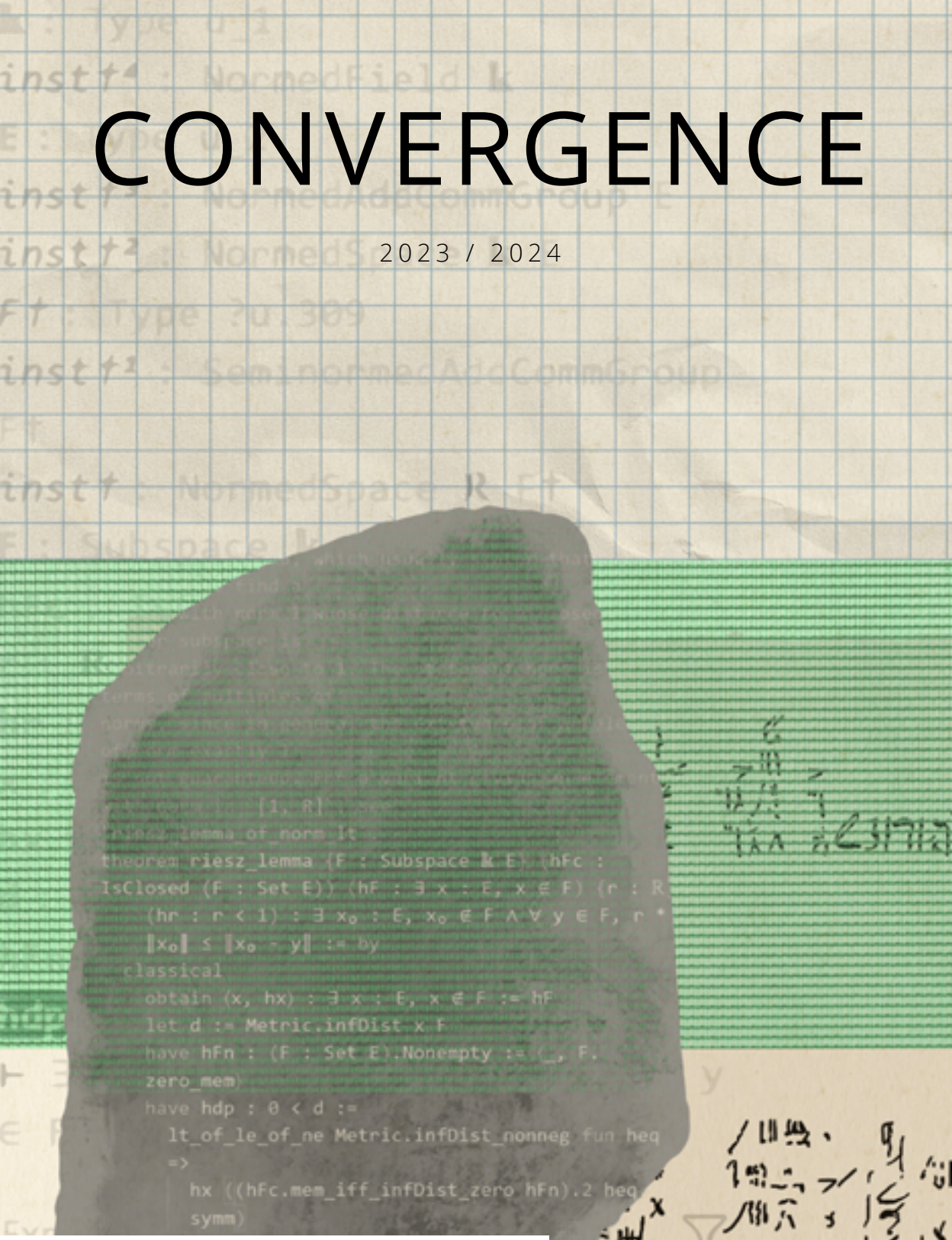
CONVERGENCE

2023 / 2024



Carnegie Mellon University
Mellon College of Science
Mathematical Sciences

CONVERGENCE

Department of Mathematical Sciences

Convergence is published yearly by the Department of Mathematical Sciences at Carnegie Mellon University for its students, alumni and friends to inform them about the department and serve as a channel of communication for our community. Readers with comments or questions are urged to send them to ptetali@andrew.cmu.edu. The department is headed by Prasad Tetali.

Editor-in-Chief
Prasad Tetali, Department Head

Editor
Jocelyn Duffy, Associate Dean for Communications

Design & Layout
Samantha Zemanek, Graphic Designer

Contributing Writers
Jeremy Avigad, Sarah Bender, Jocelyn Duffy, Tabbitha Gordon, Kirsten Heuring, Amy Pavlak Laird, Heidi Opdyke, Prasad Tetali, Emily Wertz

Photography & Images
Jonah Bayer, Digital Producer
Courtesy of Carnegie Mellon University, unless otherwise noted

Online Magazine
Gigi Wiltanger, Web Manager
Iulia Dumitriu, Web Content Administrator

Department of Mathematical Sciences
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213
www.cmu.edu/math

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Contents

Letter from the Department Head, Prasad Tetali

Dear Friends of the Department of Mathematical Sciences,

Mathematics as a field is enjoying an all-time high demand these days, popular among students seeking analytical skills as well as the employment sector, while receiving well-deserved media coverage for research advances! Industry and government labs have expressed an increased need for graduates with analytical and mathematical modeling skills, appreciating the fact that math is foundational for the success of AI, data science and machine learning. The department trains and mentors nearly 360 undergraduate students at any given time, not including the students we teach through course offerings for the wider university. On the math research front, the pace in general has accelerated. Thanks to the internet and technology assisting in the dissemination of research advances there have been an increasing number of exciting breakthroughs on long-standing open problems. The present issue of Convergence encapsulates and highlights several of these aspects, as seen through the lens of CMU's Department of Mathematical Sciences.

Our main research article features the promising and emerging topic of automated reasoning and formalized mathematics, fueled by Lean Theorem Prover and other proof assistants. The work of our colleague Jeremy Avigad and collaborators was the focus of a New York Times article in July 2023, focusing on Math and AI. Earlier this year, there were major breakthroughs in the diagonal and off-diagonal Ramsey numbers, which were both featured in the biennial Random Structures & Algorithms conference we hosted on campus. Coming full circle, a recent guest post in the Xena project describes how within six months of the breakthrough work of Campos, Griffiths, Morris and Sahasrabudhe on the diagonal Ramsey numbers, Bhavik Mehta (a Ph.D. student at Cambridge) formally verified the result in the Lean Theorem Prover.

Math faculty received top awards for their commitment to the educational mission. Bill Hrusa received the 2023 Robert E. Doherty Award for sustained contributions to excellence in education, one of the highest honors CMU bestows on its faculty. John Mackey in turn shared (with David Yaron of Chemistry) the Mellon College of Science's Richard Moore Award for sustained contributions to the educational mission of the college.

Our recent hires continue to garner national recognition. Theresa Anderson received the NSF Faculty Early Career Award, a prestigious grant given to young faculty for their exemplary role as teacher-scholars. Robin Neumayer most recently received the 2024 Sadosky Prize in Analysis, given annually by the Association for Women in Mathematics, for her outstanding contributions to calculus of variations, PDEs and geometric analysis. Other colleagues who are regularly in the news include Po-Shen Loh, whether it is about the Tartans' Putnam competition performance or as a mathematical rockstar interviewed by various news outlets on the impact of AI on the future of education; and Wes Pegden and collaborators', whose efforts are on keeping redistricting maps in check, with robust statistical tests, as state after state runs into legal challenges.

Our students receiving accolades include graduating seniors Amy Germer receiving the MCS Gilman award and Subhasish Mukherjee winning the prestigious Goldwater Scholarship. Math graduate student Wang Chi "Samson" Yeung was recognized for his dedication with the Hugh D. Young Graduate Student Teaching Award. The department continues to offer and support several undergraduate research opportunities. The articles on SEMS and SUAMI provide snapshots of several successful stories.

On the hiring front, we welcomed multiple excellent new faculty this past fall – Dylan Quintana, Matthew Rosenzweig and Johannes Wiesel, with research strengths in coding theory, PDE and math finance, respectively, along with several postdoctoral research fellows with top credentials. Also noteworthy is the recruitment of Mykhaylo (Misha) Shkolnikov as tenured full professor and Robert Simon as the new executive director of our highly visible Master of Science in Computational Finance (MSCF) program. These two appointments, together with that of Wiesel, provide much needed reinforcement to the math finance program following several recent retirements.

The classroom-to-table initiative, launched last year, has been popular among undergraduates. Several students took the opportunity to engage with some of their favorite professors, over department-paid lunch or dinner, for advice on post-graduation options and career paths.

Another initiative launched last year is to recognize graduate students in mathematical sciences for their notable contributions. Leung and Felix Weilacher shared the outstanding research prize, while Wes Caldwell received the teaching prize and Zoe Wellner the prize for diversity, outreach, and mentoring.

The department went through an external review in October 2023, the first such since 2013. The committee of six faculty from top universities spent close to two days talking to various members of the department and left with a very favorable impression of the strength of the department. The committee recommended that the department needs to hire at least five new tenure-track faculty and two or three teaching-track faculty. In turn, to accommodate and support such growth, additional space and staff have also become imperative.

If you'd like to learn more about the department, or get involved in any of our programs, please don't hesitate to reach out. We'd love to hear from you!

Faculty Notes

Simon Named Executive Director for Master of Science in Computational Finance Program

Robert S. Simon has been named the new executive director of the Master of Science in Computational Finance (MSCF) Program at Carnegie Mellon University.

Simon, who joined CMU on July 1, replaces Rick Bryant, the inaugural executive director who initiated the program in 1994. The MSCF is a joint program among the Mellon College of Science's Department of Mathematical Sciences, Dietrich College of Humanities and Social Sciences' Department of Statistics & Data Science, the Heinz College of Information Systems and Public Policy and the Tepper School of Business.

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Simon graduated from CMU in 1993 with dual degrees in information decision systems and business. He earned a Master of Business Administration from Columbia University in 1998. He most recently served as managing director at Barclays Capital Markets.

"Having worked on Wall Street for nearly 30 years, I'm excited to bring my own personal network and marry it with the current platform MSCF offers," Simon said. "I'm excited to get to be a part of innovating the curriculum in the future with coming industry changes and to help breed the culture of Wall Street both in and out of the classroom."

Simon has experience in both domestic and Asian markets in a career spanning multiple firms and asset classes. He looks forward to using his breadth of industry knowledge to benefit the program.

Program co-founders John Lehoczky and Steve Shreve are equally excited for Simon to begin his tenure.

"Bob is an absolutely ideal choice to lead the MSCF Program. He brings a wealth of experience and leadership in the financial services industry, having served as managing director at several of the most prestigious institutions in the industry," said John Lehoczky, the Thomas Lord University Professor of Statistics Emeritus. "As a graduate of CMU, he fully understands the breadth, depth and uniqueness of the MSCF curriculum."

"It is a testament to his high regard for MSCF that he has agreed to become our executive director," said Shreve, University Professor Emeritus. "Given his wealth of experience in the finance industry and his proven management skills, he is the perfect person to move MSCF forward."

■ *Emily Wertz*

Christine Gilchrist Serves Math with Stellar Support

The average workday of Carnegie Mellon University's Christine Gilchrist is anything but routine.

Gilchrist, the academic program manager for the Department of Mathematical Sciences, consistently goes above and beyond for students, faculty and staff.

"Christine is a wonderful person to have in the Department of Mathematical Sciences," said Prasad Tetali, Alexander M. Knaster Professor and Head of the Department of Mathematical Sciences. "She does a great deal for the faculty and the students. She exemplifies the famous quote 'my heart is in the work,' and does so with utmost modesty, care and kindness."

Christine has been at CMU since 2005 and has been with the Department of Mathematical Sciences since 2019. Previously, she worked at Carnegie Mellon University in Qatar and for the Mellon College of Science Dean's Office.

As the department's academic program manager, Gilchrist wears many hats, organizing social events for graduate students, proctoring exams and overseeing graduation activities.

"Christine routinely goes above and beyond to help those in the department," said Professor Bill Hrusa. He noted in particular that in 2021, at the height of the COVID-19 pandemic, Gilchrist helped him set up an online version of the Market Making Game event for Carnegie Mellon's Quant Club.

Gilchrist also provided outstanding support for the first MCS Summer Undergraduate Research Program, held in the summer of 2021. While also outside of her regular responsibilities, she helped organize the math department's component of the research program.

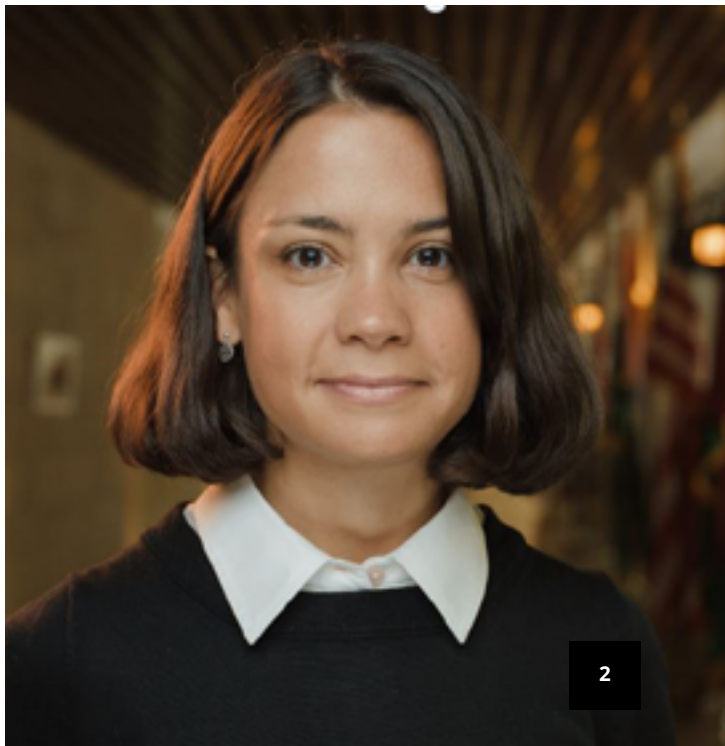
"She made me look good by simply handing me a Box folder that had everything needed to run the event," Hrusa said. "The event would not have been the success it was without Christine."

For Gilchrist, one of the most memorable recent projects she worked on was the department's 2023 External Review Self-Study Report, a document that details the work of the department from a faculty and staff perspective.

"Erin Davis and I helped to gather the materials needed and construct the 144-page document," Gilchrist said. "In the process of putting it together, I learned about the vast number of accomplishments of our faculty, students and staff. Seeing it all in one place gave me a new appreciation for the people I work with."

In 2015, Gilchrist was recognized at the Charles E. Thorpe Awards for outstanding dedication to students at CMU-Q, and in 2018 she was awarded an Outstanding Achievement Award for her exceptional work as MCS Senior Academic Coordinator. In 2023, she was nominated for an Andy Award for her commitment to excellence.

■ *Tabbitha Gordon*



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Deep Mathematics and Simple Fun

Applications to Ramsey Theory is one of the central topics in the mathematical field of random structures and algorithms.

Two major breakthroughs occurred prior to Carnegie Mellon University hosting the 21st International Conference on Random Structures & Algorithms in mid-June, allowing researchers to present the new findings in Pittsburgh.

"There's a famous anecdote of Paul Erdös who once said if aliens come to the planet Earth and say, 'We're going to destroy you unless you determine the diagonal Ramsey number R(5,5),' we should put all the world's computers and minds behind an answer," said Prasad Tetali, Alexander M. Knaster Professor and Head of the Department of Mathematical Sciences. "If they demand that we determine R(6,6), we should instead try to get rid of the aliens."

Diagonal Ramsey numbers quantify how large a graph has to be to ensure that the graph or its complement contains a group, known as a clique, of a certain size.

For example, if a mathematician wants to host a party, and they want to guarantee that there will either be a group that all know each other or a group of mutual strangers, Ramsey Theory helps them determine how large that party would have to be for these cliques to emerge. Based on the patterns that Ramsey Theory produces, if a mathematician wanted a clique of 3, they would have to host a party of 6 people. If they wanted a clique of 4, they would have to host a party of 18 people. However, researchers are unsure of the numbers of guests needed to ensure larger cliques of 5 or more.

At the conference, Julian Sahasrabuddhe, of the University of Cambridge, spoke about how he and colleagues improved the upper bound on the Ramsey number by an exponential amount, the first significant improvement in nearly 90 years.

Sam Mattheus, a postdoctoral researcher at the University of California, San Diego, also presented a breakthrough by himself and UCSD Professor Jacques Verstraete which applies constructions from finite geometry and settles a part of the Ramsey theory that had been proposed in 1947.

"We were thrilled to have talks on two exciting breakthrough results in Ramsey theory that came in the last few months," said Tom Bohman, a professor of mathematical sciences at Carnegie Mellon and a conference organizer. "The questions that these results answer were among the most important in the field of combinatorics for nearly a century. It will be interesting to see how things develop over the next few months and years as the community digests the new ideas needed to produce these breakthrough results."

The conference also featured presentations on major advances regarding phase transitions in discrete probability theory, mixing times of Markov chains and concentration of random variables defined on the random graph.

"It's always been a lively meeting with people coming in," said Joel Spencer, a mathematician and computer scientist at New York University who has attended the biennial conference since it began in 1983. "The use of probability has gotten much deeper. Originally, it was very simple probability, and now, there are a lot of deep methods, things like Brownian motion that are being used."

Between lectures on mathematical theories and findings, the participants took to Carnegie Mellon's Gesling Stadium track for the Random Run, a conference tradition.

"The Random Run is such an original idea and felt like it combined my love of running with my love of game theory," said Jacob Lehmann Duke, an undergraduate student from Williams College who won first place in the all men's category. "I run cross country and track for Williams, so I'm used to races, but I don't think I've ever run one with as enthusiastic and diverse a set of participants. I am particularly impressed with the people who ran the original Random Run in 1983 and were back toeing the line."

This was the second time that the conference was held at Carnegie Mellon. In 2015, the Department of Mathematical Sciences hosted the Random Structures & Algorithms Conference in celebration of Professor of Mathematical Sciences Alan Frieze's 70th birthday. He said he was pleased with the growth of the field.

"There's no shortage of places where this sort of analysis can be used," Frieze said. "The probabilistic method is creeping into all other areas of mathematics, and it's very powerful."

Tetali agreed, and he said he was grateful for Carnegie Mellon's support for the conference.

"The maturity and importance of this topic is reflected in the fact that at least four generations of math researchers participated in the weeklong biennial conference," Tetali said. "CMU turned out to be a perfect venue to host it."

The conference was supported by Carnegie Mellon's Department of Mathematical Sciences, the National Science Foundation and the National Security Agency. Organizers and attendees made use of infrastructure for running scientific meetings that was recently established by the Mellon College of Science.

■ *Kirsten Heuring*

An exponential improvement for diagonal Ramsey

https://arxiv.org/abs/2303.09521

The asymptotics of r(4,t)

https://arxiv.org/abs/2306.04007

Bill Hrusa Wins 2023 Robert E. Doherty Award

Carnegie Mellon University Professor of Mathematical Sciences Bill Hrusa is as much a magician as he is a mathematician.

"Bill is the magician hidden behind the curtain that makes everything happen so that students can explore their full potential," said Carnegie Mellon University alumna and University of Toronto Assistant Professor Xiaofei Shi, who wrote one of the many letters of support that led to Hrusa being awarded the 2023 Robert E. Doherty Award for Sustained Contributions to Excellence in Education.

Hrusa joined Carnegie Mellon as an assistant professor in 1982 and has been at the Pittsburgh campus save for three semesters in the 1980s when he was a visiting faculty member at the Math Research Center of the University of Wisconsin-Madison.

"Bill cares deeply about our students' learning and the educational enterprise at large," wrote Amy Burkert, vice provost for education. "He has had a tangible positive impact on the education of thousands of undergraduate and graduate students. He has also shaped and reshaped curricular practices and transformative educational programs."

Hrusa has served in administrative positions in the Department of Mathematical Sciences including as interim head, associate head and director of graduate studies. He currently directs the Bachelor of Science in Computational Finance (BSCF) program.

Martin Larsson, a professor of mathematical sciences and a member of the steering committee for the Master of Science in Computational Finance (MSCF) program, wrote that the BCSF program has flourished under Hrusa's guidance. Along with directing the BSCF program, Hrusa is the academic advisor for Carnegie Mellon's Quant Club and helps organize events such as quantitative problem-solving competitions, mock interviews and panel discussions with alumni and industry figures.

"There is now a vibrant and diverse community of students with a broad interest in computational finance," Larsson said. "Bill's efforts have also propelled the program's external reputation to ever greater heights."

The Doherty Award is Hrusa's latest accolade for teaching. He previously won the university's William H. and Frances S. Ryan Award for Meritorious Teaching and Barbara Lazarus Award as well as the Mellon College of Science's Julius Ashkin Award and the Richard Moore Award.

"I am grateful to have a job that I really love for more than 40 years where I have had the opportunity to interact with wonderful students and colleagues," Hrusa said.

Hrusa holds bachelor's of science degrees in mathematics and mechanical engineering from Syracuse University. He went on to earn a master's degree and Ph.D. in applied mathematics from Brown University.

■ *Heidi Opdyke*

John Mackey Honored with Richard Moore Award

Mathematical Sciences Teaching Professor John Mackey has been honored as a co-winner of the Mellon College of Science's 2023 Richard Moore Award.

This award is bestowed upon MCS faculty members making substantial and sustained contributions to the educational mission of the college.

"It is the opinion of many faculty in the department that John Mackey is a major reason for the tremendous improvements in our undergraduate program," said Prasad Tetali, Alexander M. Knaster Professor and Head of the Department of Mathematical Sciences.

Mackey joined Carnegie Mellon in 2003. He was promoted to associate teaching professor in 2006, became director of undergraduate studies in 2007 and a teaching professor in 2011. He won MCS' Julius Ashkin Teaching Award in 2007 and Carnegie Mellon's William H. and Frances S. Ryan Award for Meritorious Teaching in 2013. Since 2016, Mackey has held a joint appointment in the School of Computer Science.

"John's classroom teaching is legendary," said Bill Hrusa, professor of mathematical sciences. "However, his contributions to the educational mission of MCS go far beyond teaching."

Outside of the classroom, Mackey created the Carnegie Mellon University Math Club in 2004 and served as its advisor until 2015. The group hosts weekly speakers, a mentoring program and events.

Mackey served as the Carnegie Mellon coach for the annual William Lowell Putnam Competition, the premier mathematics competition for undergraduate students in North America. That effort was enhanced when Po-Shen Loh joined Carnegie Mellon and together they created the Knaster-McWilliams Scholars program as well as brought the Putnam activities to a peak. Carnegie Mellon took its first first-place finish in the 2016 Putnam Competition and consistently has a high number of students among the top competitors.

A member of the Department of Mathematical Sciences Undergraduate Curriculum Committee since its inception, Mackey has served on many committees at the department, college and university levels. His latest service is as a faculty representative for the Richard King Mellon Hall of Sciences, an ambitious new building project at Carnegie Mellon's Pittsburgh campus.

Mackey earned his Ph.D. in mathematics from the University of Hawaii at Manoa in 1994. Prior to joining Carnegie Mellon, he spent four years teaching at Dartmouth College and three years as a math preceptor at Harvard University.

■ *Heidi Opdyke*

Mathematician Theresa Anderson Receives NSF CAREER Award

Carnegie Mellon University mathematician Theresa Anderson has received a Faculty Early Career Award (CAREER) from the National Science Foundation. One of the most prestigious awards for young faculty, CAREER awards recognize and support those who exemplify the role of teacher-scholars through their outstanding research and teaching.

Anderson, an assistant professor of mathematical sciences, received the five-year grant to build bridges between number theory and harmonic analysis, two areas of mathematics often viewed as separate. Number theory, which deals with properties of whole numbers, such as quickly factoring large numbers into primes, underpins computer security and analysis of the behavior of black holes. Harmonic analysis, which takes a complicated function and breaks it up into simple pieces, is central to medical imaging and quantum states. Anderson's goal is to create new connections between these seemingly disconnected areas.

"In my work, I tend to connect areas of mathematics, pulling techniques from a variety of fields to go out of my comfort zone and explore new things," Anderson said.

Under the grant, Anderson will explore areas broadly in analysis or number theory. First, she is working to develop the infrastructure to travel between number theory and analysis in order to analyze discrete sets that encode curved surfaces. She also plans to explore hidden number theoretic properties in the building blocks of harmonic analysis. And, as a third bridge across the two fields, Anderson will be integrating Fourier analysis to better predict the behavior of a random object of algebraic interest.

The award will support Anderson's teaching and mentoring. She is creating a class on a topic involving analysis and number theory, where she will develop the needed number theory along the way. According to Anderson, this approach makes it accessible to more students and motivates by example, not by drowning them in technical machinery. The grant will enable Anderson to continue to involve undergraduates in research, including during the semester and at Carnegie Mellon's Summer Undergraduate Applied Mathematics Institute (SUAMI), an eight-week summer research program for undergraduate students.

"My goal is to teach a hands-on, example-motivated, non-traditional approach to be able to do real, significant research in a short period of time," Anderson said. "The approach of introducing new perspectives, bridging non-traditional areas and approaching problems from different angles permeates the whole NSF proposal."

■ *Amy Pavlak Laird*

New Faculty

Dylan Quintana

cmu.is/dylan-quintana

Matthew Rosenzweig

cmu.is/matthew-rosenzweig

Mykhaylo Shkolnikov

cmu.is/mykhaylo-shkolnikov

Johannes Wiesel

cmu.is/johannes-wiesel

Student Stories

AWARDS & FELLOWSHIPS

GILMAN AWARD

Amy Germer

cmu.is/AmyGermer

GOLDWATER SCHOLARSHIP

Subhasish Mukherjee

cmu.is/mukherjee-goldwater

YOUNG GRADUATE TEACHING AWARD

Samson Leung

cmu.is/samson-leung

Aristotelis Panagiotopoulos Explores Infinite Ideas

Aristotelis Panagiotopoulos' research is in mathematical logic and topological dynamics. He is interested in the foundations of mathematics and the complexities which arise in any attempt to formalize infinity.

"Ask a young child what the largest number is and then respond to their number by adding one. Their impish grin reveals that you share a universal human concept — that of infinity in its potential," said Panagiotopoulos, a postdoctoral associate in Carnegie Mellon University's Department of Mathematical Sciences. "Even though we never encounter anything infinite in the physical world, we still share a universal innate notion of infinity. I always found this fascinating. Perhaps this is what lead me into mathematics. Mathematics allows us to formalize infinity and do various things with it."

Panagiotopoulos came to Carnegie Mellon because of its long tradition in logic, set theory and combinatorics.

"At CMU there is a very strong group in logic," he said. "It's one of the best in the world. I wanted to be part of this, spend time here and work with the people here. The level of the undergraduate students at CMU is also very high and you can engage in research with them."

At Carnegie Mellon, Panagiotopoulos taught courses such as algebraic topology, calculus II and dynamics of Polish groups. Panagiotopoulos will join the University of Vienna as an assistant professor beginning in January 2024, but he will stay connected to Carnegie Mellon through a National Science Foundation grant. The NSF award will support his research related to dynamics beyond turbulence and obstructions to classification until 2025.

"One thing I find fascinating about logic is that it provides a framework for identifying incompleteness phenomena, and establishing which mathematical problems are too complex to be solvable within the context in which they were first conceived." he said. For example, a person given a straightedge and a compass will find it impossible to trisect an arbitrary angle with just those tools.

Panagiotopoulos' interests in research extend beyond the field of mathematics and into other fields such as physics, where he recently published a paper in Physical Review Letters with collaborators from the University of Pittsburgh and the University of Vienna's Institute for Quantum Optics and Quantum Information. This paper is about incompleteness theorems for observables in general relativity.

Panagiotopoulos worked as a postdoctoral researcher at the University of Münster in Germany and as a research instructor at the California Institute of Technology. He earned his doctorate in mathematics from the University of Illinois at Urbana-Champaign.

■ *Heidi Opdyke*

Postdoctoral Fellow Elisa Bellah Offers New Lessons

Elisa Bellah's interest in math started in an undergraduate math class. Now as a postdoctoral associate in Carnegie Mellon University's Department of Mathematical Sciences, she wants to spark the same passion for math in others.

"Specific courses and specific professors got me really excited about math," Bellah said. "I had always sort of enjoyed math, and it was something that felt natural to me, but I didn't really know what it meant to be a mathematician. Those few years in undergrad were really transformational for me."

Bellah started as a teaching assistant and a tutor while working on her undergraduate degree at Portland State University. She attended the University of Oregon for her doctorate and taught one class each quarter. She said the experience made her interested in pursuing teaching as a career.

"I really loved my research in grad school, but I found it hard not to be drawn toward teaching and mentoring," Bellah said. "As I was thinking of what I wanted to do after grad school, I really wanted to find a position that valued what I found most meaningful."

Bellah joined Carnegie Mellon's Department of Mathematical Sciences as a postdoctoral teaching fellow in 2022, the first year the fellowship was offered. Prasad Tetali, Alexander M. Knaster professor and head of the Department of Mathematical Sciences, said that the idea behind the fellowship was to help increase the number of effective math instructors who can also engage with undergraduates in research.

"The idea is to recruit and train postdoctoral fellows whose career path might be that of a teaching track faculty in a research university or a tenure track faculty in a 4-year college," Tetali said. "We also hope this provides another vehicle to help with our diversity efforts."

Bellah has taught multiple courses, including differential and integral calculus, matrices and linear transformations and number theory. Though she enjoys all the courses she has taught, she particularly enjoys number theory because it is her research area.

"It's been a lot of fun. The students are so excited about the material," Bellah said. "They engage a lot in the lecture. They ask great questions. Many of them stay after class just to chat about related topics, which has been a fun experience."

Bellah also has helped with summer programs at Carnegie Mellon. In 2023, she worked with students in the Summer Undergraduate Applied Mathematics Institute (SUAMI) and in the Summer Undergraduate Research Fellowships (SURF) program, which allow undergraduate students to gain research experience. She has also taught summer classes for the Summer Academy for Math and Science (SAMS), a program that allows high school students to take college-level summer courses, where she taught a class focused on number theory and cryptography.

"The summer students have this experience like, 'I didn't know this is what math was. I didn't know math was solving puzzles and making arguments,'" Bellah said. "They come here because they want to learn. They're so excited and motivated."

Bellah said the experiences she has had at Carnegie Mellon will help her find a permanent professorship where she can work with undergraduate students.

Tetali said that there are plans to expand the fellowship in the future, and Bellah has done an excellent job as the inaugural recipient.

"Elisa truly lived up to all the expectations she had set and even exceeded on some grounds," Tetali said. "The teaching duties we had assigned to her during her first year were tough, but Elisa weathered those and other challenges in her first year with much determination and poise."

■ *Kirsten Heuring*

The Department of Mathematical Sciences is accepting applications for a two-or three-year Postdoctoral Teaching Fellow beginning August 2024.

Visit the following link for more information:

https://www.cmu.edu/math/careers.html

Research Roundup

Tartans Place Among the Top 10 in Putnam Math Competition

Carnegie Mellon University had the second most students among the top 500 competitors and the CMU team placed in the top 10 of the Mathematical Association of America's 83rd William Lowell Putnam Competition, the premier mathematics competition for undergraduate students in North America.

The team comprised Adam Bertelli, now a senior in mathematical sciences; and computer science graduates Howard Halim and Brad Zhang. Zhang placed in the top 100 individual competitors and received an honorable mention. In addition, 231 students took the six-hour test individually.

"No matter how well a student performs in the competition, the experience of engaging intensely with challenging problems develops the student's mathematical power and creativity," said Daniel Ullman, the competition director.

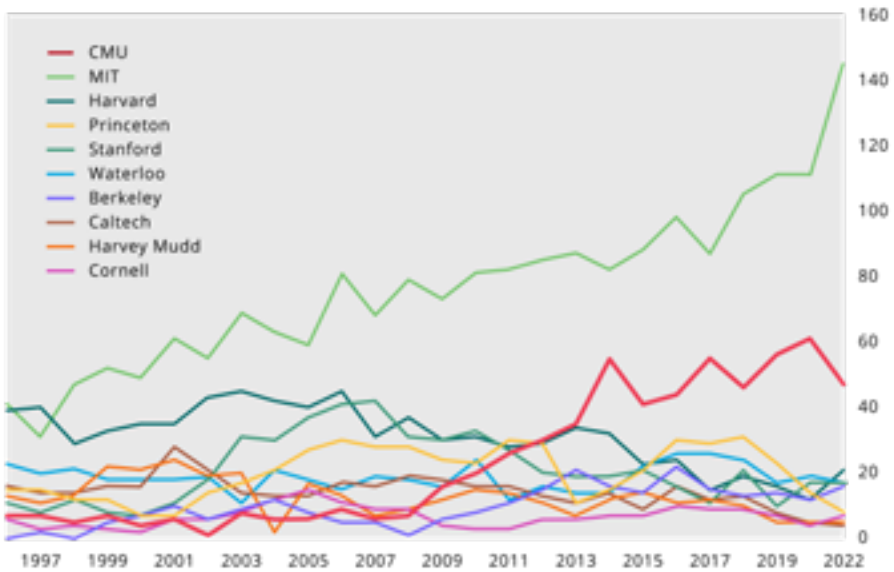
This is the 10th year in a row that Carnegie Mellon has had the second highest number of students (47) in the approximate top 500 of any university, demonstrating the excellence in mathematics among Carnegie Mellon undergraduates across the university's colleges and schools. Overall, more than 3,400 students from 456 institutions participated in the competitive competition on Dec. 3, 2022.

"Having so many students in the top 500 competitors shows how deep the math talent is at Carnegie Mellon," said Po-Shen Loh, professor of mathematical sciences and the team's coach.

Loh offers weekly seminars prior to the Putnam exam where students collaborate to develop sophisticated problem-solving techniques and inspire discussions about more advanced mathematics.

"We seek to develop a collaborative team spirit among sharp and motivated students," Loh said. "Students who take the Putnam exam are among the most creative analytical thinkers at Carnegie Mellon. Taking the time to support each other and learn together has made all of the students stronger problem solvers in their different disciplines."

■ *Heidi Opdyke*



SEMS Offers Research Experiences

As David Staudinger filled out college applications, Carnegie Mellon University's Summer Experiences in Mathematical Sciences (SEMS) program caught his eye.

"When I was researching schools, I saw that SEMS was offered, so I was aware it was an opportunity coming into my freshman year," said Staudinger, a sophomore in mathematical sciences.

Staudinger was one of 12 students who participated in 2023's SEMS. The program was proposed in 2020 by Professor of Mathematical Sciences Tom Bohman when many of the summer research and internship opportunities undergraduate students usually enjoyed were canceled because of the COVID-19 pandemic. Participants choose one of four topics to research while working in small groups under the guidance of professors and postdoctoral fellows.

Irina Gheorghiciuc, associate teaching professor and director of undergraduate research in the Department of Mathematical Sciences, said that programs like SEMS are valuable for students and advisors alike.

"SEMS is intended to be the first research experience for the students," Gheorghiciuc said. "Students can participate in this program before they are ready for internships or REUs [Research Experiences for Undergraduates]. The program helps to prepare students for serious research in mathematics. Many of their advisors are young faculty for whom this is a great opportunity to learn how to mentor students."

One of these advisors was Amzi Jeffs, postdoctoral associate in mathematical sciences. Staudinger participated in Jeffs' project: realizations and obstructions for convex codes.

"Research experiences I had when I was an undergraduate studying at Harvey Mudd College got me interested in mentoring," Jeffs said. "I got started in research working on a very similar project to what we've done here."

Jeffs' team used discrete mathematics and combinatorics to study which Venn diagram-like patterns can be cut out with convex sets. Staudinger, sophomore Henry Siegel and senior Yiqing Wang showed that a certain code can be drawn with closed sets in three-dimensional space, but using open sets requires at least four dimensions. They demonstrated how their code worked by creating a visual model with cardboard, glue and pipe cleaners.

"The topic is very accessible for undergrads, and they can really make a contribution," Jeffs said. "The code is simple, but it's demonstrating behavior that people have never found for codes like that before."

Staudinger said he had never conducted math research in this area, which was part of the appeal.

"It was a fun project to work on because there was a lot of visualization," Staudinger said. "I was exposed to the research process and was able to contribute to something."

■ *Kirsten Heuring*

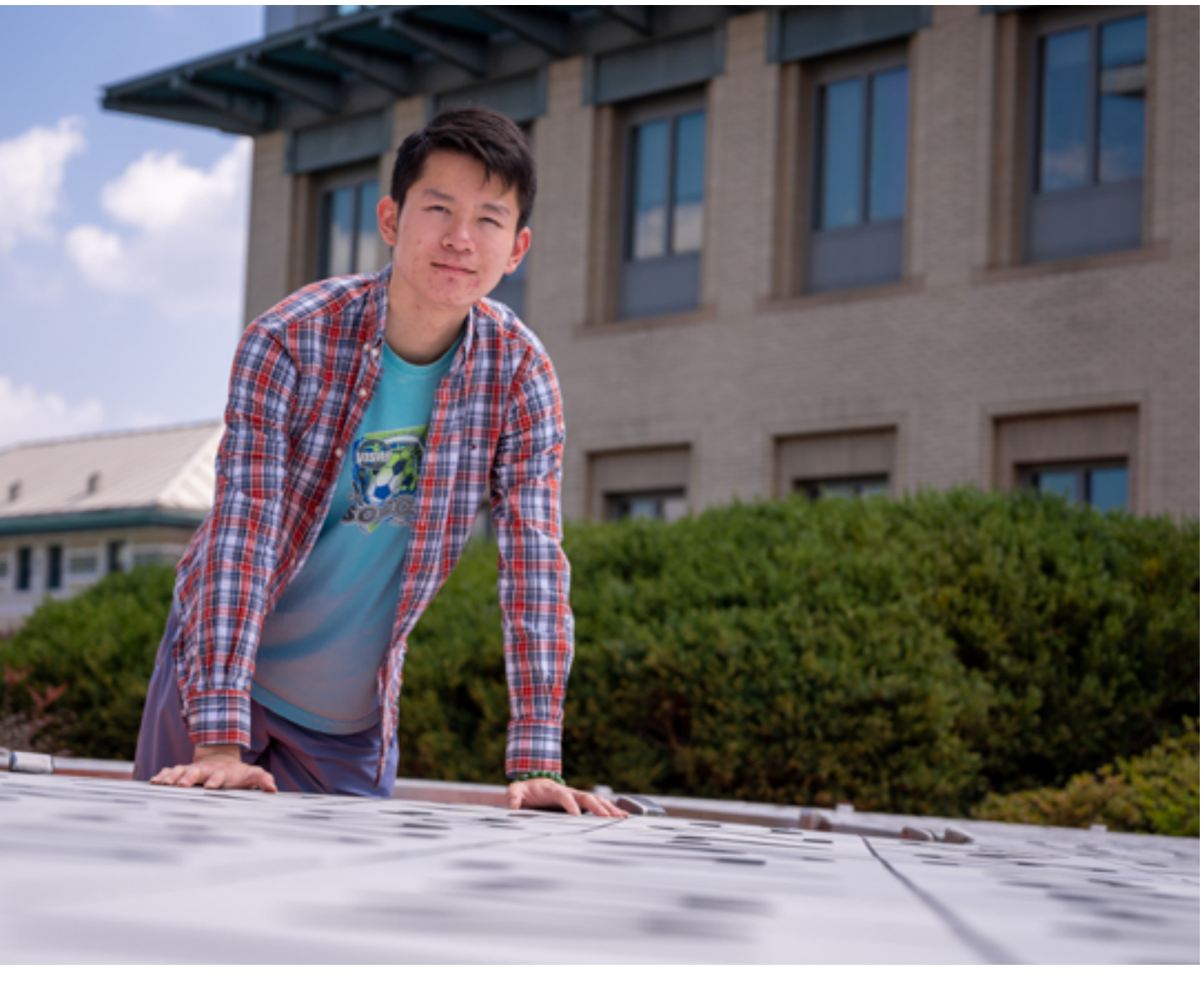
Student-Built AI Tool Licensed for Workforce Development

If the headlines are to be believed, artificial intelligence (AI) is about to make everyone's jobs obsolete. Nur Naqvi at the American Institute of AI isn't buying it.

"It's important to realize that AI's going to be used in your job, not necessarily replace your job," said Naqvi, the chief product officer at the Washington D.C.-based software company, which also runs an institute that teaches professionals about AI. "So it's going to be important for people to understand AI, not be afraid of it."

Now, thanks to an AI toolbox developed by Carnegie Mellon student Tom Tang, Naqvi can easily show professionals how AI can be used to help them in their current jobs.

Tang, a sophomore majoring in mathematical sciences, created the AI toolbox for his Fundamentals of Programming and Computer Science Class's term project. The American Institute of AI has licensed the software.



"It was really surprising that this was happening in, like, freshman year in college," Tang said.

Tang became interested in AI in high school. He taught himself AI basics watching videos online and reading books he borrowed from the library. During his junior year, he published a paper on applying AI techniques on ATLAS experiment data from CERN's Large Hadron Collider to identify the Higgs boson.

When it came time to choose a topic for his first-year programming class's term project, it was a no-brainer.

> "I really wanted to make something that was impressive to myself," Tang said. "So I made an AI toolbox. It integrates everything I know about AI, including artificial neural networks and linear and logistic regression."
>
> Tang's toolbox incorporates these core machine learning algorithms, which teach computers to process data in a way that is inspired by the human brain. He packaged the algorithms in a simple, user-friendly interface that makes it easy for a user to upload and analyze their data. The algorithms generate a visual representation of the data, predicting any trends and informing any decisions the user may need to make based on that data. It's also designed to withstand human handling errors.

"It's a very, very impressive project," said Michael Taylor, assistant teaching professor in the Computer Science Department, who teaches Fundamentals of Programming and Computer Science. "For Tom, who's new to a lot of these topics, to dive in and figure out how all this stuff works and then how to package it in a way that's genuinely useful to folks in the broader world is extraordinary."

Tang's project was one of 10 selected by his professors for the end-of-semester showcase, and his classmates voted it one of the best projects of the semester. In a twist of fate, Tang's classmate, Marya Naqvi, showed the end-of-semester showcase video to her brother, Nur.

"I saw Tom's project for maybe 10 seconds, and I thought, that's very interesting," Naqvi said.

"It's finally an easy way to do hands-on AI education that's not too complex for the majority of people," he added. "So now you can have professionals who don't necessarily have the math or computer science background but who can understand these concepts and then also apply them on actual data and see the actual results."

Tang signed a licensing agreement for his AI toolbox, giving the American Institute of AI non-exclusive rights.

"Tom showed a lot of maturity and thought during the entire process," Taylor said. "Having been in the entrepreneurship space myself, I'm well aware of the fact that there are countless pitfalls and some of them are really, really sneaky."

After doing his due diligence, with a bit of guidance from Taylor, Tang sold the toolbox to the American Institute of AI. He sent Naqvi his code, did a code review with him and taught him how to handle the interface. Naqvi has already been using it in his classes.

"Showing how these algorithms can be used by the students, in their own job, in their own capacity is extremely beneficial," Naqvi said. "We use Tom's own examples because he included all this sample data and sample analysis."

Tang, who is from Beijing, spent his summer in Pittsburgh updating the AI toolbox, training a small ChatGPT, and collaborating on a paper on quantum computing with fellow CMU students. He plans to continue pursuing his major in mathematical sciences but is looking to add a second major, possibly in computer science with a concentration in AI.

"Tom has already done great things, and I'm really excited to see what he comes up with next," Naqvi said.

■ *Amy Pavlak Laird*

Research Feature

The Formalization of Mathematics

For centuries, mathematicians and philosophers have been fascinated by the power of symbolic languages. Around the turn of the 18th century, the frenetic polymath Gottfried Leibniz envisioned a kind of general algebra in which all truths of reason would be reduced to a kind of calculus. At the same time, this would be a kind of universal language or writing, though much more precise than the ordinary languages we speak; in such a system, characters and the words themselves would direct the mind, and the errors — excepting those of fact — would only be calculation mistakes.

At the turn of the 20th century, mathematical logic made good on that promise, providing us with formal axiomatic systems that are grounded on precisely specified languages and rules of inference. Experience has shown that, in principle, mathematical arguments can be expressed in these terms. Over the last few decades, computational proof assistants have made it possible to formalize mathematics in practice. We can now write mathematical definitions, theorems and proofs in formal languages, like programming languages, that can be processed and checked by computer.

Although many mathematicians take axiomatic set theory to be the official foundation of mathematics, as far as formalization is concerned, it is useful to use a version of type theory, in which every object is viewed as an object of some type. For example, natural numbers, functions from the real numbers to the real numbers and commutative rings are represented as fundamentally different kinds of objects.

Over the last few years, a growing number of mathematicians have adopted a computerized proof assistant called *Lean* as a powerful platform for formalization. The Lean project was launched by Leonardo de Moura in 2013. My students, my postdocs and I have been working with the project since its inception, contributing formal libraries, documentation, code, infrastructure and community support. In 2021, cryptocurrency entrepreneur Charles Hoskinson endowed the Hoskinson Center for Formal Mathematics, allowing us to expand our efforts considerably. Carnegie Mellon's vibrant community of mathematicians, computer scientists and logicians makes this an especially exciting place to develop and explore the new technology.

Grassroots communities are now contributing to the development of online libraries of digitized mathematics. The Lean community maintains a social media channel where people can hang out, ask questions and collaborate, and hundreds of messages are posted there every day. There have been conferences, workshops, and summer schools. An important landmark was the completion, in 2022, of the Liquid Tensor Experiment, the verification of foundational results in geometry by Fields medalist Peter Scholze and his co-author Dustin Clausen. The project was carried out by a team of collaborators led by Johan Commelin, now at Utrecht University, with substantial contributions from Adam Topaz of the University of Alberta. Last July, research at Carnegie Mellon featured prominently in an article on formalization, automated reasoning and machine learning in the New York Times, titled "A.I. is Coming for Mathematics, Too."

Formalization is used to verify the correctness of mathematical results, but it also supports new forms of communication, collaboration, and search. It is a promising tool for teaching mathematics, since it provides students with immediate feedback as to whether their reasoning steps are correct. It also opens the door to using new technologies for mathematical discovery, including machine learning and symbolic AI. For practitioners, however, the appeal stems not only from these applications, but also from the fact that formalization provides new perspectives and a deeper understanding of mathematics itself. For example, most of us are aware of the fact that modern mathematics is based on a rich network of abstract structures, such as algebraic structures, function spaces, manifolds, and categories. But formalization often encourages us to make finer distinctions than mathematicians normally do and track additional information. Building a formal library thus enables us to explore the landscape of mathematical concepts in fine detail.

■ *Jeremy Avigad*

Alumni News

Susan Campbell and Scott Byer Reflect on Careers, Community

At work, home, and among friends, Carnegie Mellon University alumni Susan Campbell and Scott Byer believe in creating a sense of community.

"As we reflect on our experience at Carnegie Mellon, what we remember is the people who we were in community with, and we have maintained that," Campbell said.

Campbell and Byer both graduated from the Department of Mathematical Sciences with degrees in applied math with a computer science specialty in 1988. Campbell grew up in New Jersey, while Byer is from Silicon Valley.

"Carnegie resonated the best with me," Campbell said. "I liked that it was a broad curriculum. I've always found that having a variety of people to interact with is intellectually stimulating, it leads to better results, and I feel more connected to my communities that way."

Byer grew up on the Stanford University campus where his father was an applied physics professor.

"I was looking for a smaller school away from home. I was very familiar with the large campus life," he said.

Both went on to have fulfilling careers as software engineers/architects.

Campbell spent more than 30 years at HP/HPE (Hewlett Packard Enterprise). She loved coaching people, working with customers and partners and delivering software solutions. Her last role with HPE was as a master technologist within the Hybrid Cloud Software & Services and Software/CTO organizations. She intentionally worked in different business organizations and roles, learning from each job and refining what she did and did not enjoy. It's a lesson she said she hopes other learn from.

"Because of the size of HP/HPE, I was able to have many different roles and responsibilities and work on different technologies within the company," she said. "Find your authentic self. Try new things. You aren't going to know if you like it or not unless you try. Take calculated risks, don't just stay with the comfortable.".

When looking for promotions or new opportunities, Campbell said to know what your values are and to be flexible in the experiences you pursue.

"Don't be so wedded to the thing that seemed like a great opportunity if it isn't right for you," she said. "Put in a year or two, gain the experience and then move on to something more aligned to your interests."

While at Carnegie Mellon and getting her master's degree in computer science at Stanford University, she said schoolwork was contained to quarters or semesters and there was time for breaks and relaxing.

"Industry is not that way. It's constant pressure, and unless you find a way to build in breaks, you're going to have trouble," she said. For her, she would meet with friends at the gym and in more recent years, she volunteers with the nonprofit Learning Ally to read textbooks and technical manuals for accessibility. She kept her vacations work free as much as possible. "I wasn't always the best at building in breaks. You have to figure out a balance for yourself."

The industry has gone through a lot of change, but many things have stayed the same. Byer spent his career at Adobe and Google. Through his roles at Google in projects such as Fuchsia on smart displays, Android Things and operating software, he interviewed more than 250 candidates. As someone who studied math in college, Byer said that foundation they received at Carnegie Mellon is more important than people realize.

"I've seen a lot of people come through some computer science programs that didn't have any math at all, and that makes it hard to solve a lot of common problems you have to solve," he said. Another important aspect of applying for a job is communicating to the interviewer what your skills are, Byer added.

"Some of the hardest interviews are the ones where you think they have the right skills, but they didn't practice interviewing enough and have too many nerves," he said.

Like Campbell, balancing work and life isn't always the easiest for Byer. But, he found a biking group that would meet before work once a week and also played volleyball. He also volunteered at workshops to repair bicycles.

"I slowly found groups at work that would do things to help break up the day," he said. "I built barriers to avoid going too intensely."

Carnegie Mellon has never been far from Campbell and Byer's lives. They have stayed in touch with friends from Carnegie Mellon through the years via various events and Zoom calls, and engage with others via Alumni Association activities.

"It was a rigorous academic curriculum," Campbell said. "By surviving that, we were forged through fire together."

For Campbell, those strong bonds started with events such as a day-after Thanksgiving celebration for friends who couldn't make it home for the holiday. Campbell and friends were renting a home on Beeler Street at the time.

"A bunch of us either couldn't afford to — or just logistically — didn't end up going home," Campbell said. "It ended up being on Friday because I could go out on Thursday and get the shopping done and bake the pies."

Campbell carried the day-after Thanksgiving tradition with her when she moved to California for work. Byer recalls going to some of those parties even before they were a couple. The two have been together since 1992, and the parties changed over time.

"It was based on who was in the area at the time, any stray person who didn't have somewhere to go could come," she said. She would serve a traditional meal of turkey, mashed potatoes and stuffing as well as try to integrate family traditions of guests.

The events took a pause during the COVID-19 pandemic, but Campbell and Byer stayed in touch with friends via Zoom. During the pandemic they reconnected with friends from Alpha Phi Omega, a national service fraternity they both participated in during college.

Now that they are not working full-time, they're working to keep their networks close and building new ones. They have local friends and family, keep up with remote folks via Zoom, and are meeting new people through wine classes at their local community college.

■ *Heidi Opdyke*

Duane Palyka, Oral History Highlights

In 1967, Duane Palyka asked a computer to make art. By using punch cards, he fed it instructions to print a series of overlaid text characters–X's, Z's, N's–to create patterns. The result fell somewhere between minimalism and op art–swirls of light and dark geometric shapes. Each iteration of his computer program generated a different image. This was Palyka's attempt to replicate the inner workings of his subconscious. He wanted to create images that he could not predict.

However, Palyka's path to freely creating cutting-edge, computer-generated art was not without obstacles. The head of the Carnegie Mellon University computation center frowned upon using precious computer time for the creation of art. He called the undertaking "not normal," and halted Palyka's work. Luckily, CMU professor Herb Simon stepped in and offered support to Palyka through mentoring and a stipend to further his research. In 1968, Palyka's computer-generated art was exhibited alongside other pioneering computer-based artists like Nam June Paik and Alison Knowles in the Cybernetic Serendipity exhibition at the Institute of Contemporary Arts in London, England.

In his oral history interview, Palyka, who graduated with bachelor's degrees in mathematical sciences and painting and sculpture in 1968, expands upon his computer art experiments and discusses his early artwork, his aversion to working in steel mills, and the challenges of studying both math and art at CMU.

The Carnegie Mellon University Oral History Program records the real-life memories and perspectives of those who experienced the history of CMU. These interviews do not just inform listeners of the events' histories — they tell the story of how the events were experienced. The CMU Libraries preserve the interviews in the University Archives for current and future generations. The Libraries share these histories through podcasts, live events and educational and public programming.

■ *Sarah Bender*

Watch the interview at:

https://youtu.be/iYqvJDUhyUo

SUAMI

Program Offers Students, Mentors Connections

When Carnegie Mellon University's Mathematical Sciences Department hosts the Summer Undergraduate Applied Mathematics Institute (SUAMI), not just undergraduate students spend the summer in Pittsburgh conducting research. Visiting professors come too.

Ryan Moruzzi Jr., assistant professor at the California State University, East Bay, served as one of several summer mentors and project leaders for SUAMI. He spent eight weeks helping students work on problems analyzing the zero-forcing numbers of different families of graphs.

"The students took ownership of their work and looked into a lot of options," Moruzzi said.

David Offner, associate teaching professor, directs the SUAMI program. For more than 30 years, the Department of Mathematical Sciences has provided students with strong academic records — regardless of background — the opportunity to work on projects related to applied mathematics under the direction of research faculty or postdoctoral researchers.

"We have an incredibly strong and hard-working group of mentors and students engaged in cutting-edge research," Offner said.

Along with Moruzzi's group, other mentors included Assistant Professor Theresa Anderson and Elisa Bellah, a postdoctoral teaching fellow, who resolved open questions about doubling measures in the field of analysis. A group mentored by College of Engineering assistant professors Rachel Kurchin and Jerry Wang assessed the robustness of algorithms for Bayesian parameter estimation. And the group mentored by Juergen Kritschgau, a postdoctoral researcher in math, proved new theorems in anti-Ramsey theory.

Wohua Zhou, now a senior, who — like Moruzzi — is from California State University, East Bay, worked with Kritschgau.

"Working with Juergen on anti-Ramsey theory problems made me realize I want to try different things with Ramsey theory," Zhou said. "This was my first time being away from home and conducting research. It was pretty amazing."

Moruzzi said that as an undergraduate at California State Polytechnic University, he thought his only path with a bachelor's degree in math would be to teach high school.

"I was involved in a high school classroom at that point and when I moved to Michigan for my master's program, I was able to teach in the college classroom," he said. "Pretty early on in graduate school I had felt as though I wanted to be involved with students both in the classroom and teaching and being able to provide students with research experiences." He completed his doctorate at University of California, Riverside and a postdoctoral teaching position at Ithaca College in New York. Moruzzi and his four SUAMI students will stay in contact as they work on writing up some of their results for publication and the students figure out what comes next.

"It's not just about the research experience but also about connecting with students differently than in the classroom. I viewed that time as valuable for helping to shape their perceptions on what they're able to do with mathematics," he said. "It's not just about going and being a teacher. It's opening conversations about graduate school and other careers."

SUAMI alumni have gone on to become leaders in the financial industry, education advocates in government, professors and more.

Anna Rittenhouse, a rising senior from Clark Atlanta University, worked with Offner, Kurchin and Wang.

"I was applying to REUs to get a taste of the graduate student experience, and it seemed

like SUAMI was the most well rounded," she said.

Along with research, the students participate in the Mellon College of Science's Summer Scholars Program (SSP), which provides social and professional learning and development opportunities for students in several undergraduate research programs.

SSP participants went white water rafting, visited the Kennywood amusement park, rock climbed, toured the Carnegie Museums and caught a Pirates baseball game. They also participated in faculty mentor dinners.

"Part of the mentoring process is getting to know the students and share different experiences of life beyond the research," Moruzzi said. As part of their SUAMI experience, Moruzzi set aside time to check in with each student individually. "It created even more of a collaboration feel. We're doing this as a group. It's not just an opportunity to mentor students but to create a collective where they also had agency and ownership of the research project."

Michael Young, the Mellon College of Science associate dean for diversity, equity and inclusion and an alumnus of CMU, invited Moruzzi to Carnegie Mellon for the summer for SUAMI.

"We typically have a faculty mentor for SUAMI who is from another institution," Young said. "It provides them with an opportunity to work on campus, meet our faculty and other students and offer opportunities for their home institution."

Not only did Moruzzi help students work on problems, he also read applications and worked behind the scenes to recruit students and learn about the process of setting up a summer research experience.

"As I went through graduate school I saw how important it is for students to get experience as an undergraduate," Moruzzi said.

"As an undergrad it wasn't on my radar to do a program like this," he said. "As I went through graduate school I saw how important it is for students to get experience as an undergraduate. It helps students realize if they want to try new research or if this is a path that is not quite one that they want to go down."

Young participated in SUAMI as an undergraduate at the University of Florida. He said that SUAMI continues to be a recruiting tool not just for students. Faculty are often considered for programs such as the Shelley Distinguished Professorship, which is an opportunity for experienced mathematics professors to teach at CMU for an academic year.

■ *Heidi Opdyke*

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