geometry
March 25 – 29, 2024

Organizing Committee:
Béatrice de Tilière (Université Paris Dauphine)
Sanjay Ramassamy (Centre National de la Recherche Scientifique (CNRS))
Marianna Russkikh (University of Notre Dame)

This workshop brings together specialists from different fields – statistical mechanics, discrete geometry and cluster algebras – and aims at fostering interactions.

Geometric structures associated with bipartite graphs on surfaces have recently emerged and turn out to be crucial for studying a variety of problems. On the one hand, probabilists working in statistical mechanics are interested in finding appropriate embeddings of planar graphs that lead to discrete complex analysis theories, which are well suited for observing conformally invariant objects in the scaling limit. In the course of doing so, they established deep connections between specific immersions of the underlying graphs, integrability of the models, and Harnack curves. On the other hand, several spaces of geometric objects have recently been found to be parametrized by weighted bipartite graphs on surfaces, relating them to cluster algebras and integrable systems. These include objects from discrete differential geometry (e.g. Q-nets, Darboux maps), positive Grassmannians, and higher Teichmüller spaces. Moreover, connections between knot theory and the dimer model have started to emerge and beg for a better understanding.

Comments from our Participant Surveys:

- During the workshops a few time a staff member came with some information, instruction, explanation. Of those messages I have not understood a word. When you speak you should take into account (1) that a good fraction of the audience does not have american english as their native speech, (2) what you have to say is important, and is worth calling attention for. So, speak clearly and slowly.
- It would be more convenient if there are accommodations close to and handled by the institute.
- Very friendly atmosphere
- It was a great experience, keep it up!

- Very productive workshop!
- Breakfast burritos and bear claws are better than just a bunch of eggs. The eggs are often a bit overcooked and dry. I would prefer hardboiled eggs or more moist scrambled eggs
- When registering for the conference, it would be nice to ask for preferred names and what name participants want to have on their name tags.
- Please lubricate the chairs! The noise is extremely loud and annoying, and it's often hard to hear questions from the audience. Other than that everything was amazing!

SPECIAL EVENTS AND CONFERENCES

Practicum for Undergraduate Mathematicians in Combinatorics
April 13 – 14, 2024

Organizing Committee:
Anastasia Chavez (Saint Mary's College of California)
Andrés Vindas Meléndez (Harvey Mudd College)

"PUMA: Practicum for Undergraduate MAthematicians" is a series of 2-day intensive programs which will showcase a specific mathematical sciences research area. **This PUMA event, on Saturday April 13 and Sunday April 14, 2024, will feature topics in combinatorics.** A goal of this program is to expose Southern California students historically underrepresented in STEM (such as women and historically marginalized minorities) to the beauty of the subject.

The Practicum is introductory in nature and no prior discrete math or combinatorics coursework will be assumed. Students should be familiar with calculus and linear algebra, although this is not required. PUMA is designed for students who have completed minimal coursework in upper-division mathematics courses.

- **Tutorials**: Three lectures over two days to introduce topics in Matroid theory.
- **Problem Sessions**: Two graduate students will coordinate a series of three hour-long group-work sessions where students will work on problems meant to supplement the tutorials.
- **Expository Talks**: Four experts will give one-hour introductory presentations on various combinatorial topics.
- **Professional Development Sessions**: We will hold two hour-long workshops on REUs, CVs, requesting letters of recommendation, *etc*.

Comments from our Participant Surveys:

- I didn't get to meet a majority of the other participants. I guess if I had 1 suggestion it would be to switch up breakout sessions so that we're working with different students each time. BUT, our time was short, given that it was a 2-day workshop, so I'm not sure if that would've helped in this case. All in all, thoroughly enjoyed the lectures, my group, and how easy going and approachable the professors were. The professional development topics were so helpful and encouraging. THANK YOU!!

Long Program Workshop II

Integrability and Algebraic Combinatorics
April 15 – 19, 2024

Organizing Committee:
Vadim Gorin (University of California, Berkeley (UC Berkeley))
Alejandro Morales (University of Quebec Montréal)
Greta Panova (University of Southern California (USC))

The workshop will focus on recent interactions between integrable probability and algebraic combinatorics.

In one direction we have seen many applications of tools and emergence of objects from algebraic combinatorics in integrable models in statistical mechanics. The major applications concern recent advances in [colored] vertex models and interacting particle systems using symmetric functions, specifically Schur and Macdonald polynomials and their generalizations.

Another example is the study of various exclusion processes (e.g. TASEP and its relatives) and their steady states where polynomials of algebro-combinatorial significance emerge (e.g. Schubert polynomials). The third example is the emergence of dimer models and electrical networks from the algebra of the positive Grassmannian.

In the opposite direction, tools and ideas from probability and statistical physics have seen application in problems from Algebraic Combinatorics. Two examples are the asymptotics of various structure constants of representation theoretic significance (e.g. Kostka, Littlewood-Richardson, and Kronecker coefficients) and symmetries of polynomials and rational functions arising from Yang-Baxter equations.

We have seen how probability motivates new research directions in algebraic combinatorics and how algebraic combinatorics leads to new discoveries in probability. The aim of the workshop is to further stimulate the cross-infiltration of the ideas between two fields.

Comments from our Participant Surveys:

- On April, 18th (?) there was an event at IMPAN during lunch time. Some of the participants were invited, some not. But it was not clearly communicated what this event was. This seperated the group in an uncomfortable way. It is okay to have seperate events at the same facility but then it should be clearly communicated.
- It was a great experience, keep it up!
- very productive workshop!
- Breakfast burritos and bear claws are better than just a bunch of eggs. The eggs are often a bit overcooked and dry. I would prefer hardboiled eggs or more moist scrambled eggs
- When registering for the conference, it would be nice to ask for preferred names and what name participants want to have on their name tags.

Long Program Workshop III

Statistical Mechanics Beyond 2D
May 6 – 10, 2024

Organizing Committee:
Tom Hutchcroft (California Institute of Technology)
Richard Kenyon (Yale University)
Gady Kozma (Weizmann Institute of Science)
Asaf Nachmias (Tel Aviv University)
Perla Sousi (University of Cambridge)

While classical "integrable" statistical mechanics has been restricted to one and two dimensions, recent ideas have extended our understanding to (some) higher dimensional situations, or to models on non-planar graphs. These include graph limits, posets, multinomial models, random complexes and random groups, and more. While these topics are quite diverse, they nonetheless have common tools, notably the use of random walks, the graph laplacian, homology theory, and determinants. Topics will include: Benjamini-Schramm limits of graphs, unimodular measures, spanning trees and spanning complexes, chip firing/sandpile models, matroids, higher determinantal processes, random complexes, multinomial models, random groups, rigidity, and statistical physics in more than two dimensions.

Comments from our Participant Surveys:

- Very friendly atmosphere

Long Program Workshop IV

Vertex Models: Algebraic and Probabilistic Aspects of Universality
May 20 – 24, 2024

Organizing Committee:
Dmitry Chelkak (University of Michigan)
Jan de Gier (University of Melbourne)
Eveliina Peltola (Aalto University)

The interplay of integrable models of statistical mechanics with combinations of probability theory and algebraic methods such as transfer matrix formalism, diagram algebras, and quantum group techniques, has proved fruitful in the past decades in both mathematics and physics. It has been particularly beneficial to enhance interactions between researchers working at the interfaces of these areas. The aim of this workshop is to bring together experts in algebraic and probabilistic aspects of solvable lattice models as well as researchers working on related algebraic subjects who have a common interest in understanding universal phenomena such as KPZ behavior, limit shapes, and convergence of lattice models to CFT predictions. In particular, we aim to develop interactions between different approaches to the study of lattice models, such as Bethe ansatz, (inhomogeneous) CFT methods and the tangent method. Other topics of potential interest include multi-species, forest fires and sandpile models, for which such interactions are less developed as for now. We also intend to foster interactions between

researchers studying quantum groups and CFT on the one hand and probabilists working on SLE/CLE topics on the other, hoping for a fruitful synthesis of ideas and techniques.

Comments from our Participant Surveys:

- I came with my (young) family. While I was attending the lectures and giving my own, it was a bit tricky for my wife (as expected). I was happy that staff offered some coloring materials, and one colleague even brought out a puzzle for my kids. It could be a nice feature for people with families if there were a few more kid friendly items on hand. Still, I was very appreciative of the help and that my family could spend some time in the lounge area when I was inside the lecture room.
- It would be more convenient if there are accommodations close to and handled by the institute.

GREEN FAMILY LECTURE SERIES

Lectures by Hugo Duminil-Copin "From Coffee to Mathematics: Making Connections and Finding Unexpected Links" and "Critical phenomena through the lens of the Ising model", May 20, 2024 and May 21, 2024, respectively.

IPAM does not keep track of public lecture participants.

Long Program Culminating Workshop and Reunion Conferences

UCLA Lake Arrowhead Conference Center
June 9 – 14, 2024

IPAM long programs end with a culminating workshop for long-term ("core") participants. Additionally, participants from past IPAM long programs are usually invited to two reunion conferences, which take place 1.5 and 2.5 years following the completion of their long programs. Thus, normally, there are three groups at the IPAM Lake Arrowhead event: the core participants from the recently completed program (attending the culminating workshop), and the first and second reunions of two past long programs.

These co-located culminating and reunion conferences allow IPAM to track evolution of ideas we helped incubate, and plant seeds for future scientific directions. The 5-day conferences allow participants to present the research results and publications initiated by the long program but take a year or two to mature, and to further develop collaborations. The reunion conferences also help IPAM assess its success at building a successful and vital research community.

Culminating Workshop

The Geometry, Statistical Mechanics, and Integrability long program ended with a culminating workshop at the UCLA Lake Arrowhead Conference Center. The organizing committee is the same as for the long program itself. The purpose of the workshop is to summarize what is learned during the program. Working groups that formed during the long program give reports about their progress. Additionally, all participants collaborate to produce a White Paper, which serves to both capture developments discussed during the program itself and to map out potential

future developments. The white paper is available at the IPAM web site, https://www.ipam.ucla.edu/reports/white-paper-geometry-statistical-mechanics-and-integrability/

Comments from our Participant Surveys:

- Thanks for everything throughout this week
- The retreat allows to know other participants better, and to form groups/links. How about doing this at the beginning of the program? It would create an initial bond between participants which would foster collaborations right from the beginning. Of course the conclusion aspect (w/ report writing) wouldnt be covered.
- check out at 9:00 was so early :)
- Evening talks should be shorter or more fun

Reunion Conference

Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy
Reunion Conference II

This reunion occurred 2.5 years after the completion of the long program. An alumni survey of the program was performed, since this was the last activity associated with the long program. The survey gathered 23 responses. A majority of the participants indicated that their involvement in the long program at IPAM had a positive impact on their research, collaborations, and career. Participants were asked to indicate their agreement by checking the corresponding boxes for the statements that applied to them.

At the completion of the program, we also performed several bibliographic analyses of the program. The results can be found in section K.

Comments from our Participant Surveys: None

Reunion Conference

Computational Microscopy
Reunion Conference 1

This reunion occurred 1.5 years the completion of the program. An alumni survey of the program was performed, since this was the last activity associated with the long program. The long program exit survey gathered 8 responses. About 63% of those who responded self-identified as recent PhDs (5 years or less from PhD). More than one third of those responding identified as a mathematician or a statistician (37.5%), followed by computer scientists (25%), Engineers (25%) and Physical Science (12.5%).

The table below summarizes responses to the question on the value of program activities. Generally, participants rated all program components highly.

	1-POOR	2	3	4-EXCELLENT	N/A	TOTAL
Value of Opening Day activities.	12.50% 1	0.00% 0	12.50% 1	50.00% 4	25.00% 2	8
Quality or usefulness of the series of workshops.	0.00% 0	0.00% 0	12.50% 1	87.50% 7	0.00% 0	8
Quality or usefulness of the activities between workshops.	0.00% 0	0.00% 0	12.50% 1	62.50% 5	25.00% 2	8
Value of the Culminating Workshop.	0.00% 0	0.00% 0	0.00% 0	37.50% 3	62.50% 5	8
Overall merit or quality of the long program.	0.00% 0	0.00% 0	25.00% 2	75.00% 6	0.00% 0	8

#	**YOU MAY ENTER YOUR COMMENTS HERE, IF YOU WISH:	DATE
1	really enjoyed the program and the people participating it. very friendly staff and great organization!	12/13/2022 10:50 AM
2	I am answering before attending the final retreat - therefore the N/A. I am sure it will be great, just as the general program.	12/11/2022 12:09 PM

Overall, most participants were very satisfied with IPAM resources. The table below summarizes responses:

	1 - VERY DISSATISFIED	2	3	4 - VERY SATISFIED	N/A	TOTAL
Facilities (your office, the lecture hall, etc.)	0.00% 0	0.00% 0	12.50% 1	87.50% 7	0.00% 0	8
Program staff support	0.00% 0	0.00% 0	0.00% 0	100.00% 8	0.00% 0	8
Computing resources and support	12.50% 1	0.00% 0	12.50% 1	37.50% 3	37.50% 3	8
Housing resources and support	0.00% 0	25.00% 2	0.00% 0	62.50% 5	12.50% 1	8
A supportive and inclusive environment for all program participants	0.00% 0	0.00% 0	0.00% 0	100.00% 8	0.00% 0	8
Financial support and reimbursement process	0.00% 0	0.00% 0	12.50% 1	75.00% 6	12.50% 1	8
Online resources	0.00% 0	0.00% 0	12.50% 1	75.00% 6	12.50% 1	8

Comments included positive comments such as "*YouTube recording is posted very timely and in great quality.*", as well as some critical comments, such as "*The computing support IPAM was great, but there were a lot of issues with wifi during the program (my understanding is that this was a campus wide issue at UCLA).*"

The majority of participants liked collaborative opportunities they had at IPAM. The table below summarizes their responses:

	NONE	LOW	MEDIUM	HIGH	TOTAL
Collaboration within your discipline or sub-discipline.	0.00% 0	0.00% 0	37.50% 3	62.50% 5	8
Collaboration outside your discipline or sub-discipline.	0.00% 0	0.00% 0	25.00% 2	75.00% 6	8
Collaboration between junior and senior participants.	0.00% 0	0.00% 0	50.00% 4	50.00% 4	8

Almost 63% rated the possibility to collaborate outside one's discipline or sub-discipline as "high", which illustrates the highly interdisciplinary nature of this program. 100% of participants responded that the possibility of collaboration between a junior and senior participant was "medium" to "high".

Most participants agreed when presented with statements about the program meeting their expectations and being of help with furthering their career and research goals. The table below summarizes these responses:

	1 - STRONGLY DISAGREE	2	3	4 - STRONGLY AGREE	TOTAL
The IPAM long program met my expectations.	0.00% 0	12.50% 1	25.00% 2	62.50% 5	8
The long program will have a positive impact on my research and career.	0.00% 0	0.00% 0	25.00% 2	75.00% 6	8
The long program was a valuable mentoring opportunity for the "junior" participants.	0.00% 0	25.00% 2	37.50% 3	37.50% 3	8
I formed new collaborations that will lead to publications or other outcomes.	0.00% 0	0.00% 0	62.50% 5	37.50% 3	8
I would participate in another IPAM long program.	0.00% 0	12.50% 1	12.50% 1	75.00% 6	8

At the completion of the program and reunion conference, we also performed several bibliographic analyses of the program. The results can be found in section K.

Comments from our reunion conference Participant Survey:

- The only small issue that everyone seemed to encounter was the wifi. It could use an upgrade But otherwise everything was amazing!

K. PROGRAM CONSULTANT LIST

IPAM consulted a variety of scholars and practitioners in the scientific planning of its programs. The list below includes program organizers for the programs that took place during this reporting period or upcoming programs for which organizing committees have begun meeting. The list excludes IPAM's scientific staff (directors) and members of IPAM's Science Advisory Board and Board of Trustees, who are listed in "Section N, Committee Membership". On occasion, IPAM scientific staff and Board Members are organizers of workshops and long programs, in which case they are included in the list below.

First Name	Last Name	Institution Name
Anastassia	Alexandrova	University of California, Los Angeles (UCLA)
Iván	Angiono	FaMAF, Universidad Nacional de Cordoba
Anurag	Anshu	Harvard University
Srinivasan	Arunachalam	IBM Research - Almaden
Alessandra	Bernardi	Università di Trento
Dominic	Berry	Macquarie University
Andrea	Bertozzi	University of California, Los Angeles (UCLA)
Erika Tatiana	Camacho	Arizona State University
Gwyneth	Card	Columbia University
Anastasia	Chavez	Saint Mary's College of California
Dmitry	Chelkak	University of Michigan
Soonwon	Choi	Massachusetts Institute of Technology
Moo K.	Chung	University of Wisconsin-Madison
Keisha	Cook	Clemson University
Marta	Costa	University of Cambridge
Jan	de Gier	University of Melbourne
Béatrice	de Tilière	Université Paris Dauphine
Colleen	Delaney	University of California, Berkeley (UC Berkeley)
Sophia	Economou	Virginia Tech
Jens	Eisert	Freie Universität Berlin
Malena	Espanol	Arizona State University
Pavel	Etingof	Massachusetts Institute of Technology
Di	Fang	Duke University

First Name	Last Name	Institution Name
Edray	Goins	Pomona College
Vadim	Gorin	University of California, Berkeley (UC Berkeley)
Chad	Higdon-Topaz	Williams College
Lloyd	Hollenberg	University of Melbourne
Thomas	Hou	California Institute of Technology
Eric	Hudson	University of California, Los Angeles (UCLA)
Tom	Hutchcroft	California Institute of Technology
Vivek	Jayaraman	Janelia Research Campus
Marius	Junge	University of Illinois at Urbana-Champaign
Richard	Kenyon	Yale University
Marika (Maria)	Kieferova	University of Technology, Sydney
Gady	Kozma	Weizmann Institute of Science
Anna	Krylov	University of Southern California (USC)
Joseph	Landsberg	Texas A&M University - College Station
Kathryn	Leonard	Occidental College
Lek-Heng	Lim	University of Chicago
Lin	Lin	University of California, Berkeley (UC Berkeley)
Haydee	Lindo	Harvey Mudd College
Ashok	Litwin-Kumar	Columbia University
John	Lowengrub	University of California, Irvine (UCI)
Jianfeng	Lu	Duke University
Roman	Lutchyn	Microsoft Research
Hani	Mahmassani	Northwestern University
Juan Carlos	Martinez Mori	Cornell University
Arya	Mazumdar	University of California, San Diego (UCSD)
Jarrod	McClean	Google
Raghu	Meka	University of California, Los Angeles (UCLA)
Alejandro	Morales	University of Quebec Montréal
Asaf	Nachmias	Tel Aviv University
Prineha	Narang	University of California, Los Angeles (UCLA)
Deanna	Needell	University of California, Los Angeles (UCLA)
Cris	Negron	University of Southern California (USC)
Linda	Ness	Rutgers University
Marcella	Noorman	Janelia Research Campus
Greta	Panova	University of Southern California (USC)
Eveliina	Peltola	Aalto University
Julia	Plavnik	Indiana University
Mason A.	Porter	University of California, Los Angeles (UCLA)
Alicia	Prieto Langarica	Youngstown State University
Sanjay	Ramassamy	Centre National de la Recherche Scientifique (CNRS)

First Name	Last Name	Institution Name
Christian	Ratsch	Institute for Pure and Applied Mathematics
Nancy	Rodriguez	University of Colorado Boulder
Sandro	Romani	Janelia Research Campus
Richard	Ross	University of California, Los Angeles (UCLA)
Marianna	Russkikh	University of Notre Dame
Samitha	Samaranayake	Cornell University
Guillermo	Sanmarco	University of Washington
Anita	Schöbel	Fraunhofer Institute for Industrial Mathematics ITWM
Eli	Shlizerman	University of Washington
David	Shmoys	Cornell University
Michael	Siegel	New Jersey Institute of Technology
Perla	Sousi	University of Cambridge
Dan	Stamper-Kurn	University of California, Berkeley (UC Berkeley)
Amanda	Stathopoulos	Northwestern University
Konstantina	Trivisa	University of Maryland
Andrés	Vindas Meléndez	Harvey Mudd College
Zhenghan	Wang	Microsoft Research
Rachel	Ward	University of Texas at Austin
Nathan	Wiebe	University of Toronto
John	Wright	University of California, Berkeley (UC Berkeley)

L. PUBLICATIONS LIST

BIBLIOGRAPHIC ANALYSIS

2021 Tensor Methods and Emerging Applications to the Physical and Data Sciences

The following is a summary of bibliographic analysis of the long program Tensor Methods and Emerging Applications to the Physical and Data Sciences, whose last activity was in December 2023. We asked program participants to tell us about published papers that they consider to be influenced by the program. These surveys are administered before the second reunion of the program, which is normally 2.5 years after the completion of the main part of the program. Below is the resulting list:

1. Alhajjar E., et al., *A Historical Perspective on International Treaties via Hypernetwork Science*, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) **13197 LNCS** 2022-01-01. **Paper link:** *SCOPUS_ID:85126255652*
2. Aliabadi M., et al., *On the Complexity of Finding Tensor Ranks*, Communications on Applied Mathematics and Computation **3** 2021-06-01. **Paper link:** *SCOPUS_ID:85132312548*

3. Amendola C., et al., *Third-order moment varieties of linear non-Gaussian graphical models*, Information and Inference **12** 2023-09-01. **Paper link:** *SCOPUS_ID:85166552123*
4. Angelini E., et al., *MINIMALITY AND UNIQUENESS FOR DECOMPOSITIONS OF SPECIFIC TERNARY FORMS*, Mathematics of Computation **91** 2022-01-01. **Paper link:** *SCOPUS_ID:85125076079*
5. Angelini E., et al., *On the description of identifiable quartics*, Linear and Multilinear Algebra **71** 2023-01-01. **Paper link:** *SCOPUS_ID:85126804294*
6. Arnab Auddy, Ming Yuan, *On estimating rank-one spiked tensors in the presence of heavy tailed errors*, IEEE Transactions on Information Theory, 68(12), 8053-8075 2022. *MANUALLY_UPLOADED_ID:54*
7. Arnab Auddy, Ming Yuan, *Perturbation bounds for (nearly) orthogonally decomposable tensors with statistical applications*, Information and Inference: A Journal of the IMA, 12 2023.*MANUALLY_UPLOADED_ID:53*
8. Awasthi P., et al., *Efficient Algorithms for Learning Depth-2 Neural Networks with General ReLU Activations*, Advances in Neural Information Processing Systems **16** 2021-01-01. **Paper link:***SCOPUS_ID:85125031140*
9. Barthel T., et al., *On the closedness and geometry of tensor network state sets*, Letters in Mathematical Physics **112** 2022-08-01. **Paper link:** *SCOPUS_ID:85134758478*
10. Beltran C., et al., *The Average Condition Number of Most Tensor Rank Decomposition Problems is Infinite*, Foundations of Computational Mathematics 2022-01-01. **Paper link:** *SCOPUS_ID:85124358539*
11. Bidleman D., et al., *Restricted secant varieties of Grassmannians*, Collectanea Mathematica 2023-01-01. **Paper link:** *SCOPUS_ID:85149457071*
12. Blomenhofer A.T., et al., *Identifiability for mixtures of centered Gaussians and sums of powers of quadratics*, Bulletin of the London Mathematical Society 2023-01-01. **Paper link:** *SCOPUS_ID:85146911273*
13. Breiding P., et al., *Equations for GL Invariant Families of Polynomials*, Vietnam Journal of Mathematics **50** 2022-04-01. **Paper link:** *SCOPUS_ID:85125145313*
14. Breiding P., et al., *Sensitivity of low-rank matrix recovery*, Numerische Mathematik **152** 2022-12-01. **Paper link:** *SCOPUS_ID:85140295584*
15. Breiding P., et al., *Algebraic compressed sensing*, Applied and Computational Harmonic Analysis **65** 2023-07-01. **Paper link:** *SCOPUS_ID:85153497606*
16. Bridgeman J.C., et al., *Invertible Bimodule Categories and Generalized Schur Orthogonality*, Communications in Mathematical Physics **402** 2023-09-01. **Paper link:** *SCOPUS_ID:85164980570*
17. Bruzda W., et al., *Rank of a tensor and quantum entanglement*, Linear and Multilinear Algebra 2023-01-01. **Paper link:** *SCOPUS_ID:85159714176*
18. Burgelman L., et al., *Contrasting pseudocriticality in the classical two-dimensional Heisenberg and RP2 models: Zero-temperature phase transition versus finite-temperature crossover*, Physical Review E **107** 2023-01-01. **Paper link:** *SCOPUS_ID:85146715108*
19. Chiantini L., et al., *On the study of decompositions of forms in four variables*, Rendiconti dell'Istituto di Matematica dell'Universita di Trieste **54** 2022-01-01. **Paper link:** *SCOPUS_ID:85141804233*
20. Chiantini L., et al., *A Footnote to a Footnote to a Paper of B. Segre*, Trends in Mathematics 2023-01-01. **Paper link:** *SCOPUS_ID:85153254142*
21. Choi Y., et al., *Locally conservative discontinuous bubble scheme for Darcy flow and its application to Hele-Shaw equation based on structured grids*, Numerical Algorithms **92** 2023-02-01. **Paper link:***SCOPUS_ID:85132593752*
22. Cirac J.I., et al., *Matrix product states and projected entangled pair states: Concepts, symmetries, theorems*, Reviews of Modern Physics **93** 2021-12-01. **Paper link:** *SCOPUS_ID:85122122728*

23. Colbois J., et al., *Partial lifting of degeneracy in the J1-J2-J3 Ising antiferromagnet on the kagome lattice*, Physical Review B **106** 2022-11-01. **Paper link:** *SCOPUS_ID:85142208490*
24. Cole S., et al., *On Quantum Optimal Transport*, Mathematical Physics Analysis and Geometry **26** 2023-06-01. **Paper link:** *SCOPUS_ID:85160999677*
25. Conner A., et al., *Bad and Good News for Strassen's Laser Method: Border Rank of Perm 3 and Strict Submultiplicativity*, Foundations of Computational Mathematics 2022-01-01. **Paper link:***SCOPUS_ID:85135769794*
26. Derksen H., et al., *Subrank and Optimal Reduction of Scalar Multiplications to Generic Tensors*, Leibniz International Proceedings in Informatics, LIPIcs **234** 2022-07-01. **Paper link:** *SCOPUS_ID:85134423948*
27. Devos L., et al., *Haldane gap in the SU(3) [3 0 0] Heisenberg chain*, Physical Review B **106** 2022-10-15. **Paper link:** *SCOPUS_ID:85139729414*
28. Dewaele N., et al., *The condition number of many tensor decompositions is invariant under Tucker compression*, Numerical Algorithms 2023-01-01. **Paper link:** *SCOPUS_ID:85163204721*
29. Dewaele N., et al., *Three decompositions of symmetric tensors have similar condition numbers*, Linear Algebra and Its Applications **664** 2023-05-01. **Paper link:** *SCOPUS_ID:85149708442*
30. Dickenstein A., et al., *Nonlinear Algebra: Preface to Two Special Issues Dedicated to Bernd Sturmfels on the Occasion of His 60th Birthday*, Vietnam Journal of Mathematics **50** 2022-04-01. **Paper link:***SCOPUS_ID:85128502692*
31. Elizaveta Rebrova, Yu-Hang Tang, *Nonlinear Matrix Approximation with Radial Basis Function Components*, preprint 2021. *MANUALLY_UPLOADED_ID:58*
32. Francuz A., et al., *Variational methods for characterizing matrix product operator symmetries*, Physical Review B **104** 2021-11-15. **Paper link:** *SCOPUS_ID:85121149040*
33. Friedland S., et al., *Special Issue: Polynomial and Tensor Optimization*, Mathematical Programming **193** 2022-06-01. **Paper link:** *SCOPUS_ID:85130258066*
34. Friedland S., et al., *Quantum Monge-Kantorovich Problem and Transport Distance between Density Matrices*, Physical Review Letters **129** 2022-09-09. **Paper link:** *SCOPUS_ID:85138288108*
35. Geng R., et al., *On the geometry of geometric rank*, Algebra and Number Theory **16** 2022-01-01. **Paper link:** *SCOPUS_ID:85136268501*
36. Gnang E.K., et al., *A hypermatrix analog of the general linear group*, Notices of the American Mathematical Society **68** 2021-10-01. **Paper link:** *SCOPUS_ID:85117344238*
37. Han R., et al., *Exact clustering in tensor block model: Statistical optimality and computational limit*, Journal of the Royal Statistical Society. Series B: Statistical Methodology **84** 2022-11-01. **Paper link:***SCOPUS_ID:85141169988*
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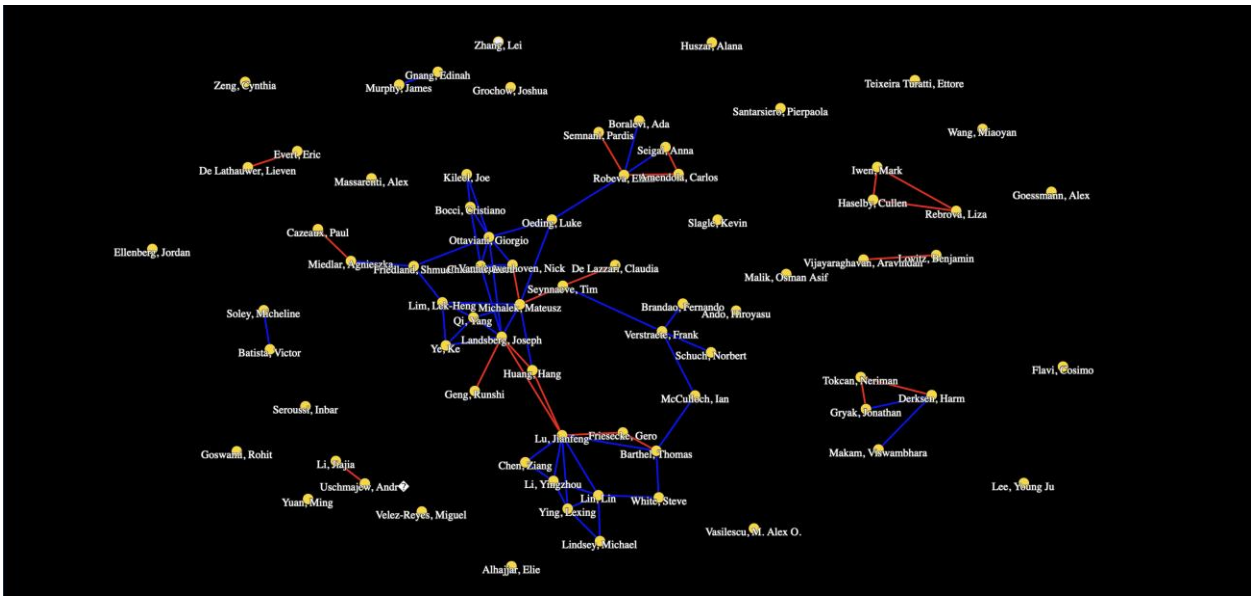
Collaboration network analysis

In addition, we have performed an automated collaboration analysis, seeking to identify pairs of collaborators that have not worked with each other prior to the program. In the graph below, such pairs are marked with red edges, while authors that collaborated prior to the year of the program are joined with blue edges.



The program had some success in forming new collaborations, bringing several new researchers to existing collaboration clusters, and forming new ones. Of note is collaborations between Hang Huang, Jinfeng Lu, and JM Landsberg, which bring together methods from mathematical physics and algebraic geometry and representation theory.

BIBLIOGRAPHIC ANALYSIS

2021 Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy

The following is a summary of bibliographic analysis of the 2021 long program Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy, whose last activity

was in June 2024. We performed several bibliographic analyses of the program. A survey was administered asking participants to report on the papers that were stimulated by the program These surveys are administered before the second reunion of the program, which is normally 2.5 years after the completion of the main part of the program. Below is the resulting list:

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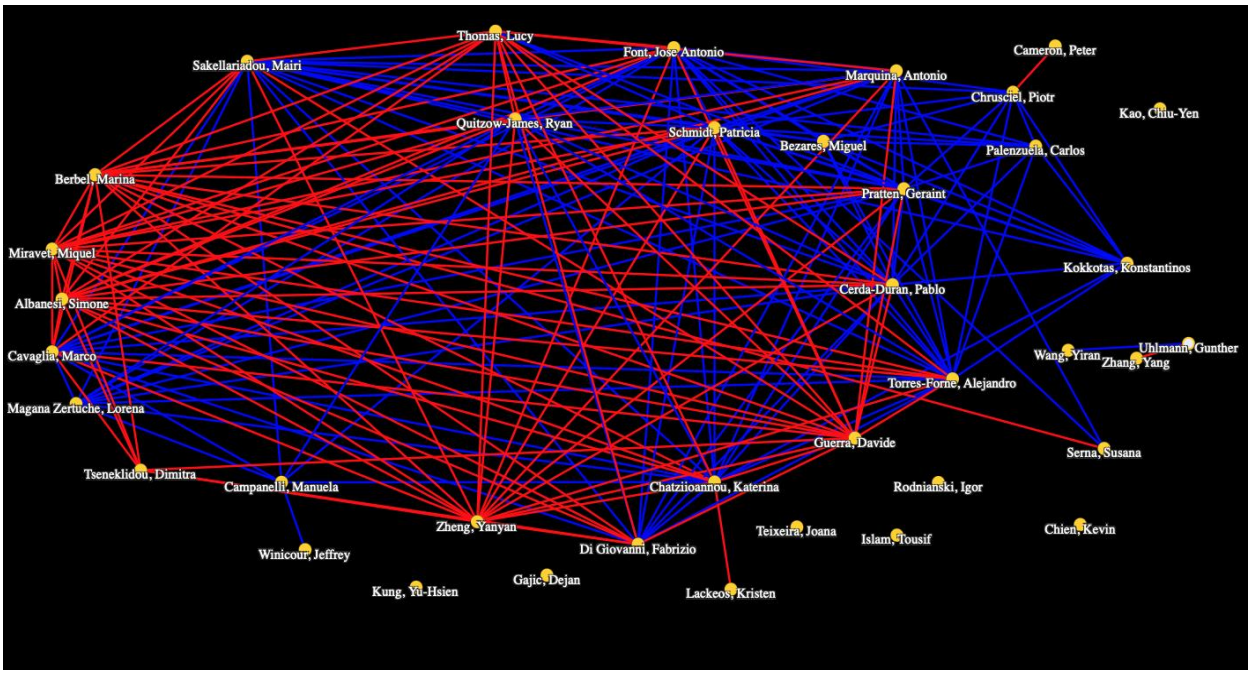
Collaboration network analysis

In addition, we have performed an automated collaboration analysis, seeking to identify pairs of collaborators that have not worked with each other prior to the program. In the graph below, such pairs are marked with red edges, while authors that collaborated prior to the year of the program are joined with blue edges.



The Gravitational Waves community is famous for several large-scale collaborations, including Ligo/Virgo, in which papers with hundreds of co-authors are published. As a result, the co-author graph is close to a complete group. It is notable that several new researchers joined these collaborations.

BIBLIOGRAPHIC ANALYSIS

Machine Learning for Physics and the Physics of Learning

The following is a summary of bibliographic analysis of the long program Machine Learning for Physics and the Physics of Learning. The program took place in fall of 2019, but its last reunion was delayed to December 2023 by COVID-19. We asked program participants to tell us about published papers that they consider to be influenced by the program. These surveys are administered before the second reunion of the program, which is normally 2.5 years after the completion of the main part of the program. Below is the resulting list:

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56. Noe F., et al., *Boltzmann generators: Sampling equilibrium states of many-body systems with deep learning*, Science **365** 2019-09-06. **Paper link:** SCOPUS_ID:85071754279
57. Noe F., et al., *Machine learning for protein folding and dynamics*, Current Opinion in Structural Biology **60** 2020-02-01. **Paper link:** SCOPUS_ID:85076863155
58. Noe F., et al., *Machine learning for molecular simulation*, Annual Review of Physical Chemistry **71** 2020-04-20. **Paper link:** SCOPUS_ID:85076843031
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60. Perez A., et al., *AdaptiveBandit: A Multi-armed Bandit Framework for Adaptive Sampling in Molecular Simulations*, Journal of Chemical Theory and Computation **16** 2020-07-14. **Paper link:** SCOPUS_ID:85088485792
61. Scherer M.K., et al., *Variational selection of features for molecular kinetics*, Journal of Chemical Physics **150** 2019-05-21. **Paper link:** SCOPUS_ID:85065980184
62. Shmilovich K., et al., *Temporally Coherent Backmapping of Molecular Trajectories from Coarse-Grained to Atomistic Resolution*, Journal of Physical Chemistry A **126** 2022-12-08. **Paper link:** SCOPUS_ID:85143062052
63. Skalic M., et al., *LigVoxel: Inpainting binding pockets using 3D-convolutional neural networks*, Bioinformatics **35** 2019-01-15, 243-250. **Paper link:** SCOPUS_ID:85058236202
64. Skalic M., et al., *Shape-Based Generative Modeling for de Novo Drug Design*, Journal of Chemical Information and Modeling **59** 2019-03-25, 1205-1214. **Paper link:** SCOPUS_ID:85062463562
65. Skalic M., et al., *PlayMolecule BindScope: Large scale CNN-based virtual screening on the web*, Bioinformatics **35** 2019-04-01, 1237-1238. **Paper link:** SCOPUS_ID:85064110947
66. Stieffenhofer M., et al., *Adversarial reverse mapping of equilibrated condensed-phase molecular structures*, Machine Learning: Science and Technology **1** 2020-12-01. **Paper link:** SCOPUS_ID:85116074616
67. Stieffenhofer M., et al., *Adversarial reverse mapping of condensed-phase molecular structures: Chemical transferability*, APL Materials **9** 2021-03-01. **Paper link:** SCOPUS_ID:85102504772
68. Stieffenhofer M., et al., *Benchmarking coarse-grained models of organic semiconductors via deep backmapping*, Frontiers in Chemistry **10** 2022-09-09. **Paper link:** SCOPUS_ID:85138791191

69. Sun C., et al., *Deep reinforcement learning for optical systems: A case study of mode-locked lasers*, Machine Learning: Science and Technology **1** 2020-12-01. **Paper link:** SCOPUS_ID:85102737717
70. Varela-Rial A., et al., *PlayMolecule Glimpse: Understanding Protein-Ligand Property Predictions with Interpretable Neural Networks*, Journal of Chemical Information and Modeling **62** 2022-01-24. **Paper link:** SCOPUS_ID:85122661620
71. Wang J., et al., *Machine Learning of Coarse-Grained Molecular Dynamics Force Fields*, ACS Central Science 2019-01-01. **Paper link:** SCOPUS_ID:85065055245
72. Wang J., et al., *Ensemble learning of coarse-grained molecular dynamics force fields with a kernel approach*, The Journal of chemical physics **152** 2020-05-21. **Paper link:** SCOPUS_ID:85090879325
73. Wang J., et al., *Multi-body effects in a coarse-grained protein force field*, Journal of Chemical Physics **154** 2021-04-28. **Paper link:** SCOPUS_ID:85105121888
74. Wu H., et al., *Stochastic normalizing flows*, Advances in Neural Information Processing Systems **2020-December** 2020-01-01. **Paper link:** SCOPUS_ID:85108206296
75. Xie S.R., et al., *Ultra-fast interpretable machine-learning potentials*, npj Computational Materials **9** 2023-12-01. **Paper link:** SCOPUS_ID:85169674980
76. Yang W., et al., *Slicing and Dicing: Optimal Coarse-Grained Representation to Preserve Molecular Kinetics*, ACS Central Science 2022-01-01. **Paper link:** SCOPUS_ID:85146605540

Additionally, our survey of participants soliciting papers which are related to the program produced the following list:

1. Abella J.R., et al., *Ape-gen: A fast method for generating ensembles of bound peptide-MHC conformations*, Molecules 2019-01-01. **Paper link:** SCOPUS_ID:85062390600
2. Abella J.R., et al., *Large-Scale Structure-Based Prediction of Stable Peptide Binding to Class I HLAs Using Random Forests*, Frontiers in Immunology **11** 2020-07-22. **Paper link:** SCOPUS_ID:85089096469
3. Abella J.R., et al., *Markov state modeling reveals alternative unbinding pathways for peptide–MHC complexes*, Proceedings of the National Academy of Sciences of the United States of America **117** 2020-12-01. **Paper link:** SCOPUS_ID:85097211070
4. Arts M., et al., *Two for One: Diffusion Models and Force Fields for Coarse-Grained Molecular Dynamics*, Journal of Chemical Theory and Computation 2023-01-01. **Paper link:** SCOPUS_ID:85172425204
5. Barnett J.W., et al., *Designing exceptional gas-separation polymer membranes using machine learning*, Science Advances **6** 2020-05-01. **Paper link:** SCOPUS_ID:85084943220
6. Bereau T., et al., *Computational compound screening of biomolecules and soft materials by molecular simulations*, Modelling and Simulation in Materials Science and Engineering **29** 2021-02-02. **Paper link:** SCOPUS_ID:85101839940
7. Bramburger J.J., et al., *Data-Driven Stabilization of Periodic Orbits*, IEEE Access **9** 2021-01-01. **Paper link:** SCOPUS_ID:85103781196
8. Brunton S.L., et al., *Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control*, Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control 2019-01-01. **Paper link:** SCOPUS_ID:85132470588
9. Brunton S.L., et al., *Special issue on machine learning and data-driven methods in fluid dynamics*, Theoretical and Computational Fluid Dynamics **34** 2020-08-01. **Paper link:** SCOPUS_ID:85089036221
10. Brunton S.L., et al., *Applying machine learning to study fluid mechanics*, Acta Mechanica Sinica/Lixue Xuebao **37** 2021-12-01. **Paper link:** SCOPUS_ID:85122237520

11. Bull-Vulpe E.F., et al., *MB-Fit: Software infrastructure for data-driven many-body potential energy functions*, Journal of Chemical Physics **155** 2021-09-28. **Paper link:** SCOPUS_ID:85116014093
12. Burov D., et al., *Kernel analog forecasting: Multiscale test problems*, Multiscale Modeling and Simulation **19** 2021-01-01. **Paper link:** SCOPUS_ID:85108422221
13. Callaham J.L., et al., *Nonlinear stochastic modelling with Langevin regression*, Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences **477** 2021-06-30. **Paper link:** SCOPUS_ID:85108546243
14. Caylak O., et al., *Wasserstein metric for improved quantum machine learning with adjacency matrix representations*, Machine Learning: Science and Technology **1** 2020-09-01. **Paper link:** SCOPUS_ID:85097812039
15. Ceriotti M., et al., *Machine learning meets chemical physics*, The Journal of chemical physics **154** 2021-04-28. **Paper link:** SCOPUS_ID:85105254998
16. Ceriotti M., et al., *Introduction: Machine Learning at the Atomic Scale*, Chemical Reviews **121** 2021-08-25. **Paper link:** SCOPUS_ID:85114982320
17. Chakraborty M., et al., *Is preservation of symmetry necessary for coarse-graining?*, Physical Chemistry Chemical Physics **22** 2020-07-14. **Paper link:** SCOPUS_ID:85088209737
18. Chen Y., et al., *Machine learning implicit solvation for molecular dynamics*, Journal of Chemical Physics **155** 2021-08-28. **Paper link:** SCOPUS_ID:85113924152
19. Chen Y.-C., et al., *Selecting the independent coordinates of manifolds with large aspect ratios*, Advances in Neural Information Processing Systems **32** 2019-01-01. **Paper link:** SCOPUS_ID:85090172416
20. Chen Y.-C., et al., *The decomposition of the higher-order homology embedding constructed from the k-Laplacian*, Advances in Neural Information Processing Systems **19** 2021-01-01. **Paper link:** SCOPUS_ID:85131807989
21. Clementi C., et al., *Fast track to structural biology*, Nature Chemistry **13** 2021-11-01. **Paper link:** SCOPUS_ID:85118167590
22. Del Rosario Z., et al., *Assessing the frontier: Active learning, model accuracy, and multi-objective candidate discovery and optimization*, Journal of Chemical Physics **153** 2020-07-14. **Paper link:** SCOPUS_ID:85088157072
23. Doerr S., et al., *TorchMD: A Deep Learning Framework for Molecular Simulations*, Journal of Chemical Theory and Computation **17** 2021-04-13. **Paper link:** SCOPUS_ID:85103792700
24. Durumeric A.E.P., et al., *Machine learned coarse-grained protein force-fields: Are we there yet?*, Current Opinion in Structural Biology **79** 2023-04-01. **Paper link:** SCOPUS_ID:85147251138
25. Evangelou N., et al., *Double Diffusion Maps and their Latent Harmonics for scientific computations in latent space*, Journal of Computational Physics **485** 2023-07-15. **Paper link:** SCOPUS_ID:85152236741
26. G Simeon, G De Fabritiis, *TensorNet: Cartesian Tensor Representations for Efficient Learning of Molecular Potentials*, Neurips 2023. *MANUALLY_UPLOADED_ID:51*
27. Galvelis R., et al., *NNP/MM: Accelerating Molecular Dynamics Simulations with Machine Learning Potentials and Molecular Mechanics*, Journal of Chemical Information and Modeling 2023-01-01. **Paper link:** SCOPUS_ID:85172913951
28. Gibson J., et al., *Data-augmentation for graph neural network learning of the relaxed energies of unrelaxed structures*, npj Computational Materials **8** 2022-12-01. **Paper link:** SCOPUS_ID:85139233691
29. Glielmo A., et al., *Unsupervised Learning Methods for Molecular Simulation Data*, Chemical Reviews 2021-01-01. **Paper link:** SCOPUS_ID:85106365598
30. Grant S., et al., *Refinement: Measuring informativeness of ratings in the absence of a gold standard*, British Journal of Mathematical and Statistical Psychology **75** 2022-11-01. **Paper link:** SCOPUS_ID:85126306964

31. Hermann J., et al., *Deep-neural-network solution of the electronic Schrödinger equation*, Nature Chemistry **12** 2020-10-01. **Paper link:** SCOPUS_ID:85091351552
32. Hermann J., et al., *Ab initio quantum chemistry with neural-network wavefunctions*, Nature Reviews Chemistry 2023-01-01. **Paper link:** SCOPUS_ID:85167355883
33. Hoffmann C., et al., *Molecular dynamics trajectories for 630 coarse-grained drug-membrane permeations*, Scientific Data **7** 2020-12-01. **Paper link:** SCOPUS_ID:85079336660
34. Hoffmann M., et al., *Reactive SINDy: Discovering governing reactions from concentration data*, Journal of Chemical Physics **150** 2019-01-14. **Paper link:** SCOPUS_ID:85059820315
35. Honrao S.J., et al., *Augmenting machine learning of energy landscapes with local structural information*, Journal of Applied Physics **128** 2020-08-28. **Paper link:** SCOPUS_ID:85095458807
36. Huo H., et al., *Unified representation of molecules and crystals for machine learning*, Machine Learning: Science and Technology **3** 2022-12-01. **Paper link:** SCOPUS_ID:85142165250
37. Husic B.E., et al., *Coarse graining molecular dynamics with graph neural networks*, Journal of Chemical Physics **153** 2020-11-21. **Paper link:** SCOPUS_ID:85096336999
38. Invernizzi M., et al., *Skipping the Replica Exchange Ladder with Normalizing Flows*, Journal of Physical Chemistry Letters **13** 2022-12-22. **Paper link:** SCOPUS_ID:85143857784
39. Kanekal K.H., et al., *Broad chemical transferability in structure-based coarse-graining*, Journal of Chemical Physics **157** 2022-09-14. **Paper link:** SCOPUS_ID:85137861720
40. Klus S., et al., *Kernel methods for detecting coherent structures in dynamical data*, Chaos **29** 2019-12-01. **Paper link:** SCOPUS_ID:85076599605
41. Klus S., et al., *Data-driven approximation of the Koopman generator: Model reduction, system identification, and control*, Physica D: Nonlinear Phenomena **406** 2020-05-01. **Paper link:** SCOPUS_ID:85079908691
42. Koelle S.J., et al., *Manifold Coordinates with Physical Meaning*, Journal of Machine Learning Research **23** 2022-05-01. **Paper link:** SCOPUS_ID:85131400093
43. Kohler J., et al., *Flow-Matching: Efficient Coarse-Graining of Molecular Dynamics without Forces*, Journal of Chemical Theory and Computation **19** 2023-02-14. **Paper link:** SCOPUS_ID:85146843935
44. Kramer A., et al., *Statistically Optimal Force Aggregation for Coarse-Graining Molecular Dynamics*, Journal of Physical Chemistry Letters **14** 2023-05-04. **Paper link:** SCOPUS_ID:85154062207
45. Langer M.F., et al., *Representations of molecules and materials for interpolation of quantum-mechanical simulations via machine learning*, npj Computational Materials **8** 2022-12-01. **Paper link:** SCOPUS_ID:85127323798
46. Langer M.F., et al., *Heat flux for semilocal machine-learning potentials*, Physical Review B **108** 2023-09-01. **Paper link:** SCOPUS_ID:85172214951
47. Libardi G., et al., *Guided Exploration with Proximal Policy Optimization using a Single Demonstration*, Proceedings of Machine Learning Research **139** 2021-01-01. **Paper link:** SCOPUS_ID:85116692080
48. Loiseau J.-C., et al., *From the POD-galerkin method to sparse manifold models*, Applications 2020-12-07. **Paper link:** SCOPUS_ID:85109225952
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51. Manohar K., et al., *Optimized sampling for multiscale dynamics*, Multiscale Modeling and Simulation **17** 2019-01-01, 117-136. **Paper link:** SCOPUS_ID:85067456447
52. Manohar K., et al., *Optimal Sensor and Actuator Selection using Balanced Model Reduction*, IEEE Transactions on Automatic Control 2021-01-01. **Paper link:** SCOPUS_ID:85107200829

53. Mardt A., et al., *Deep learning Markov and Koopman models with physical constraints*, Proceedings of Machine Learning Research **107** 2020-01-01. **Paper link:** SCOPUS_ID:85109229584
54. Mardt A., et al., *Deep learning to decompose macromolecules into independent Markovian domains*, Nature Communications **13** 2022-12-01. **Paper link:** SCOPUS_ID:85142303383
55. Marina Meila, Hanyu Zhang, *Manifold Learning: What, how and why*, Annual Reviews in Statistics and its Apllications, to appear 2024. *MANUALLY_UPLOADED_ID:49*
56. Mohr B., et al., *Data-driven discovery of cardiolipin-selective small molecules by computational active learning*, Chemical Science 2022-01-01. **Paper link:** SCOPUS_ID:85128169662
57. Mohr B., et al., *Condensed-Phase Molecular Representation to Link Structure and Thermodynamics in Molecular Dynamics*, Journal of Chemical Theory and Computation 2023-01-01. **Paper link:** SCOPUS_ID:85164832393
58. Musil F., et al., *Quantum dynamics using path integral coarse-graining*, Journal of Chemical Physics **157** 2022-11-14. **Paper link:** SCOPUS_ID:85141952715
59. Nicoli K.A., et al., *Asymptotically unbiased estimation of physical observables with neural samplers*, Physical Review E **101** 2020-02-01. **Paper link:** SCOPUS_ID:85081963694
60. Nicoli K.A., et al., *Estimation of Thermodynamic Observables in Lattice Field Theories with Deep Generative Models*, Physical Review Letters **126** 2021-01-19. **Paper link:** SCOPUS_ID:85099790084
61. Nicoli K.A., et al., *Machine Learning of Thermodynamic Observables in the Presence of Mode Collapse*, Proceedings of Science **396** 2022-07-08. **Paper link:** SCOPUS_ID:85134427182
62. Noe F., et al., *Machine Learning for Molecular Dynamics on Long Timescales*, Lecture Notes in Physics **968** 2020-01-01. **Paper link:** SCOPUS_ID:85086107785
63. Noe F., et al., *Machine learning for protein folding and dynamics*, Current Opinion in Structural Biology **60** 2020-02-01. **Paper link:** SCOPUS_ID:85076863155
64. Noe F., et al., *Machine learning for molecular simulation*, Annual Review of Physical Chemistry **71** 2020-04-20. **Paper link:** SCOPUS_ID:85076843031
65. Nuske F., et al., *Coarse-graining molecular systems by spectral matching*, Journal of Chemical Physics **151** 2019-07-28. **Paper link:** SCOPUS_ID:85070089844
66. Nuske F., et al., *Spectral properties of effective dynamics from conditional expectations*, Entropy **23** 2021-02-01. **Paper link:** SCOPUS_ID:85099977108
67. Nuske F., et al., *Tensor-based computation of metastable and coherent sets*, Physica D: Nonlinear Phenomena **427** 2021-12-01. **Paper link:** SCOPUS_ID:85115204347
68. Onken D., et al., *OT-Flow: Fast and Accurate Continuous Normalizing Flows via Optimal Transport*, 35th AAAI Conference on Artificial Intelligence, AAAI 2021 **10B** 2021-01-01. **Paper link:** SCOPUS_ID:85106614270
69. Onken D., et al., *A Neural Network Approach for High-Dimensional Optimal Control Applied to Multiagent Path Finding*, IEEE Transactions on Control Systems Technology 2022-01-01. **Paper link:** SCOPUS_ID:85131768408
70. Pettini G., et al., *On the origin of phase transitions in the absence of symmetry-breaking*, Physica A: Statistical Mechanics and its Applications **516** 2019-02-15, 376-392. **Paper link:** SCOPUS_ID:85055670390
71. Rauer C., et al., *Hydration free energies from kernel-based machine learning: Compound-database bias*, Journal of Chemical Physics **153** 2020-07-07. **Paper link:** SCOPUS_ID:85087589076
72. Ren S., et al., *Ligand Optimization of Exchange Interaction in Co(II) Dimer Single Molecule Magnet by Machine Learning*, Journal of Physical Chemistry A **126** 2022-02-03. **Paper link:** SCOPUS_ID:85123620040
73. Riera M., et al., *MBX: A many-body energy and force calculator for data-driven many-body simulations*, Journal of Chemical Physics **159** 2023-08-07. **Paper link:** SCOPUS_ID:85166155033

74. Ruthotto L., et al., *A machine learning framework for solving high-dimensional mean field game and mean field control problems*, Proceedings of the National Academy of Sciences of the United States of America **117** 2020-04-28. **Paper link:** SCOPUS_ID:85084116809
75. Ruthotto L., et al., *An introduction to deep generative modeling*, GAMM Mitteilungen **44** 2021-06-01. **Paper link:** SCOPUS_ID:85103999448
76. Schatzle Z., et al., *Convergence to the fixed-node limit in deep variational Monte Carlo*, Journal of Chemical Physics **154** 2021-03-28. **Paper link:** SCOPUS_ID:85103348611
77. Schatzle Z., et al., *DeepQMC: An open-source software suite for variational optimization of deep-learning molecular wave functions*, Journal of Chemical Physics **159** 2023-09-07. **Paper link:** SCOPUS_ID:85169758384
78. Scherer C., et al., *Kernel-Based Machine Learning for Efficient Simulations of Molecular Liquids*, Journal of Chemical Theory and Computation **16** 2020-05-12. **Paper link:** SCOPUS_ID:85084694303
79. Scherer M.K., et al., *Variational selection of features for molecular kinetics*, Journal of Chemical Physics **150** 2019-05-21. **Paper link:** SCOPUS_ID:85065980184
80. Sharma M., et al., *Inversion of convection–diffusion equation with discrete sources*, Optimization and Engineering 2020-01-01. **Paper link:** SCOPUS_ID:85088560083
81. Snyder J., et al., *Data-driven stochastic modeling of coarse-grained dynamics with finite-size effects using Langevin regression*, Physica D: Nonlinear Phenomena **427** 2021-12-01. **Paper link:** SCOPUS_ID:85114350783
82. Stieffenhofer M., et al., *Adversarial reverse mapping of equilibrated condensed-phase molecular structures*, Machine Learning: Science and Technology **1** 2020-12-01. **Paper link:** SCOPUS_ID:85116074616
83. Stieffenhofer M., et al., *Adversarial reverse mapping of condensed-phase molecular structures: Chemical transferability*, APL Materials **9** 2021-03-01. **Paper link:** SCOPUS_ID:85102504772
84. Tholke P., et al., *TORCHMD-NET: EQUIVARIANT TRANSFORMERS FOR NEURAL NETWORK BASED MOLECULAR POTENTIALS*, ICLR 2022 - 10th International Conference on Learning Representations 2022-01-01. **Paper link:** SCOPUS_ID:85147407032
85. Varolgunes Y.B., et al., *Interpretable embeddings from molecular simulations using Gaussian mixture variational autoencoders*, Machine Learning: Science and Technology **1** 2020-03-01. **Paper link:** SCOPUS_ID:85087592698
86. Wang J., et al., *Machine Learning of Coarse-Grained Molecular Dynamics Force Fields*, ACS Central Science 2019-01-01. **Paper link:** SCOPUS_ID:85065055245
87. Wang J., et al., *Ensemble learning of coarse-grained molecular dynamics force fields with a kernel approach*, The Journal of chemical physics **152** 2020-05-21. **Paper link:** SCOPUS_ID:85090879325
88. Wang J., et al., *Multi-body effects in a coarse-grained protein force field*, Journal of Chemical Physics **154** 2021-04-28. **Paper link:** SCOPUS_ID:85105121888
89. Wu H., et al., *Stochastic normalizing flows*, Advances in Neural Information Processing Systems **2020-December** 2020-01-01. **Paper link:** SCOPUS_ID:85108206296
90. Wu H., et al., *Variational Approach for Learning Markov Processes from Time Series Data*, Journal of Nonlinear Science **30** 2020-02-01. **Paper link:** SCOPUS_ID:85070209312
91. Xie S.R., et al., *Machine learning of octahedral tilting in oxide perovskites by symbolic classification with compressed sensing*, Computational Materials Science **180** 2020-07-01. **Paper link:** SCOPUS_ID:85082793843
92. Xie S.R., et al., *Machine learning of superconducting critical temperature from Eliashberg theory*, npj Computational Materials **8** 2022-12-01. **Paper link:** SCOPUS_ID:85123500963
93. Xie S.R., et al., *Ultra-fast interpretable machine-learning potentials*, npj Computational Materials **9** 2023-12-01. **Paper link:** SCOPUS_ID:85169674980
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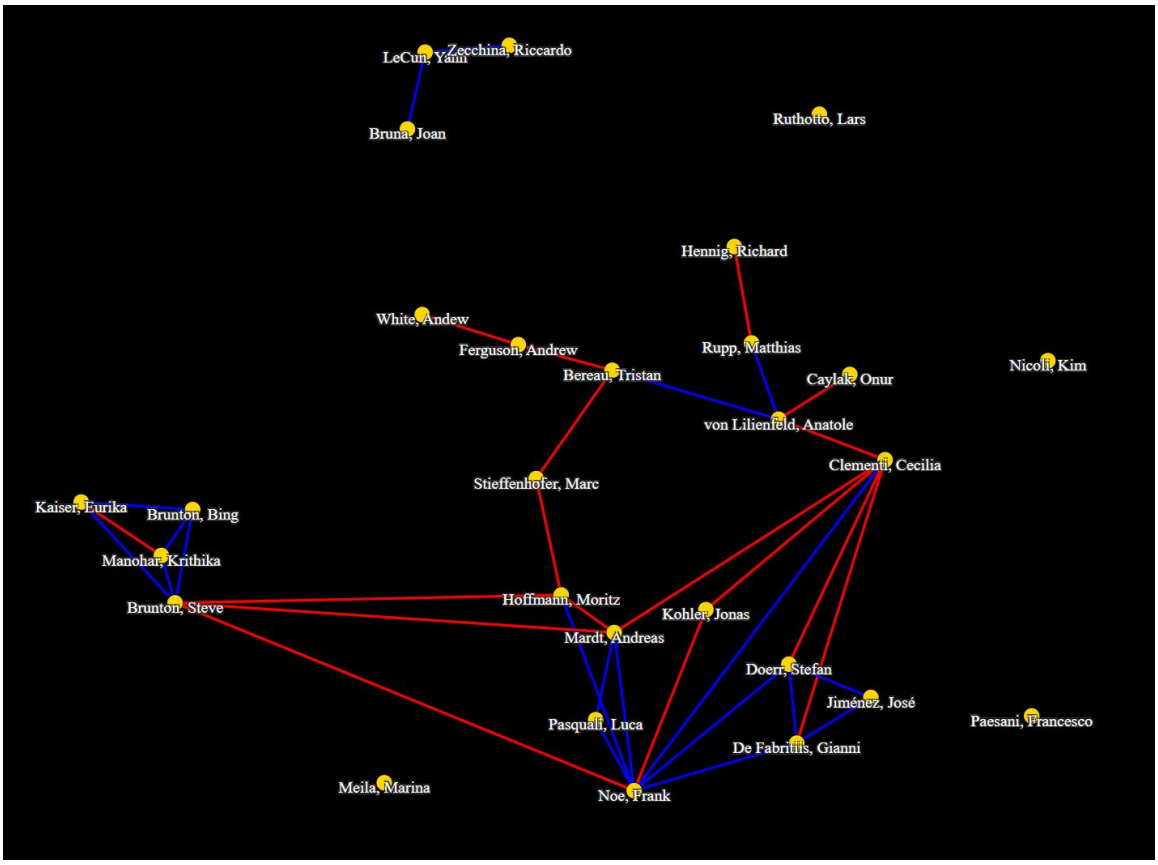
95. Yu-Chia Chen, Marina Meila, *Selecting the independent coordinates of manifolds with large aspect ratios* , Advances in Neural Information Processing (NeurIPS) 2019. *MANUALLY_UPLOADED_ID:50*
96. Zaporozhets I., et al., *Multibody Terms in Protein Coarse-Grained Models: A Top-Down Perspective*, Journal of Physical Chemistry B **127** 2023-08-10. **Paper link:** SCOPUS_ID:85167836425
97. Zhai Y., et al., *Active learning of many-body configuration space: Application to the Cs+-water MB-nrg potential energy function as a case study*, Journal of Chemical Physics **152** 2020-04-14. **Paper link:** SCOPUS_ID:85083299619
98. Zhai Y., et al., *A "short blanket" dilemma for a state-of-the-art neural network potential for water: Reproducing experimental properties or the physics of the underlying many-body interactions?*, Journal of Chemical Physics **158** 2023-02-28. **Paper link:** SCOPUS_ID:85149128133

Collaboration network analysis

In addition, we have performed an automated collaboration analysis, seeking to identify pairs of collaborators that have not worked with each other prior to the program. In the graph below, such pairs are marked with red edges, while authors that collaborated prior to the year of the program are joined with blue edges.



The program was very successful in forming new collaborations. It connected several research clusters that previously did not collaborate with each other, and it brought several new researchers to existing collaboration clusters.

M. INDUSTRIAL AND GOVERNMENTAL INVOLVEMENT

We have significant involvement of industry and government labs in our summer program, Research in Industrial Projects for Students (RIPS)-Los Angeles. Companies and other organizations sponsor research projects and one or more representatives of the organization interact with the student team. Many of them are listed as participants of RIPS and RIPS Projects Day. Additionally, significant numbers of industry and government participants took part in our long programs and workshops; the table below lists workshops with 4 or more industry participants.

Workshop Name	Industry Participants
Workshop I: Quantum Algorithms for Scientific Computation	9
Workshop II: Mathematical Aspects of Quantum Learning	5
Workshop III: Many-body Quantum Systems via Classical and Quantum Computation	8
Workshop IV: Topology, Quantum Error Correction and Quantum Gravity	7

We seek the advice of government and industry by recruiting corporate and government leaders to serve on our Science Advisory Board and Board of Trustees. See section N for a complete list of members and their affiliations.

There were 144 participants that identified as being from Government or Industry; of these 121 came to IPAM in person. There were 93 unique Government or Industry participants. Of these, 39 unique participants were organizers or speakers.

Of these, 4 unique participants came from government or military institutions, including: Pacific Northwest Laboratory, Science and Technology Facilities Council, and Lawrence Livermore National Laboratory.

There were 41 unique participants from companies such as Aerospace Corporation, Analog Devices, Google, Google Quantum, IBM Research, IBM Thomas J. Watson Research Center, Meta, Microsoft Research, Vector Institute, Xanadu Quantum Technologies, and Zapata Computing who served as speakers or organizers.

N. EXTERNAL SUPPORT

In addition to the funding listed in Table M below, IPAM receives substantial in-kind financial support from UCLA. The Director's entire salary/benefits and administrative stipend are paid directly by UCLA. The Director of Special Projects is released from two courses at the cost of replacing him by a junior person academic. IPAM is not charged for the use of its centrally located building, maintenance, or custodial care. Also, UCLA offers IPAM centralized administrative support, technology, recreational facilities, and access to renown libraries, though it is difficult to quantify such support monetarily.

IPAM received gifts towards its endowment and current use funds from several donors, including Advanced Micro Devices, Aerospace, Air Force Research, IBM, Lawrence Livermore National Laboratory, Relay Therapeutics, SAP, and Toyota. As of March 31, 2024 (the last date for which figures are available), IPAM's total endowment stood at $3,740,915. The endowment is designed to generate approximately 4% per year in income.

The table shows other funding received by IPAM from April 1, 2023 through March 31, 2024.

Table M: Other Funding Support	**2023-2024**
UCLA Funding	
Dean Physical Sciences	$94,788
Vice Chancellor for Research	$155,252
Sub-total	$250,040
Endowments and Current Gifts	
Endowments – New Gifts & Investment Income	$98,487
New Current Use Gift Funds	$123,925
Sub-total	$222,412
TOTAL	**$472,452**

O. COMMITTEE MEMBERSHIP

IPAM's committees include the Board of Trustees and Science Advisory Board. The members during the reporting period are listed below. The IPAM directors are ex officio members.

Board of Trustees, 2023-2024 Membership

Name	**Institution**	**Department or Title**
Katy Borner	Indiana University Bloomington	Distinguished Professor of Engineering and Information Science
Russel Caflisch	New York University	Director, Courant Institute
Brenda Dietrich	Cornell University	Professor, Operations Research
Katherine Ensor	Rice University	Noah G. Harding Professor of Statistics
Diana Farrell	Independent	Director and Trustee
Margot Gerritson	Stanford University	Professor, Department of Energy Resources Engineering
Edray Goins	Pomona College	Professor of Mathematics
Frank Graziani	Lawrence Livermore National Laboratory	Director, High Energy Density Science Center
Louis J. Gross	University of Tennessee, Knoxville	Professor Emeritus of Ecology and Evolutionary Biology

Overtoun Jenda	Auburn University	Professor of Mathematics
Tyler Kleykamp	Georgetown University	Fellow, State Chief Data Officer Network
Alan Lee	Analog Devices, Inc.	Chief Technology Officer
Wen Masters	Georgia Tech Research Institute	Vice President, Cyber Technologies at MITRE
Nancy Potok (Chair)	NAPx Consulting	CEO
C. Matthew Snipp	Stanford University	Professor, School of Humanities and Science
Tina Sung	Princeton University	Vice President, Federal Executive Networks
Costis Toregas	George Washington University	Director, Cyber Security and Privacy Research Institute
Mariel Vasquez	UC Davis	Director, Center for the Advancement of Multicultural Perspectives in Science
Talitha Washington	Clark Atlanta University	Professor of Mathematics, Director of the Atlanta University Center Data Science Initiative

Science Advisory Board, 2022-2023

The list below includes new members whose terms started in January 2024.

Name	Institution	Discipline or Department
Kieron Burke	UC Irvine	Professor of Chemistry and Physics
Carina Curto	Brown University	Professor of Mathematics
Jeffrey Hittinger	Lawrence Livermore Nat. Lab	Director, Center for Applied Scientific Computing
Kiran Kedlaya	UC San Diego	Professor of Mathematics
Richard Kenyon	Yale University	Professor of Mathematics
Lin Lin	UC Berkeley	Professor of Mathematics
Svitlana Mayboroda	University of Minnesota	Professor of Mathematics
Marina Meila	University of Washington	Professor of Statistics
Lauren Ancel Meyers	University of Texas at Austin	Professor of Biology and Statistics
Klaus-Robert Muller	Technische Universitat Berlin	Chair of Machine Learning Group
Jelani Nelson	UC Berkeley	Professor of Electrical Engineering and Computer Science

Eric Tchetgen Tchetgen	Wharton School, U Pennsylvania	Professor of Statistics
Jean-Luc Thiffeault	University of Wisconsin - Madison	Professor of Mathematics
Ryan Tibshirani	UC Berkeley	Professor in the Departments of Statistics and Machine Learning
Rachel Ward	University of Texas - Austin	Professor of Mathematics
Amie Wilkinson (Chair)	University of Chicago	Professor of Mathematics
Daniela Witten	University of Washington	Professor of Statistics and Biostatistics