Institute for Pure and Applied Mathematics, UCLA
Annual Progress Report for 2018-2019
Award #1440415
July 9, 2019

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EXECUTIVE SUMMARY

This report covers our activities from June 12, 2018 through June 9, 2019 (which we refer to as the reporting period). The culminating retreat of the spring long program is part of this year's report, along with the two reunion conferences, which are held the same week. This report includes the 2018 summer programs (RIPS and GRIPS). The 2019 summer programs will be included in next year's report.

IPAM held two long program in the reporting period:

- Science at Extreme Scales: Where Big Data Meets Large-Scale Computing
- Geometry and Learning from Data in 3D and Beyond

IPAM held the following workshops in the reporting period:

- RIPS Projects Day
- Mean Field Games and Applications
- Quantum Computing Materials Challenges
- Analysis and Geometry of Random Shapes
- Computational Challenges in Gravitational Wave Astronomy
- Operator Theoretic Methods in Dynamic Data Analysis and Control
- Braids, Resolvent Degree and Hilbert's 13th Problem
- Autonomous Vehicles

IPAM typically offers two reunion conferences for each IPAM long program; 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. IPAM held a total of four second reunion conferences during this reporting period.

IPAM offered five public lectures during the reporting period. We also held several special events: two Industrial Short Courses on Deep Learning and the Latest AI Algorithms and a workshop on Women in Mathematics and Public Policy.

This report includes four 2018 student research programs: Research in Industrial Projects (RIPS) in LA and Hong Kong, both for undergraduate students, and Graduate-level RIPS in Berlin and Sendai, Japan. We also cosponsored the Computational Genomics Summer Institute and Loop TransPORT 2018.

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 September 1, 2018 and August 31, 2019.

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 September 1, 2018 and August 31, 2019.

C. INCOME AND EXPENDITURE REPORT

Grant # DMS 1440415:
This table shows appropriations and expenses for the twelve-month period June 1, 2018 through May 31, 2019 for grant #1440415.

	A	B	C	D	E	F
			A-B=C		B+D=E	A-E=F
Budget Category	Appropriation Year 4	Actual Expenses for the 12 months	Balance for the 12 months	Encumbered Expenses as of May 2019	Total & Encumbered Expenses at May 2019	Encumbered Balance as of May 2019
A. Operations Fund	$1,875,402	$1,853,780	$21,622	$264,425	$2,118,205	<$242,803>
B. Participant Costs	$1,841,780	$1,884,635	<$42,855>	$21,281	$1,905,916	<$64,136>
C. Indirect Costs	$855,083	$873,740	<$18,657>	$0	$873,740	<$18,657>
Totals	$4,572,265	$4,612,155	<$39,890>	$285,706	$4,897,861	<$325,596>

IPAM received an appropriation of $4,510,000 for the twelve-month period June 1, 2018 through May 31, 2019. IPAM also received a supplement of $62,265 for the Quantum Computing Materials Challenges workshop held August 27-29, 2018. The NSF approved a rebudgeting from Participant Costs to Operations and Indirect Costs. The supplement and the rebudgeting is reflected in the appropriation.

Total expenses and encumbrances were $4,897,861 leaving a balance of <$325,596>. IPAM has a flat budget allocation of $4,510,000. We underspend the allocation in the early years of the 5-

year grant and overspend the allocation in years 4 and 5. Overall, IPAM has a positive balance as of May 31, 2019.

A. The Operational Fund (salaries, benefits, equipment, and supplies) for the twelve-month period has an appropriation budget of $1,875,402 with total expenditures of $2,118,205 leaving a balance of <$242,803>. Included in the encumbered expenses is $258,534 for the subaward with California State University, Northridge for Associate Director Maria D'Orsogna.

B. Participant Support Costs include stipends, travel, housing, and subsistence for the scientists working on IPAM Programs. Participant Support Costs for the twelve-month period has an appropriation budget of $1,841,780 with total expenditures of $1,905,916 leaving a balance of <$64,136>.

C. Indirect Costs: 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 54% facilities and administrative cost rate. Indirect costs are not applied to equipment and participant support costs. Indirect Costs for the twelve-month period has an appropriation budget of $855,083 with total expenditures of $873,740 leaving a balance of <$18,657>.

Program Income: 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. Program income received was $16,630 for the twelve-month period and is spent entirely on participant support expenses.

D.POSTDOCTORAL PLACEMENT LIST

IPAM did not appoint postdoctoral fellows in 2018-19, so we have no data to report in this section.

E. MATH INSTITUTE DIRECTORS' MEETING REPORT

Math Institute Directors' Meeting: April 26-27, 2019

Friday, April 26, 2019

1. **Introductions**
   - AIM – Brian Conrey, David Farmer
   - IAS – Helmut Hofer, Akshay Venkatesh, Nicole Maldonado
   - ICERM – Brendan Hassett, Ulrica Wilson
   - IMA – Daniel Spirn

- IPAM – Christian Ratsch, Dimitri Shlyakhtenko
- MSRI – Helene Barcelo, David Eisenbud
- SAMSI – David Banks, Elvan Ceyhan

2. IPDWG Report from Jeff Berliner, IAS Chief Information Officer

- DMS convened IPDWG in May 2017 with the hope of improving the quality and completeness of institute reports and reducing the burden of participant data collection and reporting.
- IPDWG's recommends the creation of a single platform through which institutes would submit NSF reports by email, webform, or API.
- The system would ensure a set of data integrity constraints are met, and would map or transform institute data automatically based on the agreed-upon constraints.
- Institutes could continue to collect and share data as they are doing now, with no change to internal procedures or systems (beyond adding the capacity to collect and store ORCIDs).

3. IPDWG Discussion

- Brendan Hassett expressed concerns about being dependent on another institute to fulfill obligations to NSF; privacy of data; the potential conflict of interest in submitting through an NSF competitor; and the value to institutes whose reports are already up to standard.
- Jeff said that IPDWG would design the system to protect privacy of data; the group is discussing NSF as the super-user and owner. The system would be "middle-ware," not a database.
- The discussion ended with the following questions and suggestions for NSF:
    - Question about whether individual institutes could "opt out" of a centralized system
    - Suggestion to hire an independent contractor to build and maintain a system
    - Interest in seeing a specification of the data requirements, perhaps as an XML schema
    - Suggestion for each Institute to choose an existing data-verification tool

4. Discussion on www.mathinstitutes.org

- Reviewed the following emails ("Mathinstitutes.org Recap" handout):

Date	From
02-07-18	David Eisenbud
04-28-18	Brendan Hassett
06-01-18	Richard Taylor
01-08-19	Dimitri Shlyakhtenko
01-17-19	Dimitri Shlyakhtenko

- Akshay Venkatesh asked who hosts www.mathinstitutes.org (A: ICERM) and who its intended audience is (A: politicians and journalists).
- Brendan provided some information about number of visitors to the site and length of sessions.
- Helmut Hofer asked if https://mathinstitutes.org/diversity/ could also list outreach programs not funded by MSIDI, e.g. CAARMS (A: Need to ask NSF).

5. MSIDI Report from Ulrica Wilson

- The Diversity Committee organized the 2018 "Campaign to Build Awareness on the Logistics of Participating in our Core Programs." The goal was to increase the number of people who learn about institute opportunities.
- Ulrica surveyed the math institutes in June, presented at CAARMS in July, and presented at NAM's MathFest at Spelman College in September.
- The current MSIDI grant is ending soon (MMW in October 2019 + maybe one more).
- We need to ask NSF when to submit the next MSIDI proposal and to which agency (DMS or Infrastructure?). We want to submit a 3-year proposal now and then get on a 5-year grant cycle that is staggered with the 5-year renewal cycle.
- The next MSIDI proposal will request funding to pay program leaders for their time.
- MSIDI is still supportive of Jesus De Loera's database project, but that is currently on hold for health reasons.

6. JMM Past and Present

IAS asked about the history and value of the math institutes participating in the JMM. Answers:

- The institutes began participating in the JMM by offering an open house and reception. The meeting was added a few years ago. The general consensus is that the reception is more valuable than the meeting. The reception costs each institute ~$2,000, which is worth it.
- The purpose of the reception and meeting at JMM is to strengthen our relationship with the greater math community, improve the perception that people have of the NSF institutes, and help us think beyond the NSF-math-institute perspective.
- 7,000 people attend JMM, and the reception gets a lot of traffic (partly because there is free food). It's a good program/member recruitment opportunity. NSF attends the reception, too.
- Up until 2002, each institute gave an academic talk at the reception, but those were boring.
- Attendance at the reception has gone down in recent years, possibly because the other institutes feel like we are too NSF-focused.
- Reaching out to the non-NSF institutes is a good thing to do. There aren't

necessarily concrete outcomes, but it's good for relationship building and information sharing.

- We should be careful not to monopolize the meeting because non-NSF institutes such as Fields, PIM, CRM, UNAM, MITRE, DIMACS, and SITC, also attend; however, it was also noted that the other institutes rarely contribute to creating the meeting agenda.
- The NSF-institutes take turns (two years at a time) liaising with AMS to coordinate the reception, and that institute also chairs the meeting:
    - MSRI – Until 2016
    - ICERM – 2017 and 2018
    - IPAM – 2019 and 2020 (need a volunteer institute to shadow in 2020; run 2021-2022)

7. JMM Future (Ideas for "JMM Reimagined")

- The diversity committee will explore the possibility of moving MMW from SACNAS to JMM.
- IPAM and ICERM will continue sending teams of undergraduate students.
- There was a suggestion for the institutes to organize a panel to discuss the research/new math coming out of the institutes.
- There was a suggestion to use MSRI's "Current Events" program as a model for a session at JMM. In "Current Events," Person A talks about Person B's work, which makes it more accessible.
- Institute program organizers might want to propose a JMM special session on their topic.
- IAS thought they would have difficulty sending representatives to talk about upcoming programs.
- There was a suggestion to consider asking an outside organization to chair the JMM meeting. For example, BMSA chaired the MID/April meeting one year because some people felt there was too much competition among the directors to chair their own meeting.

8. Clarification about Meeting Minutes

- Minutes must be approved by the same group of participants at their next annual meeting:
    - JMM/January 2019 → JMM/January 2020
    - MID/April 2019 → MID/April 2020
- MID/April 2018 meeting minutes were approved.

9. Next MID Meeting

- ICERM will host the next MID Meeting, April 24-25, 2020.

10. Other Topics

- Brian Conrey is the math institute representative to the 2021 U.S. Math Olympia (organized by MAA). The program raises approximately $2 million for ~8,000 participants.
- Helene Barcelo asked if the math institutes were facing any new issues. For example, MSRI has seen an increase in the number of international program participants. Other directors thought their numbers were about the same.
- Christian Ratsch shared that it seems like universities are less willing to agree to buy-outs.

11. **Summary of Questions for NSF** (to be asked by Akshay unless otherwise noted)

- Concerns about the IPDWG proposal (Brendan)
- Timing of NSF site visits
- Future of NSF funding and budget decisions
- Inclusion of non-MSIDI funded programs on the Diversity page
- Timing of the next MSIDI proposal (Ulrica)
- Clarification about the 10 Big Ideas
- Next MID at ICERM

Saturday, April 27, 2019

1. Reintroductions

- AIM – Brian Conrey, David Farmer
- IAS – Helmut Hofer, Akshay Venkatesh, Nicole Maldonado
- ICERM – Brendan Hassett, Ulrica Wilson
- IMA – Daniel Spirn
- IPAM – Christian Ratsch, Dimitri Shlyakhtenko
- MSRI – Hélène Barcelo, David Eisenbud
- SAMSI – David Banks, Elvan Ceyhan
- NSF –Joanna Kania-Bartoszynska, Nandini Kannan, Tie Luo, Juan Meza, Junping Wang, Hank Warchall

2. Concerns About the IPDWG Proposal

- Brendan shared his concern about one institute being in charge of validating everyone's data and having to rely on another institute's IT functions to fulfill duties to the grant.
- Dima voiced a concern about the assumptions that could be written into the validation code.
- Hank reminded everyone that the IPDWG was charged with assessing whether or not there was a need for such a tool, but it's possible the answer is no. The thinking was that a common expectation developed by the working group

would save everyone time and effort.

- Brendan clarified that he was more concerned with the technical specifications of the solution proposed by the group, and asked if there was an existing model that we could look at. Nandini confirmed that NSF has existing models in other divisions (not in DMS).
- David Farmer asked if NSF has a validator that the institutes could install locally or do on a server.
- Joanna reminded everyone that despite years of NSF feedback to the institutes, the data remained incomplete and virtually unusable. The charge to IPDWG was meant to help both NSF and the institutes themselves.
- Nandini asked Brendan if he would prefer a third party to validate the data (A: Yes).
- Juan asked what the recommendation was from the working group and emphasized, "That's all we want. There doesn't have to be a consensus." Nicole asked if individual institutes could opt out, and Juan reiterated they want a recommendation first.

3. Timing of NSF Site Visits

- Regarding the timing of NSF site visits, Juan sad, "Things look good," and said not to worry about possible funding gaps.
- Dima asked for the approximate amount of time between the site visit and the award. Tie answered that in the past, site visits happened in the fall and awards were made in the spring.
- Joanna said that they were no longer doing third-year site visits.
- Brendan asked if there was any reason to think this year's timeline would be very different from past cycles. Juan said no, they expect to have a busy year but don't anticipate major changes.

4. Future of NSF Funding and Budget Decisions

- Regarding the budget outlook, NSF said the FY19 budget included $237 million for DMS, and that budget passed. The FY20 budget seeks less for DMS ($223 million). The proposals look very good. And the upcoming MathFest is an excellent public relations event.

5. Clarification About the 10 Big Ideas

- Akshay asked if NSF could tell us more about the 10 Big Ideas. Juan said six of the Big Ideas are research or process-related and three of those are math-specific. Each Big Idea is slated to have
  $30M/year for each of 5 years. As such, any one Big Idea (e.g., HDR) will have $150M total. If we were talking about the 3 Big Ideas that will hopefully have strong math participation, then that number should be $90M/year, i.e. $30M each from HDR, QL, and Rules of Life.

- The institutes should be involved in these (e.g., IPAM's Quantum Computing; MBI's Rules of Life) because DMS can point to them and say the math community is involved in the Big Ideas.
- Hélène asked if it was okay to submit proposals for new workshops since the Big Ideas funding would be coming from DMS and most Institutes already receive workshop funding from DMS. Juan said, "There may be situations in which it might be appropriate for an Institute to apply to a Big Idea solicitation, but that would depend on what the solicitation is asking for. For example, in at least one case a recent RFI was asking for conference proposals so that might be OK in my opinion. Of course I would ask the Institutes to check with DMS before submitting so that we are aware of that possibility and perhaps to offer guidance."
- Juan added that it would help DMS if the institutes participated because DMS could then tell their own working groups what kind of math relates to the Big Ideas.
- Brendan asked if DMS wanted institute research papers that might relate to a Big Idea (A: Yes).
- Juan reminded the group that the Big Ideas are not exclusive to applied math, but rather open to all disciplines.
- Nandini added that NSF's TRIPODS program is a great example of how we can collectively leverage other institutions to get more funding.
- Every Big Idea has at least one DMS officer on the committee.

6. Inclusion of Non-MSIDI Funded Programs on the Diversity Page

- Akshay asked if it was okay for https://mathinstitutes.org/diversity/ to include activities not funded by MSIDI. Joanna said yes, the page is meant to be comprehensive. Hank added that the website "is enormously useful to us," both within NSF and between agencies.
- Ulrica reminded the group that at some point there was concern from NSF that the page was just a list of past events.
- Nandini said she remembered that conversation from a few years ago. They wanted to see all of the NSF-funded diversity activities in one place, but other programs were great, too. She clarified that they want it to be more than just a calendar. The goal is to feature stories, pictures, and other content that is "lively and dynamic," not just a list of dates.
- Brendan clarified that ICERM didn't have to solicit content but rather continue posting content as it is submitted to them. Joanna said yes. Institutes are responsible for sharing content.
- Hélène reiterated that the diversity committee was concerned about the page becoming a catchall of old events and looking stagnant.
- Helmut said the page should include programs like CAARMS, PCMI, and WAM.

- Ulrica said the diversity committee would take this back and look at the logistics.

7. Other Comments and Questions About www.mathinstitutes.org

- Juan stated that https://mathinstitutes.org/highlights/ seems to feature a lot of events from 2017, and asked the directors to try to keep it current.
- The group was also reminded to put the NSF logo on everything that is NSF-funded.
- Akshay asked NSF to clarify the website audience (A: "Mathematicians and everyone else"…"Congressional staffers" and "The New York Times").
- Dima reminded the group that the institutes have an agreement to post twice per year.
- Juan reiterated that they use the site "to sell all of the good things that you are doing."
- NSF made the following additional requests:
    - Include the activity date or posting date on each Highlight (better than no date at all).
    - Continue posting at least two Highlights per year, especially in April and October.
    - Share breakthroughs and highlights as soon as you can via email and upload.
- Helmut suggested that creating regular content about the modern history of math could be a good project for a post-doc, and asked if NSF would want to fund a method of tracking modern history of math. Nadini said that NSF funds Cathryn Carson at UC Berkeley, so she could point him to the right program officers.

8. Timing of Next MSIDI Proposal

- Ulrica spoke on behalf of MSIDI, suggesting we wait until the renewals are announced and submit a new MSIDI proposal in Fall 2021 for a 5-year cycle that lags 2 years behind the 5-year renewal cycle.
- Joanna said DMS needs a separate proposal to better track reports on "what we are paying for." She added the length of the grant period is flexible to make it more convenient for the institutes.
- Ulrica asked how we could fill the gap between the current award that is ending and the new 5- year period. In a follow-up conversation, it was decided that the diversity committee would submit a 2-year collaborative proposal by the end of May 2019. The proposal would cover the diversity workshops that we typically hold: 2 MMW, 1 SPO, 1 BT, and 1 Latinx; this would then be followed by a new 5-year collaborative proposal to include ideas that were developed by the main stakeholders of the underrepresented groups present at the Dec. 2018 AIM workshops.

- David Eisenbud asked if we could potentially submit one 7-year proposal (A: Unfortunately, no).

9. NSF Director's Term

- Akshay asked if the institutes could have input into the selection of the next NSF director before the current term ends in 2020 (A: It's a political appointment, so the only method would be to contact members of the National Science Board).

10. Other Topics

Akshay asked if there was anything NSF wanted to share with us. Answers:

- NSF wants to encourage PIs to put more graduate students, post-docs, and early-career mathematicians into grant proposals. This does not necessarily mean to start adding lines for graduate students in every proposal, but do consider including more graduate student support in individual research proposals. It is okay to charge overhead on graduate student support.
- NSF is putting more emphasis on partnerships, including international partnerships, and looking at ways to co-fund proposals. NSF will continue to pay for US people to attend international conferences.
- Workshop reports (e.g., RTG, Stat Workshops, Math Bio Workshops, etc.) are very useful to DMS.
- The NSF is planning a trial workshop for junior PIs at the post-doc level on writing and reviewing proposals, to include mock panels. Brendan suggested AMS and other professional organizations might be interested in helping with this; he also reminded the group about Notices' series of (12) articles written for young researchers. Dima asked if NSF would be willing to share the mock proposals and other materials for similar workshops offered by the institutes (A: Yes). David Farmer told the group that AIM has an instructional video on this topic.

11. Next MID Meeting

ICERM will host the next MID Meeting, April 24-25, 2020.

F. PARTICIPANT SUMMARY

In this report, we are reporting on participants of programs that took place between June 12, 2018 and June 9, 2019. We have included the participants of the culminating retreat of the spring long program, as well as the two reunion conferences, all of which were held on June 9-14, 2019. This report does not include the participants of our "RIPS" summer programs which start on June 11 or later.

Note that "Public Lectures" includes just one person (a faculty member) who was not part of a workshop. We do not collect RSVPs.

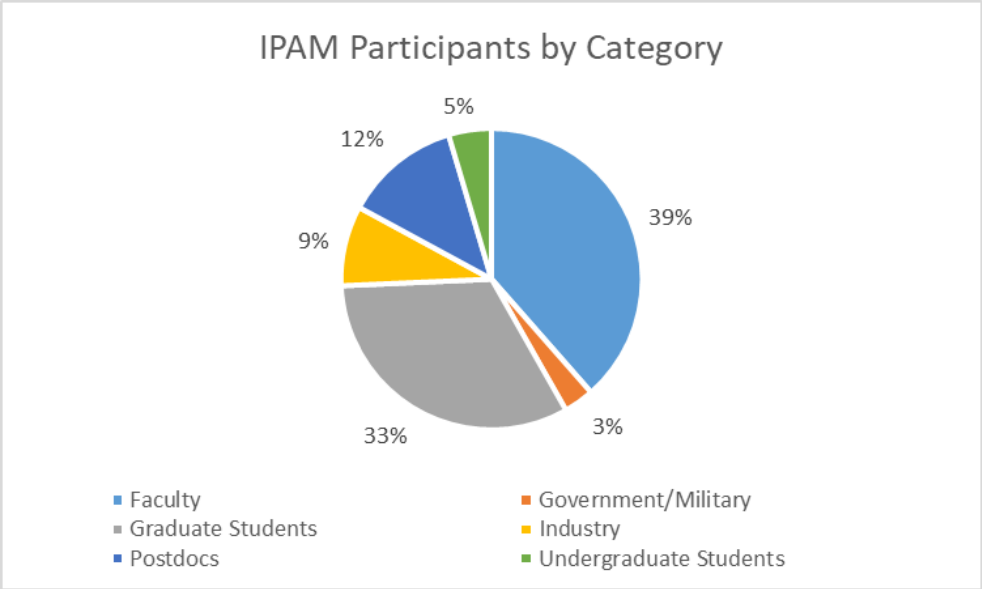
Table F-1: All Participants' Gender and Ethnicity by Program Type (June 12, 2018 - June 9, 2019)							
		Gender		Underrepresented Ethnic Groups			
Program Type	Total Participants	Female	No. Reporting Gender	Amer. Indian	Black	Hispanic	No. Reporting Ethnicity
Long Program	109	19	107	0	1	7	102
Workshops	1364	291	1323	2	18	73	1277
Public Lectures	1	0	0	0	0	0	0
Student Research Programs	83	28	79	1	5	9	81
Summer Schools	71	14	69	0	4	7	65
Special Events and Conferences	80	50	79	1	6	4	78
Reunion Conferences	71	17	68	0	0	5	65
Total	1779	419	1725	4	34	105	1668
Percent of No. Reporting		24.3%		0.2%	2.0%	6.3%	
			All underrepresented ethnic groups:		*143*	*8.57%*	

There were 1,080 unique participants for this same period. (Some of the participants attended more than one program, usually multiple workshops within a long program.) Out of those reporting gender, 26.6% were women. Out of those reporting ethnicity, 8.4% of unique participants were members of an underrepresented ethnic group.

IPAM tries to balance the expectation that we primarily serve the U.S. community (citizens and permanent residents) with the goal of attracting the best organizers, speakers and participants in the relevant fields. See Table F-2.

Table F-2: All Participants' Citizenship by Program Type (June 12, 2018 to June 9, 2019)			
Program Type	U.S. Citizens & Permanent Residents	No. Reporting Citizenship & Residency	Percent
Long Programs	35	108	32%
Workshops	624	1335	47%
Summer School	24	70	34%
Student Research Programs	70	82	85%
Special Events and Conferences	68	78	87%
Reunion Conferences	27	67	40%
Total	813	1632	50%

The majority of IPAM participants are faculty and graduate students. See the pie chart below for the percentage of participants in each category.



G. POSTDOCTORAL PROGRAM SUMMARY

Postdocs participated in many of IPAM's programs during the reporting period (June 12, 2018 to June 9, 2019). Three postdocs participants in IPAM's student research program, RIPS, as academic mentors. See tables G-1 and G-2.

Table G-1: Postdocs' Gender and Ethnicity by Program Type (June 12, 2018 - June 9, 2019)

Program Type	Total Participants	Gender		Underrepresented Ethnic Groups			
		Female	No. Reporting Gender	Amer. Ind.	Black	Hisp.	No. Reporting Ethnicity
Long Program	16	5	16	0	0	2	16
Workshops	160	42	155	1	0	14	138
Summer School	17	5	17	0	1	0	14
Student Research Programs	3	2	2	0	0	1	2
Special Events and Conferences	3	2	3	0	0	0	3
Reunion Conferences	23	8	23	0	0	2	20
Total	222	64	216	1	1	19	193
Percent of No. Reporting		29.6%		0.5%	0.5%	9.8%	
			All underrepresented ethnic groups:		*21*	*10.88%*	

Table G-2: Postdocs' Citizenship by Program Type (June 12, 2018 to June 9, 2019)			
Program Type	**U.S. Citizens & Permanent Residents**	**No. Reporting Citizenship & Residency**	**Percent**
Long Programs	1	16	6%
Workshops	35	160	22%
Summer School	6	17	35%
Student Research Programs	2	3	67%
Special Events and Conferences	2	3	67%
Reunion Conferences	5	23	22%
Total	50	222	23%

H. GRADUATE STUDENT PROGRAM SUMMARY

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 tables H-1 and H-2.

Table H-1: Graduate Students' Gender and Ethnicity by Program Type (June 12, 2018 - June 9, 2019)							
		Gender		**Underrepresented Ethnic Groups***			
Program Type	**Total Participants**	**Female**	**No. Reporting Gender**	**Amer. Indian**	**Black**	**Hispanic**	**No. Reporting Ethnicity**
Long Program	40	7	39	0	0	1	36
Workshops	454	120	445	0	4	20	433
Summer School	38	9	36	0	0	6	36
Student Research Programs	15	4	14	0	1	0	15
Special Events and Conferences	13	13	13	0	1	1	13
Reunion Conferences	18	4	17	0	0	1	17
Total	578	157	564	0	6	29	550
Percent of No. Reporting		27.8%		0.0%	1.1%	5.3%	
			All underrepresented ethnic groups:		*35*	*6.36%*	

Table H-2: Graduate Students' Citizenship by Program Type (June 12, 2018 to June 9, 2019)			
Program Type	**U.S. Citizens & Permanent Residents**	**No. Reporting Citizenship & Residency**	**Percent**
Long Programs	9	40	23%
Workshops	136	451	30%
Summer School	6	37	16%
Student Research Programs	13	15	87%
Special Events and Conferences	10	13	77%
Reunion Conferences	4	17	24%
Total	178	573	31%

I. UNDERGRADUATE STUDENT PROGRAM SUMMARY

Undergraduate students participate in RIPS-LA and RIPS-Hong Kong (summer student research programs), and RIPS Projects Day (workshop).

Table I-1: Undergraduate Students' Gender and Ethnicity by Program Type (June 12, 2018 - June 9, 2019)							
		Gender		**Underrepresented Ethnic Groups**			
Program Type	**Total Participants**	**Female**	**No. Reporting Gender**	**Amer. Indian**	**Black**	**Hispanic**	**No. Reporting Ethnicity**
Workshops	38	18	38	0	2	7	37
Student Research Programs	44	19	43	1	2	8	42
Total	82	37	81	1	4	15	79
Percent of No. Reporting		45.7%		1.3%	5.1%	19.0%	
	All underrepresented ethnic groups:				*20*	*25.32%*	

Table I-2: Undergraduate Students' Citizenship by Program Type (June 12, 2018 to June 9, 2019)			
Program Type	**U.S. Citizens & Permanent Residents**	**No. Reporting Citizenship & Residency**	**Percent**
Workshops	24	38	63%
Student Research Programs	30	44	68%
Total	54	82	66%

J. PROGRAM DESCRIPTION

The programs are listed in chronological order by start date. The list includes all IPAM programs with start dates between **June 12, 2018 through June 9, 2019**.

Most IPAM workshops include poster sessions; all participants are invited to present a poster, and graduate students are especially encouraged to participate. Most of IPAM's lectures, including lectures during workshops and public lectures, are available online.

We conduct evaluation of all IPAM programs. We administer an online, anonymous survey to all workshop participants. Long programs and our RIPS Program have pre-program and post-program surveys, which can be matched to compare responses before and after to some questions. We also conduct exit interviews with the junior participants of long programs. The reports are available upon request, and anonymous quotes from the surveys for some of the programs are included under the description of the program.

PUBLIC LECTURE: The Melting Rubik's Cube: From Fluids to Combinatorics and Vice Versa by Yann Brenier. JUNE 27, 2018.

This lecture was open to the public. No registration was required, therefore, the attendees do not appear in our participant list.

Speaker Bio:
Yann Brenier is a remarkable mathematician. He is one of the founders of the mathematical theory of optimal transport and has made numerous original observations in other fields. He obtained his doctorate at the University Paris IX – Dauphine in 1982. Brenier spent a year at UCLA as an E.R. Hedrick Assistant Professor in 1985, then returned to France as the Director of Research at Inria, Rocquencourt for four years. In 1990, Brenier began teaching at Université Paris 6 while concurrently teaching at Ecole Normale Supérieure. Brenier has been the Director of Research at CNRS since 2012. He was a junior member of the Institut Universitaire de France (1996-2000) and an invited sectional lecturer at ICM 2002.

Abstract:
The mathematical description of fluids like water goes back to the Swiss mathematician Leonard Euler in the middle of the 18th century. If we think at a discrete level, for instance in terms of pixels, the motion of water looks very much like a very fast succession of permutations exchanging pixels, a little like a "melting rubik's cube". We will discuss this analogy in more details, in connection with the mathematical theory of optimal transportation and its numerous applications.

STUDENT RESEARCH PROGRAM: Research in Industrial Projects for Students (RIPS) Hong Kong 2018. JUNE 12 - AUGUST 12, 2018.

RIPS Hong Kong is the international version of our RIPS Los Angeles program.

In collaboration with Hong Kong University of Science and Technology (HKUST), IPAM recruits eight U.S. students to work on cross-cultural teams with eight HKUST students on four projects, each sponsored by a company based in the region. 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 sponsors will be announced in March.

The program is nine weeks. IPAM provides the U.S. participants with a travel allowance and a stipend of $3,500. Housing and most meals are also included. *Hong Kong students:* please consult the HKUST announcement for the benefits they offer local students.

U.S. citizens are eligible for RIPS-Hong Kong. Participants must be tolerant of and adaptable to cultural differences. English is the only language required for participation. The local students, academic mentors and industry mentors will speak English.

Students will stay in residence halls and eat most meals in the campus dining halls. The HKUST math department provides technical support and offices, and offers some cultural activities and Cantonese lessons. There were four projects. Projects vary, but all involve some math, statistics, data, and computing:

Sponsor	**Title of Project**
AECOM	Air Ventilation Assessment
Real AI	Applying Q-Learning to Algorithmic Bitcoin Trading
Tencent	Music Generation
Using.ai	Semi-supervised Learning for Visual Semantics

The beautiful HKUST campus overlooks beautiful Port Shelter on the Clear Water Bay peninsula, several miles east of the city center. Public transportation is convenient and inexpensive. Weekends are available for sightseeing.

Here are some quotes from the U.S. students in RIPS-HK 2018, collected in a post-program survey:

"RIPS is a great opportunity to work on an industrial project in a research atmosphere. The mentors are very supportive and enthusiastic, and the entire program offers many opportunities for learning and growth. I would absolutely recommend RIPS to other undergraduate students. The program offers the opportunity to both learn new skills and explore potential career paths or research areas. In addition to this, the Hong Kong RIPS experience also offers great cultural value as you have the opportunity to explore and meet new people from different walks of life." *Matthew Thomas Sturm, Real AI team*

"I'm interested in pursuing natural language processing in graduate school, and I would not have gained any exposure to this field if not for RIPS. Being in Hong Kong for the summer was an absolutely unforgettable experience." *Katherine Thai, Real AI team*

"RIPS was very beneficial in honing skills I already had. My RIPS experience exposed me to a lot of different applications in industry which will definitely aid me in deciding between going straight to industry after school, or first going to graduate school. I would recommend RIPS to anyone who wants to experience living and working abroad." *Gabrielle Ferra, Tencent team*

"RIPS allows students to employ mathematical techniques developed in the class room to problems that impact everyone around us. RIPS has opened my eyes to the possibilities of interaction between industry and academia. I still intend to enter academia, but I will seek out future collaboration with industry scientists. Outside of the math experience itself, living in Hong Kong and working closely with local students was an amazing cultural experience. I greatly enjoyed this program and intend to apply to the graduate version next summer." *Sajant Anand, AECOM team*

"I learned a lot about machine learning and using it to solve industrial problems. Learning how to work within a team of your peers was illuminating. I will use this experience as a stepping stone towards industry internships. Yes, I would recommend RIPS to other undergraduate students. It's especially a good choice if one is graduating. It's a lethal combo of interesting work and whole lot of fun!" *Biraj Pandey, Using.ai team*

SUMMER SCHOOL: Mean Field Games and Applications. JUNE 18 - 29, 2018.

Organizing Committee
David Ambrose (Drexel University)

Wilfrid Gangbo (University of California, Los Angeles (UCLA))
Ryan Hynd (University of Pennsylvania)

Mean field games theory is a framework developed to advance the understanding of problems in game theory with a very large number of agents. This theory has been prominently applied in areas such as economics, crowd dynamics and network engineering. In recent years, there has been a surge of interest in mean field games as several tools have been brought to bear on its important problems, including theory of stochastic differential equations, methods of optimization, optimal transport theory, numerical methods and numerical analysis, among others.

The summer school, Mean Field Games and Applications, will be a series of lectures that aims to introduce graduate students and postdocs to this recently accessible and fast growing area. The main goals of the summer school are: (i) To introduce students and postdocs to Mean Field Games and certain cognate areas through lectures by leading researchers; (ii) To make available to the wider mathematical community a series of broad-interest talks on mean field games; (iii) To provide a collaborative environment that is welcoming to underrepresented minorities and women and which brings scientists together with trainees from varied backgrounds.

The summer school lecturers have also been selected to provide points of view from different aspects of mean field games and to emphasize a variety of applications. In addition to lectures, there will be tutorial-style activities to allow participants to work with problems in mean field games themselves. Therefore, participants will have an opportunity to learn the state of the art within mean field games research, to learn about applications of this theory to other research areas and also to get involved with research on this exciting topic. Moreover, leading experts and practitioners will be present to facilitate interaction and collaborative activities.

Here are a couple of the anonymous comments from participants, collected through the survey:

“The workshop was extremely useful! We could see the landscape of different approaches to MFG systems. Also, we could learn about the state-of-the-art in MFG theory.”

“The lectures and speakers were of the highest quality and provided an in-depth view into the topic.”

STUDENT RESEARCH PROGRAM: Graduate-Level Research in Industrial Projects for Students (GRIPS)-Sendai 2018. JUNE 18 - AUGUST 10, 2018.

Graduate-Level Research in Industrial Projects for Students (GRIPS) in Japan will offer 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 will work on cross-cultural teams on research problems designed by industrial sponsors. The projects will be of serious interest to the sponsor and will offer a stimulating challenge to students; most will involve both analytic and computational work. At the end of the program, the teams will present the results of their work and prepare a final report. IPAM will encourage 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 will 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. Japanese students may go to this site for information and an application.

This program is partially supported by an IRES grant from NSF's Office of International Science and Engineering.

The projects will involve both analytical and computational work. The two 2018 projects were:

Project 1: Toyota – Design for the Next Generation Energy and Mobility Platform

Rapid suburban sprawl in metropolitan areas in Japan has led to the rapid development of peripheral satellite cities. High-speed railway networks and motorways have significantly contributed to improving the connection between established metropolitan areas and these new peripheral cities. But at the same time, due to rapid population growth, sprawled suburban areas with small-scale residential developments were built without schematic road network planning.

As a result, key functions of the city for the citizen's lives, such as commerce, administration, and schools, are diffused to suburban area, on the premise of using private cars. But such developments are not sustainable or desirable as the population ages and as energy conservation becomes more important. In principle, a higher quality of life can be achieved if key city functions are aggregated in city centers around the main railway stations. This requires better and more efficient public transportation networks in conjunction with small personal mobility.

In this research program, the students will investigate how to re-locate key city functions to the city center while optimizing small personal mobility and public transportation by applying the Internet of Things (IoT).

Quote from Jeffrey Yeh, a U.S. student on this team: "I believe that my GRIPS experience will certainly help my career in the positive way. Before participating this research program, my research was heavily guided by my professors and I was restricted what I actually wanted to do. I was glad that we can pick our ways to lead our research. I expanded my knowledge by figuring out our goals through this research. I will definitely recommend GRIPS to other graduate students. It is often difficult for me to see the real applications of mathematics while studying it, and this program really helped me to see the connection between math and industry problems."

Quote from Skyler Seto, a U.S. student on this team: "The educational value of GRIPS for me came surprisingly not in the form of mathematical insights or knowledge, but from learning to work in a large team (of very diverse backgrounds) to develop a cohesive project idea without a direct supervisor. For graduate students (such as myself) this was very challenging, but I'm thankful to have had the opportunity to practice this. The GRIPS program is highly dependent on the team and projects. I would recommend GRIPS to a student looking to learn to work on an

interdisciplinary project, and looking to practice doing independent work; and to anyone who has interest in the project area (and has some familiarity with the area)."

Project 2: NEC – Reliable Wireless Networking Systems for Industrial Internet-of-Things

In this project, students will deal with problems in Internet-of-Things (IoT) systems at various industrial scenes like factories and construction sites. In these scenarios, workers and managers want to improve their productivity using IoT systems, but poor wireless network connections to their local or handheld devices prevent introduction of such IoT systems. One of the reasons is that the reliability of wireless connections is quite sensitive to external condition such as the weather or the movements of things such as people, mobile robots etc. Besides, surrounding environment in these scenarios changes intermittently. In some cases, radio (e.g. Wi-Fi, LTE) power also has to be taken into account to minimize impacts for production machines as well as the condition mentioned above. Such conditions and limitations make it even more difficult to ensure the reliability of the wireless connections.

There is wide variety of research related with to wireless networking covering optimization theory, stochastic geometry, random graph theory, and mathematical-intensive persistent homology theory. However, such mathematical performance analysis of wireless networks was not possible because these methods rely on resorting to (extreme) simplifications or assumptions such as the case in which all the nodes in the network are required to transmit at the same bit-rate. But such simplifications are often not appropriate and neither fit in our scenarios nor to the case of actual wireless networks.

We would like to investigate methods to build reliable wireless network system for Industrial IoT. In order to achieve our goal, we need to improve previous work that resulted from both theoretical aspects as well as and practical aspects, and then integrate these methods properly.

This project would be divided into subprojects, some of which are listed below:

-Control Wi-Fi dead spots by controlling radio direction and power

-Estimate time series communication possibility in the change of external conditions

-Investigate models of external environments/conditions that affects communication possibility

Quote from Hannah Horner, a U.S. student on this team: "I would definitely recommend GRIPS to other graduate students, especially if they have any interest in traveling abroad. GRIPS is a great program for students to get applied research experience and the opportunity to live in a foreign country. Working with an international team on an industrial problem is a great experience to help prepare for a career in research after graduate school."

Research in Industrial Projects for Students (RIPS) 2018. JUNE 25 - AUGUST 24, 2018.

The Research in Industrial Projects for Students (RIPS) Program provides an opportunity for talented undergraduate students to work in teams on a real-world research projects 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 program is nine weeks. IPAM provides each undergraduate student with a travel allowance and a stipend of $3,500. Housing and most meals are also included.

RIPS-LA students will live in residence halls on the UCLA campus and will work at IPAM. We expect to have nine projects. The project sponsors are announced in March. Projects vary, but all involve some math, statistics, data, and computing.

RIPS Sponsor	**Project**
Aerospace Corporation	Comparing Object Correlation Metrics for Effective Space Traffic Management
Air Force Research Lab	Decomposition of Nonlinear Systems Dynamics into Multiple Time Scales
AMD	Exploration of Reinforcement Learning in Computer Games
Google LA	Threshold Optimization in Multiple Binary Classifiers for Extreme Rare Events Using Predicted Positive Data
Gum	Augmented Reality for Non-Homogeneous Textures
HRL Laboratories	Modeling Microstructure Evolution during Additive Manufacturing
Lawrence Livermore National Lab (LLNL)	Cellular-Scale Modeling of Oncogenic Proteins
Praedicat	Information Extraction and Aggregation from Unstructured Web Data for Business Profiling
UNC Lineberger Comprehensive Cancer Center (UNCC)	Using Quality-of-life Scores to Guide Radiation Therapy Dosing

Comments from students in RIPS2018 on the post-program survey:

“Overall, excellent. The program is very well-structured. The industry mentors and academic advisors with whom I interacted are incredibly smart and were very invested in our group and

our group's success." *Colleen Chan, AFRL team*

"It was a great experience. I really get the feeling how it feels like to work with sponsor. I have worked with academic mentor before, but industry mentor was a whole new experience." *Osman Akar, Gum team*

"RIPS was a great opportunity to explore a very different kind of math than I usually see in coursework during the year. I would recommend RIPS to any students with a background in mathematics, computer science, and statistics, who want to practice using all of these skills in a flexible, interdisciplinary way." *Adam Quinn Jaffe, Aerospace team*

"It was a wonderful program that presented me with a great many opportunities. It introduced me to applied mathematics and has ended up shaping the future of my studies and has led me to pursue more applied math in my undergraduate career. It has significantly shaped my choice in studying more applied mathematics, and perhaps even pursuing more research in the area of numerically solving PDEs." *Bernardo Hernandez, LLNL team*

"RIPS has a very unique educational value, because it gives students the chance to use their mathematical and computational skills and apply them to an industrial project that has expectations and standards that do not match those of an academic project. I believe my RIPS experience will impact the types of graduate programs I will apply to as well as the types of jobs I will consider in the future, now that I have a better sense of what it is like to be involved in industrial research. I am now more open to pursuing a career in the industry and to applying to graduate programs with a more applied and computational focus." *Giulia Pintea, UNCC team*

"Given the innovate idea of providing students the experience of an industry-cum-academic experience. Apart from the work I did here, helped me a lot about managing a project and working as a team towards a research problem. The excellent availability of resources adds on to what I was able to achieve during this summer. RIPS is a dream program. The team here takes care of everything, so we can just focus on work. The kind of work we did here is much more interesting than any other research internship because you can see your innovation making an impact in the industry, which make our work much more valuable." *Himanshu Ahuja, Praedicat team*

"It was interesting to see what kinds of skill sets are valuable to industry as well as the types of problems that were proposed. We also learned a lot from doing the project…it was valuable research experience that also showed possible career paths outside academia." *Erin Stafford, LLNL team*

"I would recommend RIPS to other students because it is a very well organized program and the fact that it combines working both with academia and with a sponsor makes it invaluable and unique. This is because you can experience how it is to do research, in the same time as experiencing that you need to give some deliverables to the sponsor, so you have a real responsibility. Working in teams is also a very good thing about RIPS because earlier or later in one's career, one will have to work in teams very often. Thus, the earlier you learn to do it, the

better chances to have a successful career, being it in academia or in a company. Also, during this project, you can greatly improve your report writing, presentation, communication skills, but also improve your coding skills." *Juliana Tabian, Gum team*

"RIPS is unique in that the projects we work on stem from industrial applications. As such, we have first-hand experience in both research and industry--an opportunity not offered elsewhere. I've learned to appreciate the value of teamwork and to manage the quandaries that arise from it. Second, I've learned to manage vexations that arise from long-term research." *Elvis Nunez, AMD team*

"It is a different experience to everything I had done before, it mixes the beauty and formalism of mathematics with real life problems and we work to get results that will affect directly the world. RIPS teaches us the value of working as a team to complement each other, we all have different strengths and weaknesses, we have taken different classes than the other members of our team and part of the program is learn how to use those different strengths towards a common goal. Before the program I had never had contact with applied math, I considered myself as a pure mathematician. Now, I know that my abilities in math can be useful in real world and I am now considering new career choices. After my experience in RIPS I know I have a lot of different options to use mathematics and that academia is not the only path." *Jonathan Galvan Bermudez, LLNL team*

"RIPS immensely helped me understand both research and industrial work. The most important thing I learned is how to coordinate people to work towards the same goal. If there's ever a program that can meet any undergraduate student's expectation for academic and industrial experience that would be RIPS." *Liang Shi, Praedicat team*

Graduate-Level Research in Industrial Projects for Students (GRIPS)-Berlin 2018. JUNE 25 - AUGUST 17, 2018.

Graduate-Level Research in Industrial Projects for Students (GRIPS) will offer graduate students in mathematics and related disciplines the opportunity to work on industry-sponsored research problems. Students from the U.S. and Germany will work on cross-cultural teams on three research problems designed by the industrial sponsor. The projects will be of serious interest to the sponsor and will offer a stimulating challenge to students; most will involve both analytic and computational work. At the end of the program, the teams will 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 will also receive a meal allowance and a stipend. (These terms apply to U.S. participants recruited by IPAM.)

IPAM's partner in Berlin is the newly formed Research Campus MODAL (Mathematical Optimization and Data Analysis Laboratories), which promotes exchange and collaboration between public institutions and private (industrial) partners. The current academic partners of

MODAL are the Free University of Berlin (FU Berlin) and the Konrad-Zuse Zentrum für Informationstechnik Berlin (ZIB).

The projects will involve both analytic and computational work. The three 2018 projects were:

Project 1: 1000Shapes GmbH – Biotechnology

Building on state-of-the-art database technology, students will develop new machine-learning techniques to analyze medical massive data sets. First, students will learn the necessary biological foundation needed to successfully complete the project. They will then use data from a large clinical trial to model medical phenomena based on ideas from the areas of compressed sensing, machine learning, and network-of-networks theory.

Tumor diseases rank among the most frequent causes of death in Western countries coinciding with an incomplete understanding of the underlying pathogenic mechanisms and a lack of individual treatment options. Hence, early diagnosis of the disease and early relapse monitoring are currently the best available options to improve patient survival. This calls for two things: (1) identification of disease specific sets of biological signals that reliably indicate a disease outbreak (or status) in an individual. We call these sets of disease specific signals fingerprints of a disease. And (2), development of new classification methods allowing for robust identification of these fingerprints in an individual's biological sample. In this project we will use -omics data sources, such as proteomics or genomics. The advantage of -omics data over classical (e.g. blood) markers is that for example a proteomics data set contains a snapshot of almost all proteins that are currently active in an individual, opposed to just about 30 values analyzed in a classical blood test. Thus, it contains orders of magnitudes more potential information and describes the medical state of an individual much more precisely. However, to date there is no gold-standard of how to reliably and reproducible analyze these huge data sets and find robust fingerprints that could be used for the ultimate task: (early) diagnostics of cancer.

Most of the data coming from available bio-medical data sources, such as images or proteomics data, is ultra high-dimensional and very noisy. At the same time, this data exhibits a very particular structure, in the sense that it is highly sparse. Thus the information content of this data is much lower than its actual dimension seems to suggest, which is the requirement for any following step in this project: the dimension reduction of the data with as little loss of information as possible.

Unfortunately the sparsity structure of this data is complex, (in most cases) not known a-priori, and usually does not coincide with often assumed patterns such as joint sparsity or Gaussian noise. This means, although the data is highly sparse, the sparsity structure as well as the noise distribution is non-standard. However, specifically adapted dimension reduction strategies such as compressed sensing do not readily exist e.g. for proteomics data.

However, methods exist that allow to identify the sparsity structure of the contained information from very high-dimensional, noisy -omics and imaging data. Once this has been achieved, the next step is the integrating of the (low-dimensional) information into one unified mode. We will

use a network-based approach, modelling the various biological levels through a multiplex network coming from existing databases such as known protein/protein or gene/protein interactions. The hope is that this model can shed some light on the mechanisms of osteoarthritis and maybe even allow new ways of early diagnosis of this disease.

Project 2: Deutsche Bahn – Public Transport

The RailLab located at Zuse Institute cooperates with DB Fernverkehr to develop an optimization core that helps to operate the Intercity-Express (ICE), Germany's fastest and most prestigious train, in the most efficient way. This is achieved by determining how the ICEs should rotate within Germany and, thereby, reducing the number of empty trips. The software has now been deployed in production at DB Fernverkehr for several years.

Deutsche Bahn (DB) is the Germany's major railway company. It transports on average 5.4 million customers every day over a rail network that consists of 33,500 km of track, and 5,645 train stations. DB operates in over 130 countries world-wide. It provides its customers with mobility and logistical services, and operates and controls the related rail, road, ocean and air traffic networks.

Students will learn to think about railway networks from a planner's perspective. Making up ICE rotations sounds easy at first, but students will soon find out that a lot of constraints have to be taken into account and do not forget about the size of Germany's rail network! This makes finding and understanding suitable mathematical programming models a difficulty of its own. It will be the students' daily business to deal with huge data sets. They will write scripts to process the data and extract useful information. The past project assignments included to find out how robust optimization methodology can be incorporated in the optimization process and to develop a rotation plan for the situation that a restricted amount of train conductors is available, e.g. in a strike scenario.

Quote from U.S. student Ariel Nikas, a student on this team: "GRIPS gives valuable experience in working on an industry-style project with defined goals. I think this experience solidified my desire to remain modeling continuous problems."

Project 3: Open Grid Europe – Gas Networks

Real-world networks from various domains have been shown to be small-world (large local clustering coefficient and small diameter) and scale-free (node degrees follow a power law). Additionally, they are often showing a hierarchical organization, since they reflect the modularity of the underlying system. An important step in understanding these complex systems is to identify sub-networks and their hierarchical structure. Having this knowledge allows for example to derive strategies for optimal transportation through these types of networks. However, most existing methods are designed to find non-overlapping subnetwork and don't allow nodes being shared by different modules. It is easy to see that this limitation needs to be overcome to analyze complex networks such as the German gas network. This is because a main purpose of the network is to distribute gas to actual regional sub-structures such as cities while many cities share large pipelines coming e.g. from storage systems. To make things even more

complicated, most real-world networks such as the gas network change over time. A simple example is the down time of parts of the network for maintenance, e.g. shutting down a pipe connecting two sub-networks.

The aim of this project is to analyze time-evolving hierarchical networks, such as the German gas-network, in order to understand their inner structure. Based on this structural understanding, processes based on these networks will be modelled, simulated and compared to real world phenomena. An example for such a processes is the gas-flow within such a system, including its physical properties. Once structural understanding and process understanding is achieved, the ultimate goal will be to use this knowledge to understand the inner logic of such a complex system with respect to flow prediction between the sub-systems over time. A typical question would be: given the demand of a particular sub-system (e.g. a large consumer) over time – what will be the demand tomorrow? Students will learn in this project that answering the question is fairly easy if particular smoothness conditions can be assumed (e.g. about the demand, as often done in modelling courses at university) but painfully fails using standard approaches if real world scenarios are targeted. And students will learn what can be done in these cases.

SUMMER SCHOOL: 2018 Computational Genomics Summer Institute. 2018 CGSI Long Course: JULY 11 - AUGUST 3; **2018 CGSI Short Course #1:** JULY 16 - 20; **2018 CGSI Short Course #2:** JULY 30 - AUGUST 3.

CGSI Co-organizers:
Fereydoun Hormozdiari, UC Davis
David Koslicki, Oregon State University
Kirk Lohmueller, UCLA
Ran Blekhman, University of Minnesota

CGSI Program Co-directors:
Eleazar Eskin, UCLA
Eran Halperin, UCLA
Dima Shlyakhtenko, UCLA IPAM

The development of high-throughput genomic technology has transformed biomedical sciences and provides a limitless potential for developing new personalized treatments for disease. However, analyzing the data generated by these technologies requires tremendous computational resources and significant computational and statistical expertise. The Computational Genomics Summer Institute (CGSI) aims to bring together researchers interested in methods development at the intersection of computational genetics and functional genomics.

Because IPAM was a cosponsor, we did not include the participants in our participant list or in the participant tables in this report.

SPECIAL EVENT: Loop TransPORT 2018. JULY 23-24, 2018.

LoopTransPort 2018 was the first premier conference on all aspects of the future of Hyperloop transportation. The main goal is to initiate and facilitate communication between scientists with expertise in areas related to the Hyperloop technology advancement.

LoopTransPort 2018 featured invited plenary keynotes, oral and poster presentations addressing the latest developments in Hyperloop related transportation technologies ranging from fundamental science, engineering and applied technologies to architecture, urban impact and infrastructure economics, as well as sessions focused on specific topics:

Session 1: Magnetic Levitation
Session 2: Organizational Design, Innovation, and Feasibility
Session 3: Pod/Capsule Technology
Session 4: Safety
Session 5: Architecture and Economic

Because IPAM was a cosponsor, we did not include the participants in our participant list or in the participant tables in this report.

WORKSHOP: Quantum Computing Materials Challenges. AUGUST 27 - 29, 2018.

Organizing Committee
Motoko Kotani (Tohoku University, Mathematics)
Mitchell Luskin (University of Minnesota, Twin Cities)
Noa Marom (Carnegie Mellon University)
Matthias Troyer (Microsoft Research)
Zhenghan Wang (Microsoft Research, Microsoft Station Q)

Materials that behave as quantum bits (qubits) will be the quantum chips that underlie a future quantum economy. Currently, a variety of materials have been proposed as qubit materials ranging from topological phases of matter to nitrogen-vacancy centers in diamond. Advancing the understanding and prediction of qubit materials is essential to the second quantum revolution centering on quantum computing. This three-day workshop will explore the mathematical modeling of materials for quantum computing by bringing together people from the materials modeling and simulation and quantum computing communities. The goal is to identify the grand challenges and propose possible solutions in the modeling and simulation of qubit materials and quantum devices for the engineering of a large-scale useful quantum computer.

The meeting will bring together mathematicians and scientists working on a wide spectrum of topics related to materials modeling and simulation of qubit materials. Speakers will present the fundamental concepts underlying the particular mathematical/scientific focus of the talk to stimulate active discussion and possible collaboration.

Comments from our participant survey:

"The role of the IPAM to gather researchers across disciplines and to discuss intensively the direction and methods of emerging research interests and areas. Mathematics become more and more essentials in many societal problems, while those inspire mathematical developments. I hope the IPAM keeps taking the missions."

"The challenges in the field of quantum computing will require cross-disciplinary efforts. Putting together a diverse group of mathematicians and physicists helped to articulate the challenges and the progress in the field from many fronts."

LONG PROGRAM: Science at Extreme Scales: Where Big Data Meets Large-Scale Computing. SEPTEMBER 12 - DECEMBER 14, 2018.

Organizing Committee
Joachim Buhmann (ETH Zürich)
Hans-Joachim Bungartz (Technical University Munich (TUM), Computer Science)
Emmanuel Candes (Stanford University, Applied and Computational Mathematics)
Claudia Draxl (Humboldt-Universität)
Jeffrey Hittinger (Lawrence Livermore National Laboratory, Center for Applied Scientific Computing)
Frank Jenko (Max Planck Institute for Plasma Physics and UCLA, Physics and Astronomy)
David Keyes (King Abdullah Univ. of Science and Technology (KAUST), Applied Mathematics and HPC)
Alan Lee (AMD)
Tandy Warnow (University of Illinois at Urbana-Champaign, Computer Sciences)

The breathtaking progress in both computer technologies and advanced methods to effectively and efficiently exploit them opens the door for a completely "new kind of science" at the beginning of the 21st century. This paradigm change has been brought about by two waves of innovations. The first wave primarily focused on High Performance Computing (HPC). Simulations and optimizations enable breakthroughs in the fundamental understanding or improvement of processes and systems in various domains of science and engineering. The second wave, which started later, aims at the comprehensive modeling of natural science, engineering, and societal phenomena in a data-driven way, with an even broader impact, also reaching the social sciences and humanities. Data sets from observations, experiments, simulations, imaging, digitization, or social networks as well as business or patient data are collected, processed, and analyzed.

The fusion of HPC and Big Data is a new, emerging field with an endless number of applications and an enormous game changer potential. This Long Program aims at being a catalyst at this frontier of science by bringing together leading innovators and pioneers from applied mathematics (scientific computing, optimization, data analytics, statistics etc.), computer science (HPC, data engineering, data analytics, visualization, imaging etc.), and various applications areas.

The program consists of opening day, tutorials, a series of workshops, and a culminating workshop at UCLA's Lake Arrowhead Conference Center. Most participants, including several distinguished senior scientists, will be in residence at IPAM continuously for the entire period. Between the workshops there will be a program of activities, such as seminars and discussion groups, involving long-term and short-term participants as well as visitors.

Comments from our participant survey:

"Posting slides and videos of the talks was incredibly useful to 'catch up' on portions of the workshops that I had to miss because of other engagements."

"The IPAM long program didn't meet my expectations. It far succeeded them."
"The first time I came to IPAM was for a week-long workshop (NDLT Feb 2018). I met another student there who, on probably day three, told me 'coming here is the best thing that has ever happened to me in my life!' While I wouldn't rank my experience at IPAM above many big life experiences, I can absolutely say that coming back for a long program based on my initial experience with IPAM was one of the best decisions I've made professionally. Not only did I have access to leading experts in my field, they were ready, willing, and able to speak with me. Several people from the program actively helped review my work and provided suggestions when I was stuck, and I have since used some of the connections I made there to expand my network. My home university doesn't offer much in the way of coursework or cutting-edge research in my field, so this type of immersive experience was perfect for me. I have recommended IPAM programs to so many people!"

"A splendid format. Keep the openness toward topics involving 'maths & XYZ', that's rather unique and extremely important/fruitful."

WORKSHOP: Science at Extreme Scales: Where Big Data Meets Large-Scale Computing Tutorials. SEPTEMBER 13 - 18, 2018.

Part of the Long Program "Science at Extreme Scales: Where Big Data Meets Large-Scale Computing"

Organizing Committee: Same as for long program

The program opens with four days of tutorials that will provide an introduction to major themes of the entire program and the four workshops. The goal is to build a foundation for the participants of this program who have diverse scientific backgrounds. The topics covered during the tutorials will include the following:

Large-scale data analytics
-An overview of typical challenges and approaches
-Statistical foundations of modern data analytics
-A primer on machine learning
-Deep learning: Recent successes and next steps
-Hardware aspects of large-scale data analytics

Large-scale simulation
-An overview of typical challenges and approaches
-Scalable algorithms for HPC
-Multi-fidelity approaches and model-order reduction
-Uncertainty quantification and predictive computational science
-Hardware aspects of large-scale simulation

Large-scale data management
-An overview of typical challenges and approaches
-Handling BD: Efficient data representation and compression
-Hardware aspects of large-scale data management

Big Data and HPC Visualization

PUBLIC LECTURE: Green Family Lecture Series: "Sailing Through Data: Discoveries and Mirages" by Emmanuel Candes. SEPTEMBER 24, 2018.

This lecture was part of the 2018 Green Family Lecture Series. It was open to the public. Registration was not required, so no participants are reported.

Speaker Bio:
Emmanuel Candès is the Barnum-Simons Chair in Mathematics and Statistics and a Professor of Electrical Engineering at Stanford University. He received his PhD in statistics from Stanford in 1998. His research interests include computational harmonic analysis, statistics, information theory, signal processing and mathematical optimization. He has received many awards, including the McArthur Fellowship in 2017 and the Alan T. Waterman Award from NSF in 2006. He is an elected member of the National Academy of Sciences (2014) and of the American Academy of Arts and Sciences (2014). He has given over 60 plenary lectures at major international conferences including the International Congress of Mathematicians (2014).

Abstract:
For a long time, science has operated as follows: a scientific theory can only be empirically tested, and only after it has been advanced. Predictions are deduced from the theory and compared with the results of decisive experiments so that they can be falsified or corroborated. This principle formulated by Karl Popper and operationalized by Ronald Fisher has guided the development of scientific research and statistics for nearly a century. We have, however, entered a new world where large data sets are available prior to the formulation of scientific theories. Researchers mine these data relentlessly in search of new discoveries and it has been observed that we have run into the problem of irreproducibility. Consider the April 23, 2013 Nature editorial: "Over the past year, Nature has published a string of articles that highlight failures in the reliability and reproducibility of published research." The field of Statistics needs to re-invent itself to adapt to the new reality where scientific hypotheses/theories are generated by data snooping. We will make the case that statistical science is taking on this great challenge and

discuss exciting achievements. In particular, we will introduce the method of knockoffs, which reliably selects which of the many potentially explanatory variables of interest (e.g. the absence or not of a mutation) are indeed truly associated with the response under study (e.g. the risk of getting a specific form of cancer).

PUBLIC LECTURE: Green Family Lecture Series: "The Knockoffs Framework: New Statistical Tools for Replicable Selections" by Emmanuel Candes. SEPTEMBER 27, 2018.

This lecture was part of the 2018 Green Family Lecture Series. It was open to the public. Registration was not required, so no participants are reported.

Speaker Bio: See above.

Abstract:
A common problem in modern statistical applications is to select, from a large set of candidates, a subset of variables which are important for determining an outcome of interest. For instance, the outcome may be disease status and the variables may be hundreds of thousands of single nucleotide polymorphisms on the genome. In this talk, we develop an entirely new read of the knockoffs framework of Barber and Candès (2015), which proposes a general solution to perform variable selection under rigorous type-I error control, without relying on strong modeling assumptions. We show how to apply this solution to a rich family of problems where the distribution of the covariates can be described by a hidden Markov model (HMM). In particular, we develop an exact and efficient algorithm to sample knockoff copies of an HMM, and then argue that combined with the knockoffs selective framework, they provide a natural and powerful tool for performing principled inference in genome-wide association studies with guaranteed FDR control. Finally, our methodology is applied to several datasets aimed at studying the Crohn's disease and several continuous phenotypes, e.g. levels of cholesterol.

This is joint work with Rina Barber, Yingying Fan, Lucas Janson, Jinchi Lv, Chiara Sabatti and Matteo Sesia.

WORKSHOP I: Big Data Meets Large-Scale Computing. SEPTEMBER 24 - 28, 2018.

Part of the Long Program "Science at Extreme Scales: Where Big Data Meets Large-Scale Computing"

ORGANIZING COMMITTEE

Hans-Joachim Bungartz, Chair (Technical University Munich (TUM), Computer Science)
Emmanuel Candes (Stanford University, Applied and Computational Mathematics)
Chris Johnson (University of Utah, Imaging & Biomedical Computing)
David Keyes (King Abdullah Univ. of Science and Technology (KAUST))
Marina Meila (University of Washington)

Increasingly large data sets are being ingested and produced by simulations. What experience from large-scale simulation is transferable to big data applications? Conversely, what new optimal algorithms will emerge that are motivated by data-intensive applications being pushed to large scales? How will they enrich traditional simulation? As long as the software stacks, production facilities, and even developer and user communities remain separate, many opportunities for mutual enhancement will be unrealized. This workshop will discuss:

- benefits of *in situ* convergence of simulation, analytics, and machine learning
    - steering in high-dimensional parameter space
    - smart data compression
    - data-driven modeling (e.g., refinement of empirical functions through learning)
    - physics-based "regularization" of analytics
    - simulation as a source of training data
    - learning to impute missing data
- evolving requirements of high-performance analytics and simulation
- scalable hierarchical algorithms for analytics and simulation
- detecting and exploiting data sparsity
- open problems, where no scalable methods yet exist

The workshop will bring together analysts and developers of computationally and data-intensive applications interested in early exploitation of extreme-scale computing platforms to define common ground and seek new opportunities.

Comments from our participant survey:

"This workshop has opened up my eyes in many aspects. I'm really enjoying the talks even when they are irrelevant to my research."

"Overall the conference was great. My research happens to be in topological data analysis, and I think there is a great potential for TDA to help with many of the problems discussed at this conference."

"I appreciate the high-quality videos posted online (so quickly!) so I can review new-to-me topics at my leisure."

SPECIAL EVENT: An Industrial Short Course on Deep Learning and the Latest AI Algorithms. OCTOBER 1 - 2, 2018.

IPAM offers an industrial short course on deep learning and the latest algorithms in artificial intelligence. This is a 2-day course that is primarily aimed at industrial participants. The course will be given by Professor Xavier Bresson from the Nanyang Technological University (NTU) in Singapore, who is a leading researcher in the field of deep learning. This course will be limited to 20 participants, and early registration is strongly advised. The registration fee for this course is $1,800 for those who register by August 7. The course will include the theory of deep learning techniques as well as practical exercises.

Comments from emails received by staff:

"I would recommend this [course] to people…looking to get a crash-course introduction to machine learning." *Scott Moe, AMD*

"I very much enjoyed [Professor] Xavier's course. I think the format of the class was very nice. The exercises were excellent… [and] greatly aided in understanding the material. The short length of the course was the selling point for Aerospace to allow me to attend." *Yanina Landa, Aerospace*

SPECIAL EVENT: Modern Math Workshop 2018. OCTOBER 10 - 11, 2018. (SAMSI)

ORGANIZING COMMITTEE

Hélène Barcelo, *Mathematical Sciences Research Institute (MSRI)*
Elvan Ceyhan, *Statistical and Mathematical Sciences Institute (SAMSI)*
Sudipta Dasmohaptra, *Statistical and Mathematical Sciences Institute (SAMSI)*
Christian Ratsch, *Institute for Pure and Applied Mathematics (IPAM)*
Ulrica Wilson, *Institute for Computational and Experimental Research in Mathematics (ICERM)*

The Mathematical Sciences Diversity Initiative held the Modern Math Workshop (MMW) prior to the SACNAS National Conference. The 2018 MMW was hosted by SAMSI at the *Henry B. Gonzalez Convention Center,* San Antonio, Texas on *October 10th and 11th, 2018*. This workshop focused on encouraging undergraduates, graduate students and recent PhDs from underrepresented minority groups to pursue careers in the mathematical sciences and build research and mentoring networks. The Modern Math Workshop is a pre-conference event at the SACNAS National Conference. The MMW included a keynote lecture, mini-courses, research talks, a question and answer session and a reception. This year's reception was sponsored by *USAA*.

SAMSI was the lead organizer of the MMW, therefore, SAMSI listed it as one of their programs. The participants of this program are not included in IPAM's participant list for 2018-2019.

WORKSHOP II: HPC and Data Science for Scientific Discovery. OCTOBER 15 - 19, 2018.

Part of the Long Program “Science at Extreme Scales: Where Big Data Meets Large-Scale Computing”

Organizing Committee
David Balaban (AMGEN Inc, Research & Development Informatics)
George Biros (University of Texas at Austin)
Claudia Draxl (Humboldt-Universität)
Frank Jenko (Max Planck Institute for Plasma Physics and UCLA)
Klaus-Robert Müller (Technische Universität Berlin)

With the gradual establishment of computational science as the “third pillar of science” over the last few decades, it has been steadily moving from a supporting towards a leading role. HPC applications – usually based on numerically solving sets of ODEs or PDEs – are increasingly expected to supplement a test-based approach, helping to establish a *truly predictive* computational science. With pre-exascale simulations involving and producing ever-increasing amounts of data, also from experiments or observations, there exist various critical open questions at the interface of extreme-scale data handling and HPC, including the following:

- Can we devise innovative pathways to overcome the communication bottleneck on large supercomputers by exploiting information efficiency at extreme scales – e.g., by data compression/reconstruction or variable precision computing – as well as by minimizing data motion via algorithmic advances?

- With simulations often producing very large data sets and databases, how can these be efficiently analyzed and visualized? What is the most effective use of machine learning in this context? Can we develop novel techniques for automated scientific discovery from complex scientific data?

- How can we move towards a much more integrated analytics of experimental/observational and simulation data, based on methods from modern data science? This may involve, e.g., complex types of uncertainty quantification, inverse problems, and data assimilation.

These (and related) challenges and opportunities affect a wide range of scientific communities, from plasma physics and materials science to medicine and the geosciences, and will be discussed in an interdisciplinary fashion at this workshop.

This workshop focuses on applications that are typically driven by ODEs and PDEs. It complements the third workshop in this long program which focuses on applications that are typically data driven.

Workshop III: HPC for Computationally and Data-Intensive Problems. NOVEMBER 5 - 9, 2018

Part of the Long Program “Science at Extreme Scales: Where Big Data Meets Large-Scale Computing”

Organizing Committee
Joachim Buhmann (ETH Zürich)
Jennifer Chayes (Microsoft Research)
Vipin Kumar (University of Minnesota, Twin Cities)
Yann LeCun (New York University, Canadian Institute for Advanced Research)
Tandy Warnow (University of Illinois at Urbana-Champaign, Computer Sciences)

Advances in machine learning, combinatorial optimization, and other types of mathematics, statistics, and computer science are increasingly being developed to address pressing problems in many disciplines, including systems biology, genomic biology, medicine, and social sciences. HPC enables these methods to scale to large datasets, but real world datasets are also highly heterogeneous. Hence, the computational challenges arising in this context go far beyond the "embarrassingly parallel" (i.e., a large number of relatively simple/cheap single analyses/runs to be done) and will require more HPC topics to be addressed in large-scale data analytics. We will discuss the question: What are the implications, needs, opportunities, and limitations?

This workshop focuses on applications where the dataset size requires new approaches and can benefit from HPC. These applications are also characterized by multiple types of mathematics and computer science, including combinatorial and graph-theoretic algorithms, so that this workshop complements the second workshop in this long program, which focuses on applications that are typically driven by ODEs and PDEs.

There was a women's luncheon during this workshop.

Comments from our participant survey:

"Many thanks for organizing this truly excellent workshop! The closing discussion was very interesting and stimulating."

"It was nice to hear from a variety of women in national labs and academia (both senior and junior professors) about their experiences in a casual environment."

"It was an opportunity to talk with graduate students about career opportunities in the national laboratories -- a topic which is not familiar to many graduate students."

"There aren't a lot of women in STEM relative to men, and it matters to be acknowledged."

SPECIAL EVENT: Blackwell-Tapia Conference 2018. NOVEMBER 9 - 10, 2018. (ICERM)

Organizing Committee
Carlos Castillo-Chavez (*Arizona State University)*
David Eisenbud (*Mathematical Sciences Research Institute and UC Berkeley)*
Brendan Hassett (*ICERM/Brown University)*
Jacqueline Hughes-Oliver *(North Carolina State University)*
Robert Megginson (*University of Michigan)*

Mariel Vazquez (*UC Davis)*
Robin Wilson (*California State Polytechnic University, Pomona)*
Ulrica Wilson (*Morehouse College)*

The NSF Mathematical Sciences Institutes Diversity Committee hosts the 2018 Blackwell-Tapia Conference and Awards Ceremony. This is the ninth conference since 2000, held every other year, with the location rotating among NSF Mathematics Institutes. The conference and prize honors David Blackwell, the first African-American member of the National Academy of Science, and Richard Tapia, winner of the National Medal of Science in 2010, two seminal figures who inspired a generation of African-American, Native American and Latino/Latina students to pursue careers in mathematics.

The Blackwell-Tapia Prize recognizes a mathematician who has contributed significantly to research in his or her area of expertise, and who has served as a role model for mathematical scientists and students from underrepresented minority groups, or has contributed in other significant ways to addressing the problem of underrepresentation of minorities in math.
The 2018 recipient of the Blackwell-Tapia Prize is Dr. Ronald E. Mickens, the Distinguished Fuller E. Callaway Professor in the Department of Physics at Clark Atlanta University.
The conference will include scientific talks, poster presentations, panel discussions, ample opportunities for networking, and the awarding of the Blackwell-Tapia Prize. Participants are invited from all career stages and will represent institutions of all sizes across the country, including Puerto Rico.

Goals of the conference are to:
-Recognize and showcase mathematical excellence by minority researchers
-Recognize and disseminate successful efforts to address under-representation
-Inform students and mathematicians about career opportunities in mathematics, especially outside academia
-Provide networking opportunities for mathematical researchers at all points in the higher education/career trajectory

ICERM was the lead organizer of this event, therefore, ICERM listed it as one of their programs. The participants of this program are not included in IPAM's participant list for 2018-2019.

WORKSHOP IV: New Architectures and Algorithms. NOVEMBER 26 - 30, 2018.

Part of the Long Program "Science at Extreme Scales: Where Big Data Meets Large-Scale Computing"

Organizing Committee
Nina Balcan (Carnegie Mellon University)
David Brown (Lawrence Berkeley National Laboratory)
Jeffrey Hittinger (Lawrence Livermore National Laboratory, Center for Applied Scientific Computing)

Andreas Krause (ETH Zurich)
Alan Lee, Chair (AMD)

Over the last decade, the computing needs of modern enterprise and industry have expanded to include machine intelligence, cloud computing, and HPC. In the next decade, these communities will rely on the development of novel algorithms and architectures to overcome the power, data movement, interconnect, and related software challenges associated with computing at extreme scales and the end of Moore's Law. Consumer-driven markets, new use cases for computing, and physical limitations necessitate disruptive changes throughout the entire compute ecosystem. From fundamental technologies such as non-volatile memory, accelerators, and FPGAs to emerging paradigms such as quantum and neuromorphic computing, we face dramatic challenges in system, software, and algorithm design. This workshop aims to involve all stakeholders to foster multi-disciplinary dialog and explore critical issues at the confluence of architectures, algorithms, and applications.

REUNION CONFERENCE: Culture Analytics Reunion Conference II. DECEMBER 9-14 2018.

The reunion conference was organized by the original long program organizing committee.

This was the second reunion conference for participants of the spring 2016 long program "Culture Analytics." It was a timely get-together to continue some of the collaborations that were started during the long program and at the first reunion. Presentations were given by all participants, with plenty of time between talks for discussions and collaborations.

WORKSHOP: Analysis and Geometry of Random Shapes. JANUARY 7 - 11, 2019.

Organizing Committee
Mario Bonk (University of California, Los Angeles (UCLA))
Joan Lind (University of Tennessee)
Steffen Rohde (University of Washington)
Eero Saksman (University of Helsinki)
Fredrik Viklund (Royal Institute of Technology (KTH))
Jang-Mei Wu (University of Illinois at Urbana-Champaign)

In recent years the investigation of analytic and geometric objects that arise from natural probabilistic constructions has gained a lot of attention. Often these probabilistic constructions are motivated by models in mathematical physics. Prominent examples for some recent developments are the stochastic Loewner equation (SLE), the continuum random tree (CRT), the Brownian sphere, Bernoulli percolation on the integers, random surfaces produced by Liouville Quantum Gravity" (LQG), or curves obtained from random conformal weldings. There is some indication that concepts from quasiconformal analysis and geometry are relevant for the exploration of these topics, but it is likely that one has to extend the scope of the classical theory.

The aim of the workshop is to provide an opportunity for a fruitful interaction between complex analysts, geometers, and probabilists. The underlying general philosophy is the desire to extend deterministic methods from conformal geometry and analysis for potential applications in probabilistic settings that arise in modern research. We want to bring together mathematicians with diverse research backgrounds to identify interesting problems for the study of random shapes generated by relevant probabilistic models and foster the development of the necessary analytic tools for their investigation.

Comment from our participant survey:

"Excellent talks and discussions. That the schedule wasn't too tight was great in view of discussion and collaboration. Videos of the lectures are also useful. IPAM provided good facilities and atmosphere and the staff was very helpful."

SPECIAL EVENT: Women in Mathematics and Public Policy. JANUARY 22 - 25, 2019.

Organizing Committee
Erin Hartman (University of California, Los Angeles (UCLA))
Mary Lee (The RAND Corporation)
Aisha Najera Chesler (The RAND Corporation, Engineering and Applied Sciences)
Lynn Vavreck (University of California, Los Angeles (UCLA), Co-founder, Cooperative Campaign Analysis Project)

The Women in Math and Public Policy workshop is designed to bring together women in mathematics, science, engineering, and policy to work on pressing research topics in the fields of cybersecurity and climate change. These two topics were chosen because of their wide-reaching policy impacts and reliance on various mathematical techniques. The goal is to have a diverse and multidisciplinary cohort of women at different stages in their careers, from graduate students to senior researchers. In addition to working in small groups on a specific research project, there will also be opportunities for networking and to attend talks by keynote speakers.

The public is welcome to attend the two keynote lectures by Lucy Jones (Caltech) and Kristin Lauter (Microsoft Research).

This workshop is organized by the RAND Corporation, a non-profit, nonpartisan, public policy think tank, and UCLA's Institute for Pure and Applied Mathematics. It is partially supported by NSF-HRD 1500481 – AWM ADVANCE grant.

Comments from our participant survey:

"Thanks for inviting me. As you know, I had questions about how it would go, but I think that things went really well and I really enjoyed getting to know both the participants and the RAND people."

"The knowledge and skills I got from this workshop: learnt how to use Python from the post-doc in my group who taught everyone and I got to see what climate data looks like. I do think these kinds of workshops are essential and need to be recurrent…I think the structure outside of "group work" was very well planned starting with presentation of all the teams/projects, having a progress report halfway with climate and policy groups separately and then group presentation on the last day. I think the venue at the Luskin was excellent. It was a great start for an all women workshop and I am so glad I attended it."

WORKSHOP: Computational Challenges in Gravitational Wave Astronomy. JANUARY 28 - FEBRUARY 1, 2019.

Organizing Committee
Marco Cavaglia (University of Mississippi)
Matt Choptuik (University of British Columbia)
Elena Cuoco (European Gravitational Observatory)
Jose Antonio Font (University of Valencia)
Antonio Marquina (University of Valencia)
Stanley Osher (University of California, Los Angeles (UCLA))

The Nobel-Prize-winning observations of gravitational waves by the Advanced LIGO and Virgo detectors have opened an entirely new window to study the universe. The detection of the first gravitational-wave signal, GW150914, on September 14th, 2015, can be considered one of the greatest scientific milestones of all time, confirming a century-old prediction of Albert Einstein's Theory of General Relativity. At present, gravitational waves have been detected from mergers of binary black holes and binary neutron stars. Different types of gravitational-wave signals from other sources await to be detected, as e.g. core-collapse supernovae, spinning neutron stars, white-dwarf binary mergers, and even stochastic backgrounds of astrophysical or cosmological origin.

The detection of gravitational waves is, foremost, a technological challenge. In addition, there are significant mathematical and computational difficulties hampering the process of detection. One of them involves the solution of Einstein's gravitational field equations, either through approximate methods or by fully numerical means, to generate waveform signals to aid the identification of the event types and the inference of their physical properties. Another major computational difficulty is the analysis of large volumes of non-Gaussian, non-stationary noisy data, aggravated by the presence of transient spurious signals (glitches) that may not only disturb astrophysical signals but also mimic true signals, increasing the false-alarm rate and producing a decrease in the detectors' duty cycle.

This workshop will bring together experts in the field of mathematical and numerical relativity, and researchers in gravitational-wave data analysis, who will discuss recent advances for the detection and reconstruction of gravitational-wave signals from advanced interferometers. It will cover aspects ranging from the formulation of Einstein's theory of General Relativity, including state-of-the-art numerical methodology for the generation of waveform templates from astrophysical systems, to gravitational-wave detector characterization, data analysis, and parameter estimation, with modern mathematical and numerical approaches.

Comments from our participant survey:

"It was a great program! I will certainly recommend IPAM workshops to colleagues and I hope to visit again."

"I really think that the level of the workshop was excellent, with top level talks and a lot of discussion."

PUBLIC LECTURE: Green Family Lecture Series: "From Einstein to Gravitational Waves," by Barry Barish. JANUARY 28, 2019.

This lecture was open to the public No registration was required; therefore, the attendees do not appear in our participant list.

Speaker Bio:
Barry Barish is a leading expert on gravitational waves. He is the Linde Professor of Physics, Emeritus at Caltech and recently joined the faculty at UC Riverside. At Caltech, Barish was the principal investigator, then director of the Laser Interferometer Gravitational-wave Observatory (LIGO). He created the LIGO Scientific Collaboration (LSC), which now enables more than 1000 collaborators world-wide to participate in LIGO. In 2017, Barish was awarded the Nobel Prize in Physics along with Rainer Weiss and Kip Thorne for their contributions to the LIGO detector and the observation of gravitational waves. Barish earned a Ph.D in experimental high energy physics at UC Berkeley in 1962.

Abstract:
The development of our understanding of gravity from Isaac Newton's 'Universal Gravity,' to Albert Einstein's 'Theory of General Relativity' and theory of gravity, will be reviewed. The quest for gravitational waves from Einstein's original proposal of their existence to their detection, announced 100 years later, will be presented.

PUBLIC LECTURE: Green Family Lecture Series: "Gravitational Waves and a Future New Science," by Barry Barish. JANUARY 30, 2019.

This lecture was open to the public No registration was required; therefore, the attendees do not appear in our participant list.

Speaker Bio: See above.

Abstract:
The science of gravitational waves will be reviewed from the tests of general relativity to the birth of multi-messenger astronomy. The future of this new science on earth and in space will be discussed.

WORKSHOP: Operator Theoretic Methods in Dynamic Data Analysis and Control. FEBRUARY 11 - 15, 2019.

Organizing Committee
Didier Henrion (Centre National de la Recherche Scientifique (CNRS), Laboratoire d'Analyse et d'Architecture des Systemes (LAAS))
Senka Maćešić (University of Rijeka)
Igor Mezic (University of California, Santa Barbara (UCSB))
Mihai Putinar (University of California, Santa Barbara (UCSB))

In a visionary outline of mathematics and its future at the beginning of the 20th century, Poincaré suggested that complicated dynamics governed by non-linear partial differential equations can be reduced to and analyzed by the linear infinite dimensional spectral methods advocated by Hilbert and Fredholm. Poincaré's prophecy became reality after 1920 —due to not less visionary contributions of Carleman, Koopman and von Neumann. Although originally aimed at ergodic theory of measure-preserving systems, these linear operator reductions of dynamical systems have far reaching implications for dissipative systems of modern interest, and a much wider, unexpected area of applicability. But, it was only in the 1990s that potential for wider applications of the operator-theoretic approach were realized. Over the past two decades, the trend of applications of this approach has further evolved from the perspectives of theory, computation and numerical methods.

The hallmark of the work on the operator-theoretic approach in the last two decades is the linkage between geometrical properties of dynamical systems with the geometrical properties of the level sets of Koopman eigenfunctions in state space, and Koopman modes in configuration space. This approach also provides an opportunity for study of high-dimensional evolution equations in terms of dynamical systems concepts via a spectral decomposition, and links with associated numerical methods for such evolution equations. From this operator-theoretic framework, new data-drive algorithms are developed that give insight in the underlying processes even in the non-autonomous cases or in the presence of uncertainty. Applications to fluid dynamics, large power networks, climatology, physiology, pharmacology, disease dynamics, social precesses, synthetic and molecular biology, robotics, and numerous other fields of science and engineering have followed the theoretical and computational developments.

The workshop will bring together experts in different facets of Koopman operator perspective on dynamical and control systems. It will be an interplay between ergodic theory, operator theory, geometric dynamical systems, control theory and convex optimization, estimation, computational aspects of global optimization and applied linear algebra.

Comments from our participant survey:

"This was an excellent workshop! I got many new ideas by listening and interacting with the attendees."

"It was great as we become familiar with practically relevant problems that need to be addressed using some rigorous analysis."

"It's been a wonderful workshop with a good spectrum of speakers, plenty of time to mingle and

discuss. The support and organization provided by IPAM was excellent. Another great IPAM workshop; I hope there will be many more for me."

WORKSHOP: Braids, Resolvent Degree and Hilbert's 13th Problem. FEBRUARY 19 - 21, 2019.

Organizing Committee
Benson Farb (University of Chicago)
Eriko Hironaka (American Mathematical Society)
Mark Kisin (Harvard University)
Zinovy Reichstein (University of British Columbia)
Jesse Wolfson (University of California, Irvine (UCI))

The purpose of this workshop is to bring focused attention to Hilbert's 13th problem, and to the broader notion of resolvent degree. While Abel's 1824 theorem — that the general degree n polynomial is only solvable in radicals for n<4n<4 — is well known, less well known is Bring's 1786 proof that a general quintic is solvable in algebraic functions of only one variable. Hilbert conjectured that for a general sextic, one needs algebraic functions of two variables, and that for a general degree 7 polynomial, one needs algebraic functions of three variables. More generally, it is natural to expect that as $n \to \infty$, so does the minimal number of variables needed to solve the general degree n polynomial. In a celebrated theorem, Arnol'd and Kolmogorov proved that, at the level of continuous functions, there is no local obstruction to reducing the number of variables to one. Thus, a resolution of Hilbert's problem must lie deeper. Resolvent degree was introduced by Brauer in order to provide a rigorous statement of these conjectures. While no progress has yet been made on these conjectures, the study of resolvent degree is receiving renewed attention and an influx of ideas from related fields, including:

- the theory of essential dimension
- uniformization of moduli spaces
- braid monodromy
- p-adic Hodge theory

This workshop will bring together young and established researchers who work in these fields to explore topics related to Hilbert's conjectures, to facilitate interaction between subdisciplines, and to lay the groundwork for future progress. The workshop will be organized around mini-courses by experts which will be aimed at 1) conveying the methods that can be brought to bear from each area, and 2) formulating problems concerning resolvent degree that seem particularly tractable using these methods.

Comment from our participant survey:

"The workshop was great. It exceeded my expectations. Great conference for stimulating interest in this area and for interacting with new people!"

WORKSHOP: Autonomous Vehicles. FEBRUARY 25 - MARCH 1, 2019.

Organizing Committee
Ruzena Bajcsy (University of California, Berkeley (UC Berkeley), CITRIS)
Paola Goatin (Institut National de Recherche en Informatique Automatique (INRIA))
Jana Kosecka (George Mason University)
Benedetto Piccoli (Rutgers University)
Benjamin Seibold (Temple University)
Daniel Work (Vanderbilt University)

Autonomous vehicles are now entering our roadways, and together with connectivity, electrification, and the sharing economy, they will fundamentally change how our society will transport people and goods in the future. Recent technological and engineering advances have enabled developers to achieve impressive feats in the autonomous systems sector; and at the same time there are critical gaps in the understanding of learning-based safety-critical systems, human-cyber-physical systems interactions, the resulting transportation system-level consequences, and the mathematical foundations needed to address those challenges. This workshop brings together experts in cyber-physical systems, machine learning, transportation engineering, and applied mathematics, both from academia and from industry, to help bridge the technical gaps and to facilitate exchange and collaboration across disciplinary boundaries.

Comments from our participant survey:

“Since this was a fairly application driven workshop, the lectures were all topical and relevant. All the lectures that I attended were very interesting. I especially enjoyed the discussions during and after the lectures.”

LONG PROGRAM: Geometry and Learning from Data in 3D and Beyond. MARCH 11 - JUNE 14, 2019.

Organizing Committee
Ron Kimmel (Technion - Israel Institute of Technology, Intel Perceptual Computing)
Rongjie Lai (Rensselaer Polytechnic Institute)
Yann LeCun (New York University, Canadian Institute for Advanced Research)
Guido Montufar (University of California, Los Angeles (UCLA))
Stanley Osher (University of California, Los Angeles (UCLA))
Olga Sorkine-Hornung (ETH Zürich)
Gabriele Steidl ((Universität Kaiserslautern)
Hongkai Zhao (University of California, Irvine (UCI))

Fast acquisition and routine use of 3D data due to the advance of modern technology and computer power makes 3D description of the real world imminent and practical in many applications such as 3D modeling, virtual reality, 3D camera, 3D printing and prototyping, etc.

It is increasingly important and urgent for efficient processing, analysis, and intelligent use of a large variety of 3D data. Although many advanced technologies and efficient computational tools are well developed for 2D images from acquisition to processing, analysis, understanding and learning, their counterparts for 3D modeling and shape analysis are more challenging and less developed. From a mathematical point of view, image space is linear since it can be simply regarded as a space of two variable functions defined on a rectangular domain sampled by a uniform grid in practice. However, shape space is nonlinear and shape geometry is more challenging to represent, characterize and analyze. This makes higher-level tasks for shape analysis and understanding even more challenging. Beyond 3D shapes, understanding and learning geometric structures for data in high dimensional spaces is also of great importance in practice.

Recently, a lot of progress has been made in developing computational models and tools based on geometric theory. In particular, these developments provide computational techniques for extracting local and global intrinsic features and structures that are invariant under various transformations or embeddings. On the other hand, recent advances in machine learning, supervised or non-supervised, can be very effective in learning robust and distinctive features and used for data or application specific tasks such as recognition and classification. The goals of this program are to (1) further advance mathematical and computational techniques for 3D modeling and shape analysis, (2) design effective problem specific approaches combining geometry and machine learning, i.e., learning geometry from geometry, (3) generalize our understandings and techniques for shape analysis to geometric data analysis in higher dimensions.

WORKSHOP: Geometry and Learning from Data Tutorials. MARCH 12 - 15, 2019.

Part of the Long Program “Geometry and Learning from Data in 3D and Beyond”

Organizing Committee
Ron Kimmel (Technion - Israel Institute of Technology, Intel Perceptual Computing)
Rongjie Lai (Rensselaer Polytechnic Institute)
Yann LeCun (New York University, Canadian Institute for Advanced Research)
Stanley Osher (University of California, Los Angeles (UCLA))
Olga Sorkine-Hornung (ETH Zürich)
Hongkai Zhao (University of California, Irvine (UCI))

The program opens with four days of tutorials that will provide an introduction to major themes of the entire program and the four workshops. The goal is to build a foundation for the participants of this program who have diverse scientific backgrounds.

For those participating in the long program, please plan to attend Opening Day on March 11, 2019, as well. Others may participate in Opening Day by invitation from the organizing committee.

Comment from our participant survey:

"The preparation and organization of this workshop are excellent: clear, informative, and timely correspondence, incl. responses to questions and problems; generous financial support; friendly and well available staff…I'm feeling welcome and comfortable here, the staff prepares a great environment to work in."

WORKSHOP I: Geometric Processing. APRIL 1 - 5, 2019.

Part of the Long Program "Geometry and Learning from Data in 3D and Beyond"

Organizing Committee
Philipp Grohs (Universität Wien, Geometry)
Ron Kimmel (Technion - Israel Institute of Technology, Intel Perceptual Computing)
Simon Masnou (Université de Lyon I)
Gabriele Steidl ((Universität Kaiserslautern)

Over the last few decades, it has become common to treat data as samples belonging to geometric manifolds or more general nonlinear metric spaces. Together with increasing computer power, this has opened the way to new acquisition and representation methods, and to new data processing techniques; leading to very challenging theoretical and practical questions which require an interplay between differential and metric geometries, optimization, PDEs, stochastic analysis, and computer science.

This workshop aims to bring together leading experts in these fields and young researchers to exchange ideas, create synergies, and enhance current and outline future directions of research.

Comments from our participant survey:

"IPAM is a fantastic opportunity, especially for those of us on sabbatical who get an opportunity for a truly immersive learning experience. What a resource! Thank you NSF!

"IPAM is a fantastic place to visit and learn. Great job building collegiality between attendees, lecturers, academics, students, and everyone else!"

WORKSHOP II: Shape Analysis. APRIL 15 - 19, 2019.

Part of the Long Program "Geometry and Learning from Data in 3D and Beyond"

Organizing Committee
Mirela Ben Chen (Technion - Israel Institute of Technology)
Ron Kimmel (Technion - Israel Institute of Technology, Intel Perceptual Computing)
Rongjie Lai (Rensselaer Polytechnic Institute)
Martin Rumpf (Rheinische Friedrich-Wilhelms-Universität Bonn)
Justin Solomon (Massachusetts Institute of Technology)

Fast acquisition technology and broad availability of 3D data underscore the need for advanced tools that process and analyze 3D shapes. Unlike image and signal processing which handle functions on flat domains with well-developed tools for processing and learning, 3D shapes present unique challenges due to their irregular and weak structure.

Despite breakneck progress in the development of tools for these tasks, many challenges remain in automatically analyzing, processing, and understanding 3D geometry. In particular, recent advances in machine learning have shown advancement in signal and image processing, while the processing of 3D shapes is less developed. This workshop aims to bring world-leading researchers in mathematics and computer science to study, explore, collaborate, and develop new ideas and research directions in combining traditional 3D shape analysis with recent developments of learning.

Comments from our participant survey:

"This was a fantastic workshop and I am grateful for the funding provided by IPAM. I had the opportunity to meet the other graduate students in this research area and speak with professors. I hope to attend more sessions in the future."

"The overall workshop was amazing. I totally hold a positive opinion. Just one little comment is: the so-called workshop thing is not that "workshop". All the speakers were really advanced. They gave great and mind-blowing lectures but also made the workshop more like a conference/seminar."

WORKSHOP III: Geometry of Big Data. APRIL 29 - MAY 3, 2019.

Part of the Long Program "Geometry and Learning from Data in 3D and Beyond"

Organizing Committee
Stanley Osher (University of California, Los Angeles (UCLA))
Guillermo Sapiro (Duke University)
Rebecca Willett (University of Chicago)
Hongkai Zhao (University of California, Irvine (UCI))

Exploring, understanding and utilizing geometric structures of big data can be of crucial importance in data analysis and machine learning algorithms. For example, the set of image patches or 3D surfaces usually stays near a low dimensional manifold. This manifold structure can be used to efficiently characterize similarities and dissimilarities. It is also desirable to design features that are invariant under certain transformations or group actions. When these features are used as input or desired properties are incorporated into learning structures and algorithms, the accuracy, efficiency, and interpretability of the whole process is significantly enhanced. In this workshop, we aim to investigate and study the possibilities and potential of the integration of geometry, modeling, and learning from theory and principle to practice and implementation in order to take advantage of both model-based and learning-based approaches.

There was a women's luncheon during this workshop.

Comments from our participant survey:

"This workshop covered a variety of topics. I learnt a lot about different aspects of machine learning techniques and scientific computing applications."

"Very nice workshop. I will spread the word about your programs to my colleagues."

"Great to see this topic dealt with so in-depth. In general, IPAM is doing great work bridging math and CS."

"Appreciate the diversity in the topics of the talks."

WORKSHOP IV: Deep Geometric Learning of Big Data and Applications. MAY 20 - 24, 2019.

Part of the Long Program "Geometry and Learning from Data in 3D and Beyond"

Organizing Committee
Xavier Bresson (Nanyang Technological University, Singapore)
Yann LeCun (Facebook, Canadian Institute for Advanced Research)
Stanley Osher (University of California, Los Angeles (UCLA))
Rebecca Willett (University of Chicago)

Deep learning techniques have achieved impressive performance in computer vision, natural language processing and speech analysis. These tasks focus on data that lie on Euclidean domains, and mathematical tools for these domains, such as convolution, downsampling, multi-scale, and locality, are well-defined and benefit from fast computational hardware like GPUs. However, many essential data and tasks deal with non-Euclidean domains for which deep learning methods were not originally designed. Examples include 3D point clouds and 3D shapes in computer graphics, functional MRI signals on the brain structural connectivity network, the DNA of the gene regulatory network in genomics, drugs design in quantum chemistry, neutrino detection in high energy physics, and knowledge graph for common sense understanding of visual scenes. This major limitation has pushed the research community in recent years to generalize neural networks to arbitrary geometric domains like graphs and manifolds. Fundamental operations such as convolution, coarsening, multi-resolution, causality have been redefined through spectral and spatial approaches. Recent results for these non-Euclidean data analysis problems show promising and exciting new tools for applications in many fields.

The goals of this workshop are to 1) bring together mathematicians, machine learning scientists and domain experts to establish the current state of these emerging techniques, 2) discuss a framework for the analysis of these new deep learning techniques, 3) establish new research directions and applications of these techniques in neuroscience, social science, computer vision,

natural language processing, physics, chemistry, and 4) discuss new computer processing architecture beyond GPU adapted to non-Euclidean domains.

Comments from our participant survey:

“This workshop brought in fresh views of the emerging field, deep geometric learning, ranging from theory to applications. It's interesting and enlightening.”

“Overall, I thought the workshop was excellent. I am grateful for the opportunity to attend. It exposed me to various areas that I can explore further on my own. And gave me the opportunity to interact with various participants with similar goals and interests. I feel very encouraged to take a sabbatical in the near future and apply for a long program. I think it was excellently organized. The duration of lectures and interspersed breaks was excellent, allowing sufficient time to recover and gain the most from the talks. Themes by day were also a good idea.”

“Having the breakout room with the TV live stream was convenient. Especially when so many of us have paper submissions coming up. It also presents the opportunity for quick/valuable offline clarifications to be made by peers while the talks are happening in real time.”

WORKSHOP: Geometry and Learning from Data in 3D and Beyond Culminating Workshop at Lake Arrowhead. JUNE 9 - 14, 2019.

The culminating workshop was organized by the long program organizing committee.

The final workshop in the long program, Geometry and Learning from Data in 3D and Beyond, which was held at Lake Arrowhead Conference Center, provided an opportunity for the program’s core participants to report on their work during the past three months and to discuss futures projects. Many of the collaborations and interactions that were formed during the program had a chance to deepen.

Comments from participant emails to staff:

“Thank you all a lot, GL2019 was a fantastic and strongly inspiring program for me! I could talk to so many people and experts, I'll try and keep in touch with a couple of them. Moreover, I had many insights and thoughts - and likewise many more questions now. As much as I can manage, I will continue working on what I learnt during GL2019. There is plenty to read, explore, and turn from a diffuse, rough idea into something solid and new.” *Kai Sandfort (Karlsruher Institut für Technologie)*

“I want to thank you for contributing to such a nice program. I have learned a lot these past months and it was really lovely meeting you all. I wish you all good luck. Keep up the good work.” *Sumukh Bansal (Dhirubhai Ambani Institute of Information and Communication Technology)*

REUNION CONFERENCE: Complex High-Dimensional Energy Landscapes Reunion Conference I. JUNE 9 - 14, 2019.

The reunion conference was organized by the original long program organizing committee.

This was the first reunion conference for participants of the fall 2017 long program "Complex High-Dimensional Energy Landscapes." It was a timely get-together to continue some of the collaborations that were started during the long program and at the first reunion. Presentations were given by all participants, with plenty of time between talks for discussions and collaborations.

REUNION CONFERENCE: Understanding Many-Particle Systems with Machine Learning Reunion Conference II. JUNE 9 - 14, 2019.

The reunion conference was organized by the original long program organizing committee.

This was the second reunion conference for participants of the fall 2016 long program "Understanding Many-Particle Systems with Machine Learning." It was a timely get-together to continue some of the collaborations that were started during the long program. Presentations were given by all participants, with plenty of time between talks for discussions and collaborations.

OUTREACH ACTIVITIES, 2018-2019

IPAM continues to strengthen its partnerships with two- and four-year schools in the Los Angeles area to increase the representation of minorities and women in its programs. IPAM invited students from East Lost Angeles College (ELAC) to attend the 2018 Research in Industrial Projects for Students (RIPS) "Projects Day," as well as a separate event in which ELAC students were invited to UCLA for math-related activities to engage students and increase their level of interest in the subject area. During the latter event, former IPAM Associate Director, Jorge Balbás, gave a specially formatted public lecture talk on "Fluid Dynamics: Bernoulli's Principle and the Improbable Flight of the Bumblebee" that was accessible for the students.

IPAM invited students from Santa Monica College, Cal State Northridge, other local schools and their Mathematics Engineering Science Achievement (MESA) chapters to attend the fall 2018 Green Family Lecture Series. In addition, IPAM supports the UCLA chapter of Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS): Our Outreach Coordinator attends quarterly meetings and encourages SACNAS members to participate in IPAM programs. The chapter used IPAM facilities for a K-12 educational event, an undergraduate research symposium for community college students, and occasional other meetings and study sessions.

In the past year, IPAM representatives attended national diversity conferences to promote math programs to underrepresented groups. The Associate Director and Outreach Coordinator

attended the 2018 Modern Math Workshop and SACNAS National Conference in San Antonio to advertise upcoming opportunities and to network with faculty and students. IPAM shared a booth at the 2018 SACNAS National Conference with four other math institutes (MSRI, ICERM, SAMSI, and AIM). In January 2019, former RIPS mentor Claudia Falcon represented IPAM at the Nebraska Conference for Undergraduate Women in Math (NCUWM) to promote the RIPS 2019 summer program and to talk to undergraduate women about opportunities in math. Three RIPS students from the 2018 RIPS program also attended the conference and presented their research; IPAM paid for their travel.

IPAM awarded Berland Foundation awards to four participants with family in the past year. The funds helped pay for child care, housing, or other expenses necessary to allow them to fully participate in the workshop or long program.

Finally, IPAM advertised its RIPS (undergraduate) and GRIPS (graduate) programs through minority institutions and organizations.

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 O, Committee Membership. On occasion, IPAM scientific staff and board members are organizers of workshops and long programs, and are therefore included in the list below.

Name	Institution
Diogo Aguiar Gomes	King Abdullah Univ. of Science and Technology (KAUST)
Pilar Ariza	University of Sevilla
Alán Aspuru-Guzik	Harvard University
Ruzena Bajcsy	University of California, Berkeley (UC Berkeley)
David Balaban	NAVICAN
Nina Balcan	Carnegie Mellon University
Mirela Ben Chen	Technion - Israel Institute of Technology
George Biros	University of Texas at Austin
Mario Bonk	University of California, Los Angeles (UCLA)
Xavier Bresson	Nanyang Technological University, Singapore
David Brown	Lawrence Berkeley National Laboratory
Joan Bruna	New York University
Steve Brunton	University of Washington
Joachim Buhmann	ETH Zürich
Hans-Joachim Bungartz	Technical University Munich (TUM)
Jeff Calder	University of Minnesota, Twin Cities
Eric Cances	École Nationale des Ponts-et-Chaussées

Emmanuel Candes	Stanford University
Marco Cavaglia	Missouri University of Science and Technology
Jennifer Chayes	Microsoft Research
Matt Choptuik	University of British Columbia
Tom Chou	University of California, Los Angeles (UCLA)
Cecilia Clementi	Rice University
Kyle Cranmer	New York University
Elena Cuoco	European Gravitational Observatory
Jerome Darbon	Brown University
Moritz Diehl	University of Freiburg
Claudia Draxl	Humboldt-Universität
Craig Evans	University of California, Berkeley (UC Berkeley)
Fariba Fahroo	Air Force Office of Scientific Research (AFOSR)
Benson Farb	University of Chicago
Will Feldman	University of Chicago
Jose Antonio Font	University of Valencia
Jacob Foster	University of California, Los Angeles (UCLA)
Wilfrid Gangbo	University of California, Los Angeles (UCLA)
Ben Glocker	Imperial College
Paola Goatin	Institut National de Recherche en Informatique Automatique (INRIA)
Mark Green	University of California, Los Angeles (UCLA)
Philipp Grohs	Universität Wien
Erin Hartman	University of California, Los Angeles (UCLA)
Didier Henrion	Centre National de la Recherche Scientifique (CNRS)
Eriko Hironaka	American Mathematical Society
Jeffrey Hittinger	Lawrence Livermore National Laboratory
Ryan Hynd	University of Pennsylvania
Jonathan Jacobs	University of California, Los Angeles (UCLA)
Frank Jenko	Max Planck Institute for Plasma Physics and UCLA
Marti Jett	Army Futures Command, Medical Research, Fort Detrick
Chris Johnson	University of Utah
Eurika Kaiser	University of Washington
Efthimios (Tim) Kaxiras	Harvard University
David Keyes	King Abdullah Univ. of Science and Technology (KAUST)
Ron Kimmel	Technion - Israel Institute of Technology
Mark Kisin	Harvard University
Jana Kosecka	George Mason University
Andreas Krause	ETH Zurich
Vipin Kumar	University of Minnesota, Twin Cities
Gitta Kutyniok	Technische Universität Berlin
J. Nathan Kutz	University of Washington
Rongjie Lai	Rensselaer Polytechnic Institute
Yann LeCun	New York University
Alan Lee	AMD
Mary Lee	The RAND Corporation

Joan Lind	University of Tennessee
Mitchell Luskin	University of Minnesota, Twin Cities
Senka Maćešić	University of Rijeka
Dionisios Margetis	University of Maryland
Noa Marom	Carnegie Mellon University
Antonio Marquina	University of Valencia
Simon Masnou	Université Claude Bernard Lyon 1
Emeran Mayer	University of California, Los Angeles (UCLA)
Marina Meila	University of Washington
Igor Mezic	University of California, Santa Barbara (UCSB)
Jeff Miller	University of California, Los Angeles (UCLA)
Guido Montufar	University of California, Los Angeles (UCLA)
Klaus-Robert Müller	Technische Universität Berlin
John Murray	Yale University
Aisha Najera Chesler	The RAND Corporation
Marc Niethammer	University of North Carolina
Frank Noe	Freie Universität Berlin
Jonathan Novak	University of California, San Diego (UCSD)
Adam Oberman	McGill University
Stanley Osher	University of California, Los Angeles (UCLA)
Aydogan Ozcan	University of California, Los Angeles (UCLA)
Francesco Paesani	University of California, San Diego (UCSD)
Igor Pak	University of California, Los Angeles (UCLA)
Greta Panova	University of Southern California (USC)
Virginia Pasour	U.S. Army Research Office
Ankit Patel	Rice University
Grigorios Pavliotis	Imperial College
Benedetto Piccoli	Rutgers University
Mihai Putinar	University of California, Santa Barbara (UCSB)
Ben Recht	University of California, Berkeley (UC Berkeley)
Zinovy Reichstein	University of British Columbia
Fraydoun Rezakhanlou	University of California, Berkeley (UC Berkeley)
Steffen Rohde	University of Washington
Lorenzo Rosasco	Università di Genova
Daniel Rueckert	Imperial College
Martin Rumpf	Rheinische Friedrich-Wilhelms-Universität Bonn
Matthias Rupp	Fritz-Haber-Institut der Max-Planck-Gesellschaft
Eero Saksman	University of Helsinki
Guillermo Sapiro	Duke University
Katya Scheinberg	Lehigh University
Christof Schuette	Freie Universität Berlin
Rebecca Segal	Virginia Commonwealth University
Benjamin Seibold	Temple University
Jin Keun Seo	Yonsei University
Blerta Shtylla	Pomona College

Suzanne Sindi	University of California, Merced
Dejan Slepcev	Carnegie Mellon University
Justin Solomon	Massachusetts Institute of Technology
Alicia Solow-Niederman	University of California, Los Angeles (UCLA)
Olga Sorkine-Hornung	ETH Zürich
Panagiotis Souganidis	University of Chicago
Takis Souganidis	University of Chicago
Gabriele Steidl	Universität Kaiserslautern
Andrew Stuart	California Institute of Technology
Claire Tomlin	University of California, Berkeley (UC Berkeley)
Daniela Tonon	Université de Paris IX (Paris-Dauphine)
Michael Unser	École Polytechnique Fédérale de Lausanne (EPFL)
Ruth Urner	York University
Shashaank Vattikuti	National Institutes of Health (NIH)
Lynn Vavreck	University of California, Los Angeles (UCLA)
Rene Vidal	Johns Hopkins University
Fredrik Viklund	Royal Institute of Technology (KTH)
Tandy Warnow	University of Illinois at Urbana-Champaign
Michael Weinstein	Columbia University
Paul Weiss	University of California, Los Angeles (UCLA)
Andew White	University of Rochester
Rebecca Willett	University of Chicago
Jesse Wolfson	University of California, Irvine (UCI)
Daniel Work	Vanderbilt University
Stephen Wright	University of Wisconsin-Madison
Jang-Mei Wu	University of Illinois at Urbana-Champaign
Yunan Yang	New York University
Jong Chul Ye	Korea Advanced Institute of Science and Technology (KAIST)
Lenka Zdeborová	Commissariat à l'Énergie Atomique (CEA)
Riccardo Zecchina	Bocconi University
Melanie Zeilinger	ETH Zürich
Hongkai Zhao	University of California, Irvine (UCI)

L. PUBLICATIONS LIST

This report includes publications that resulted from the spring 2016 and fall 2016 long programs, as well as the publications of our Director, Deputy Director, Associate Director, and Director of Special Projects from the past year. We asked the participants of Culture Analytics (spring 2016) and Understanding Many-Particle Systems with Machine Learning (fall 2016) to list their publications that were a result of or significantly influenced by the IPAM program as both groups completed their second reunion conferences during this reporting period. These publications were entered into the project reports "products" form in Research.gov. We chose not to include pre-prints. We confirmed that the publications in this report were not reported in our previous annual reports.

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-LA and RIPS-LA Projects Day. Companies also sponsor projects in RIPS-Hong Kong and Graduate RIPS-Berlin and Sendai; in these cases, the sponsors are recruited by our partners, Hong Kong University of Science and Technology, MODAL (Berlin), and RACMaS (Sendai).

IPAM received some gifts and grants during this period from government and military agencies to support specific programs, including:

- An IRES grant through NSF-OISE supports RIPS-Hong Kong (ended Aug 31, 2018; $222,865)
- IRES grant through NSF-OISE supports GRIPS-Berlin (9/1/2018-8/31/2021; $233,235)
- Research in Industrial Projects for Students (RIPS) collects sponsorship fees from its corporate and other sponsors, which cover some of the program expenses
    - Livermore National Lab: RIPS2018; $1,400.00
    - Airforce: RIPS2018; $25,000
- ONR supported the workshop on New Architectures and Algorithms ($100,000)

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 O for a complete list of members and their affiliations.

Out of all of IPAM's participants during this reporting period, 36 of them held positions in government or military organizations, and 100 worked in industry. 26 of our workshops speakers came from companies such as Google, AMD, IBM, Microsoft Research, Facebook, Adobe, and Microsoft Research. Ten of our workshop speakers came from government or military labs which include Los Alamos, Argonne, Lawrence Berkeley, Lawrence Livermore, Sandia, and Oak Ridge National Labs.

N. EXTERNAL SUPPORT

In addition to the funding listed in Table N below, IPAM receives substantial in-kind financial support from UCLA. The Director's entire salary 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. IPAM is not charged for the use of its building or for custodial care. The value of these items is considerable. Additionally, senior long-term participants from other universities are usually funded on a teaching replacement-buyout basis, by which they are released from teaching for the cost of hiring a

junior person as a replacement. The table shows other funding received by IPAM from June 1, 2018 through May 31, 2019.

Table N: Other Funding Support	
Federal Funding	
Office of Naval Research (High Performance Computing)	$100,000
NSF-IRES Track 1 - GRIPS Berlin	$78,914
Sub-total	$178,914
Support from Foundations and Endowments	
UC Regents Matching - IPAM's Director Endowment	$208,450
Simon's Foundation - Current Spending	$192,985
IPAM Director's Endowment Fund	$30,499
Schwinger Foundation	$25,095
Green Family Foundation Endowment	$4,811
Sub-total	$461,840
UCLA Funding	
Dean Physical Sciences	$134,004
Vice Chancellor for Research	$133,602
Luskin Endowment - Thought Leadership	$20,000
Sub-total	$287,606
Industrial Affiliates and Other Support	
Aerospace Corporation	$25,000
Air Force	$25,000
Amazon	$25,000
Google, Inc	$25,000
Gum Gum, Inc.	$25,000
HRL, Inc	$25,000
Microsoft	$10,000
Praedicat	$15,000
UNC Lineberger Comprehensive Cancer Center	$28,500
Sub-total	$203,500
Others	
Other Donors	$7,810
TOTAL	$1,139,670

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, 2018-2019 Membership

Name	Institution	Department or title
David Balaban	Amgen	
Katy Börner	Indiana University, Bloomington	Distinguished Professor of Engineering and Information Science
Russel Caflisch	New York University	Director, Courant Institute
Tony Chan	KAUST	President
Brenda Dietrich	Cornell University	Professor
Karina Edmonds	Google	Google Cloud University Relations Lead
Katherine Ensor	Rice Univeristy	Noah G. Harding Professor of Statistics
James Gidney	The Aerospace Corporation	Director, Navigation and Geopositioning Systems Department
Mark Green	UCLA	Mathematics
Alfred Hales	CCR West	
Sallie Keller	Virginia Tech University	Professor of Statistics, Director
Steven Koonin	New York University	
Alan Lee	AMD Research	Corporate Vice President of Engineering Research
Monique Miller	Wilshire Funds Management	Managing Director
Nancy Potok	US Government	Chief Statistician
Ronald Stern	UC Irvine	
Tatiana Toro	University of Washington	Mathematics
Leland Wilkinson	H2O.ai	Chief Scientist
Jeannette Wing	Columbia University	Director, Data Science Institute

Science Advisory Board, 2018-2019 Membership

Name	Institution	Discipline or department
Alexei Borodin	MIT	Mathematics
Michael Brenner	Harvard	School of Engineering and Applied Sciences
Emery Brown	MIT	Professor of Medical Engineering and of Computational Neuroscience
Robert Calderbank	Duke University	Director of the Information Initiative
Emmanuel Candes	Stanford University	Professor of Mathematics and of Statistics
Cecilia Clemente	Rice	Chemistry

Cynthia Dwork	Harvard University, SEAS	Gordon McKay Professor of Computer Science
Jordan Ellenberg	Univ of Wisconsin	Mathematics
Peter Wilcox Jones	Yale University	Mathematics
Yann LeCun	New York University/Facebook	Computer Science
David Levermore	University of Maryland	Applied Math
Xihong Lin	Harvard	T H Chan School of Public Health
Robert Klaus-Mueller	TU Berlin	Machine Learning Group
Assaf Naor	Princeton	Mathematics
Pablo Parrilo	MIT	Electrical Engineering and Computer Science
Terence Tao	UCLA	Mathematics
Luca Trevisan	UC Berkeley	Electrical Engineering and Computer Science
Amie Wilkinson	Univ. of Chicago	Mathematics