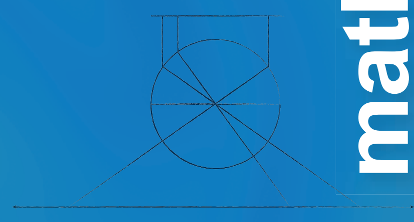
mathematical sciences news 2016



Carnegie Mellon University

contents

2016

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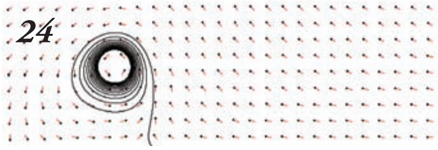
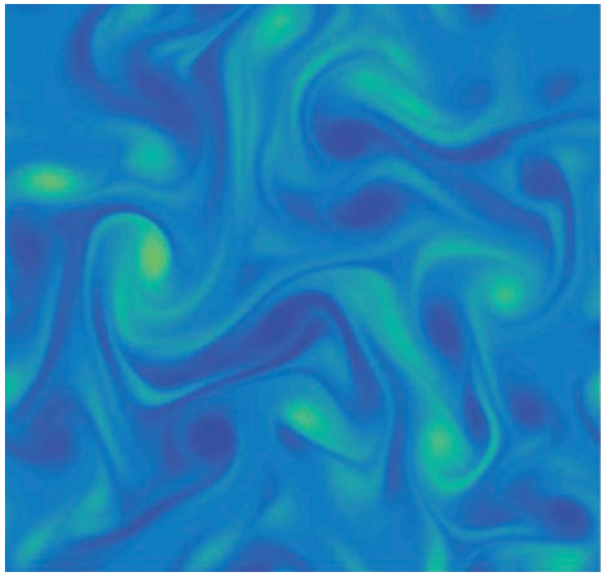
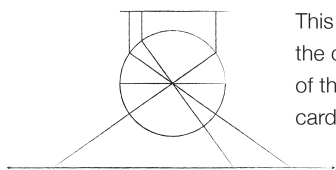




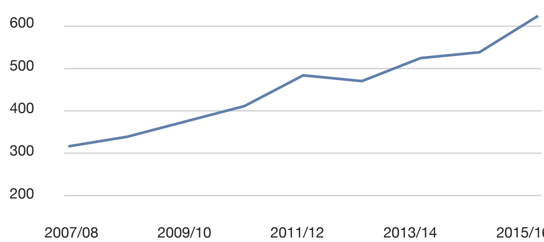
About the cover

The image on the cover is a simulation of a system of nonlinear partial differential equations whose form and parameters have been learned directly from a given fluid dynamics dataset, without prior knowledge of the modeling equation. The learned system is related to the Navier-Stokes equation with large Reynolds numbers; note the appearance of turbulence. For more on numerical analysis and machine learning see the profile of the work of assistant professor Hayden Schaeffer on pages 12-17.



This image is a proof that the cardinality of an interval of the real line is equal to the cardinality of the full line.

Total undergraduate enrollment:
21-241 Matrices and Linear Transformations



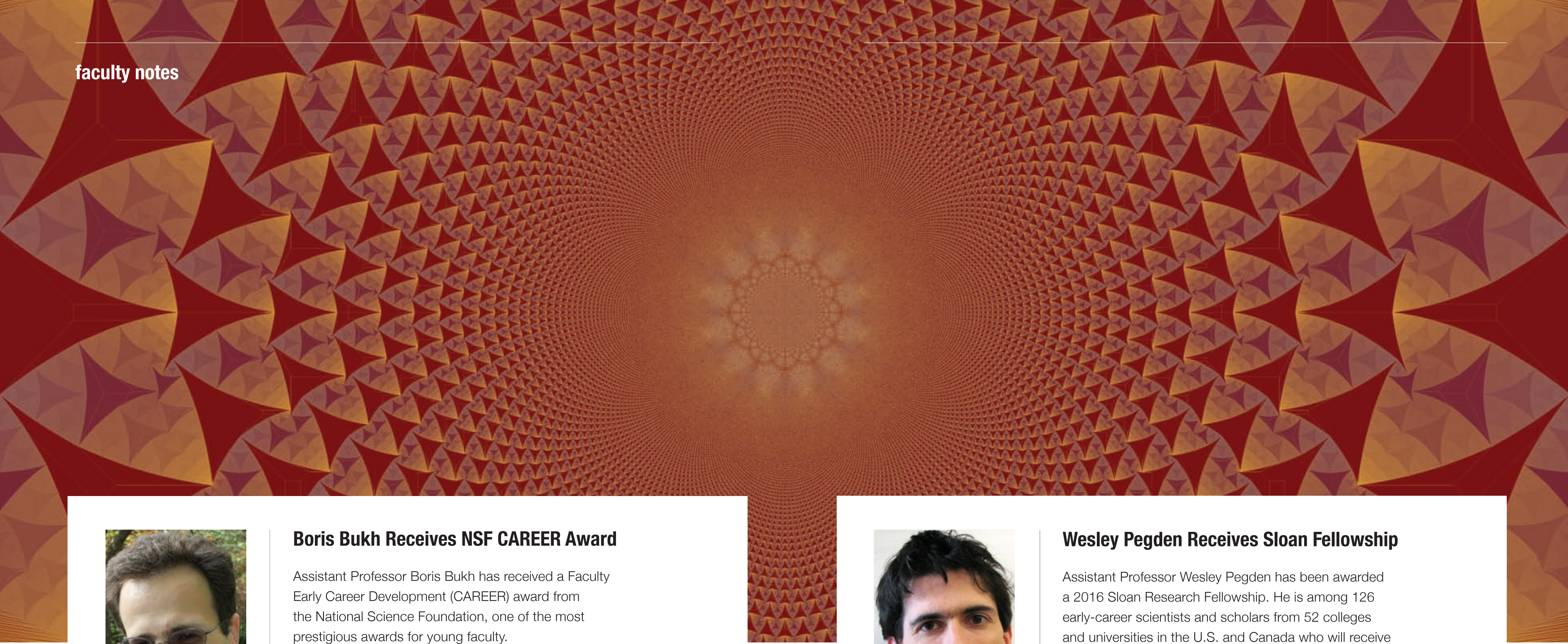
Letter from Mathematics Department Head, Tom Bohman

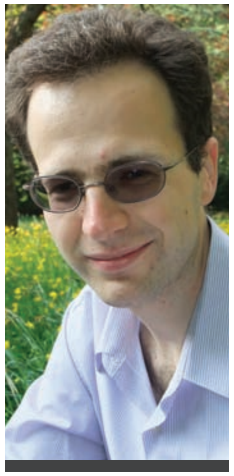
This issue of the Department of Mathematical Sciences Newsletter highlights the research of the most recent addition to our faculty, Hayden Schaeffer. Professor Schaeffer is a computational analyst with interests in PDE imaging science and machine learning. Some of his recent work utilizes ideas from compressed sensing to develop data-driven methods for the numerical solution of PDE (pages 12-17). While his focus is on improving computations for evolution equations, this research direction has the potential to produce methods for learning the underlying PDE models themselves. Professor Shaeffer's work in this area is supported by the Air Force Office of Scientific Research's Young Investigator award. He is one of 58 junior researchers from across the sciences and engineering—and only one of two who are in mathematics departments—to receive this award.

Computation and sophisticated approaches to data have become steadily more important over time, to the point that they are now pervasive in the scientific enterprise. The appointment of Rebecca Doerge, who is a statistician, as the new dean of the Mellon College of Science is a reflection of this reality (for more on Dean Doerge, see page 10). The growing importance of computation and sophisticated approaches to data also has led to a growing interest in mathematics — beyond calculus — among Carnegie Mellon students with a broad array of majors. Total undergraduate enrollment in 21-241 Matrices and Linear Transformations (and parallel courses) gives very clear evidence of this trend. (See chart on adjacent page.)

Furthermore, interest in the mathematics major itself continues to be robust. Our success in drawing students to the mathematics degree continues to bring many challenges to the department, such as providing undergraduate research and capstone experiences for our many mathematics majors. Through the generous support of several of our mathematics alumni, we recently initiated some endowed funds that are helping the department meet these challenges. While these funds are already having an impact (see the story on page 24), they are not fully financed. There is still much more to be done, and I hope you'll consider helping us by donating to the Innovation Fund for Mathematical Sciences.

I hope that the many alumni of the Department of Mathematical Sciences have a chance to reconnect with the department by visiting math.cmu.edu/alumni and letting us know what's new with you!





Boris Bukh Receives NSF CAREER Award

Assistant Professor Boris Bukh has received a Faculty Early Career Development (CAREER) award from the National Science Foundation, one of the most prestigious awards for young faculty.

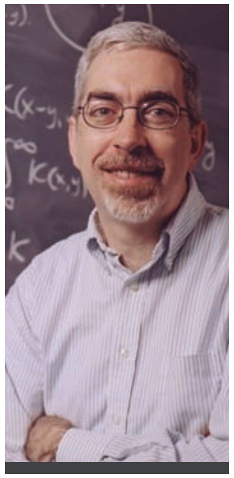
Bukh received the five-year grant to support his research into developing a powerful and novel approach to establish connections between combinatorics and algebra. He plans to investigate in depth the interplay between extremal structures common to both of these areas of mathematics. There are several problems currently known to be at the interface of these two fields, including explicit constructions of Ramsey graphs, constructions of large graphs not containing a specific subgraph, bounds on spherical codes, zero-error capacities of communication channels and set families with restricted intersections. Bukh is an expert in creating novel algebraic and geometric methods for application to such combinatorial problems. He will work closely with both undergraduate and graduate students on this research project. He also plans to write a book for both students and experts that covers the new techniques.

Wesley Pegden Receives Sloan Fellowship

Assistant Professor Wesley Pegden has been awarded a 2016 Sloan Research Fellowship. He is among 126 early-career scientists and scholars from 52 colleges and universities in the U.S. and Canada who will receive $55,000 to further their research.

Pegden studies problems in probabilistic combinatorics, combinatorial game theory, graph theory and discrete geometry. His recent focus has been on the Abelian sandpile (pictured above), a simple deterministic diffusion process on the lattice that produces striking fractal limits. His paper with CMU alumnus Charles Smart (S 2002, CS 2002) on the convergence of the Abelian sandpile gives a new paradigm for understanding the sandpile's scaling limit. More recently, he and his colleagues have used this paradigm to analyze the fractal geometry of the sandpile process through a computationally established Apollonian property of such quadratic growths, a construction that may ease progress on problems unrelated to the sandpile, including number-theoretic conjectures related to Apollonian circle packings.

In addition to his work on the Abelian sandpile, Pegden also has been working with Mathematical Sciences Professor Alan Frieze to develop new perspectives on the hardness of the Traveling Salesman Problem in the natural geometric setting.



Robert Pego Receives Simons Fellowship in Mathematics

Professor Robert Pego will spend next semester at Brown University with nearly 100 mathematicians for a program on singularities and waves in incompressible fluids. Pego, whose broad research area is non-linear models of fluid dynamics and clustering behavior, will attend the Institute for Computational and Experimental Research in Mathematics' (ICERM) semester program at Brown thanks to a fellowship from the Simons Foundation's Mathematics and Physical Sciences division. Only 37 mathematicians were named Simons Fellows in Mathematics in 2016.

"ICERM will provide a great environment for collaborating with experts who work on various aspects of mathematical fluid dynamics. It will be exciting to exchange ideas and develop new thoughts about this research topic," Pego said.

Pego, who was recently named a fellow of the American Mathematical Society, tends to focus his research efforts on problems in fluid dynamics that involve competing influences: those that spread things out and those that focus or aggregate structures. A classic example of this is solitary waves on water. Pego recently published a paper proving the stability of these solitary waves to infinitesimally small influences or perturbations. During his semester at ICERM, Pego plans to address the particular problem of the existence of a permanent wave in an infinite channel with a periodic bottom. In a coordinate frame traveling at constant speed, such a wave should be periodic in time.

Another of Pego's research interests is microdroplet formation. One particular problem he's investigating is: Given two shapes, is there an incompressible fluid flow that takes one shape into the other? Pego and collaborators Dejan Slepčev (CMU) and Jian-Guo Liu (Duke) were inspired by a principle discovered in the 1960s that states that such fluid flows are the shortest distance between two configurations, when measured in the space of incompressible 'deformations.' They realized that if you're trying to do this with shapes, then you actually get shorter paths if the shape breaks up into millions of tiny droplets. A current research interest of Pego and CMU graduate student Yue Pu, who will be joining Pego at ICERM, is in trying to understand the implications of this notion, including understanding the different ways that can get you from one shape to another, and specifically whether there is an exact path between two arbitrary different shapes.

Gautam Iyer Receives Simons Fellowship

Gautam Iyer is spending the 2016 spring and fall semesters focusing on his research with support from Carnegie Mellon and a fellowship from the Simons Foundation. As a Simons Fellow in Mathematics, Iyer, an associate professor of Mathematical Sciences, will keep CMU as his home base but travel extensively to visit collaborators at the University of Warwick in the U.K., Stanford University and the University of Wisconsin, Madison to name just a few.

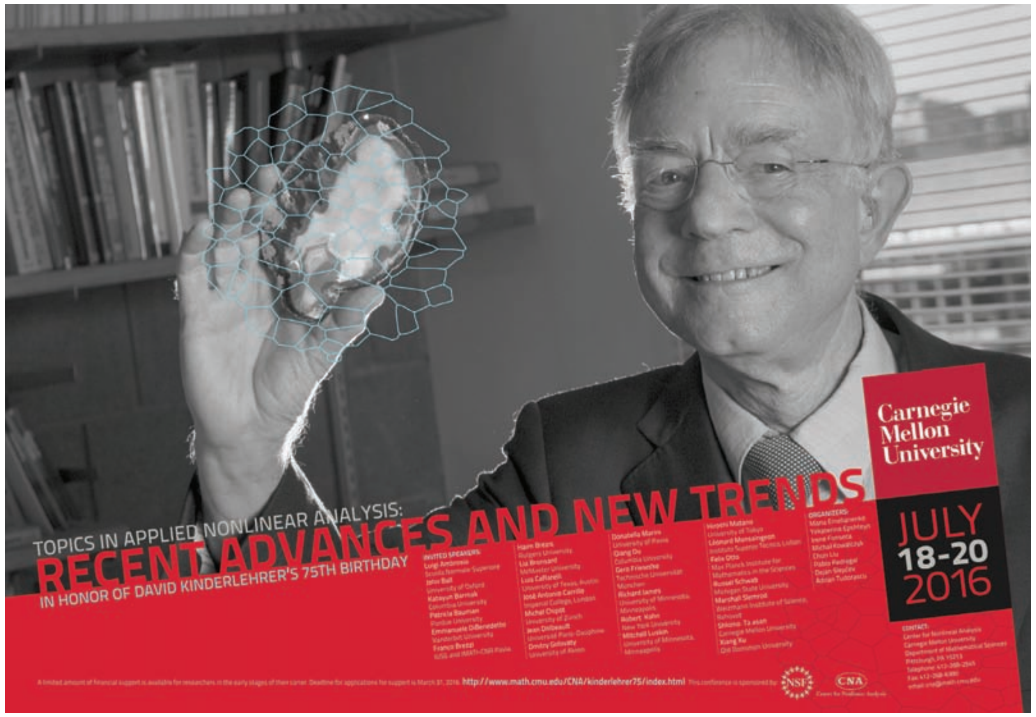
Iyer's research program is focused on the mathematical analysis of partial differential equations and related probabilistic problems that arise in applied mathematics. He plans to spend his sabbatical studying a variety of problems including anomalous diffusive effects observed on intermediate time scales, Bose-Einstein condensation in low- density plasmas, vortex nucleation in super-conductors, fluid mixing, and the duality between branching and coalescence.

CMU Hosts Conference in Honor of Professor David Kinderlehrer

A diverse group of mathematicians and scientists gathered on CMU's campus July 18-20 for Topics in Applied Nonlinear Analysis: Recent Advances and New Trends, a conference in honor of David Kinderlehrer's 75th birthday.

Kinderlehrer, the Alumni Professor of Mathematical Sciences and professor of materials science and engineering, is a leader in applied analysis, especially as it pertains to materials science research. His work in these areas is a testament to the dynamic multidisciplinary initiatives he has forged between mathematicians and allied scientists. Kinderlehrer co-founded Carnegie Mellon's Center for Nonlinear Analysis in 1991, and was its director from 1994-1998. His work ranges from free boundary problems to the theory of optimal transport. He has made important contributions to advancing materials science research, in particular the discovery, with Shlomo Ta'asan and their colleagues, of a new paradigm-changing characterization of microstructure.

Kinderlehrer is a prominent postdoctoral mentor and thesis advisor to many scientific leaders, a great many of whom attended the conference. Also in attendance was Kinderlehrer's mentor and collaborator Louis Nirenberg, co-recipient with the late John Nash of the 2015 Abel Prize.



Pictured above: Professor Kinderlehrer with some of his former doctoral students and postdocs.

Carnegie Mellon University Welcomes the 7th Dean of the Mellon College of Science, Rebecca W. Doerge

Rebecca W. Doerge is a statistical bioinformatician; she joined the Mellon College of Science on August 1, 2016 as its seventh dean. Previously the Trent and Judith Anderson Distinguished Professor of Statistics at Purdue University, Doerge served as head of Purdue's Department of Statistics from 2010-2015 and oversaw its growth into one of the largest statistics departments in the country. She brings a career-long commitment to collaborating across disciplinary borders and supporting basic science research to MCS.

As an undergraduate at the University of Utah in the 1980s, Doerge pursued a degree in pure mathematics, a field that she absolutely loved. Her desire to use her skills to make an impact in the world landed her in the lab of Ryk Ward, a human geneticist, where she worked on a mathematical problem having to do with information content in human pedigree data. That project in human genetics was the basis of her master's thesis in mathematics. So started Doerge's career as an interdisciplinary researcher, something that was almost unheard of at the time.

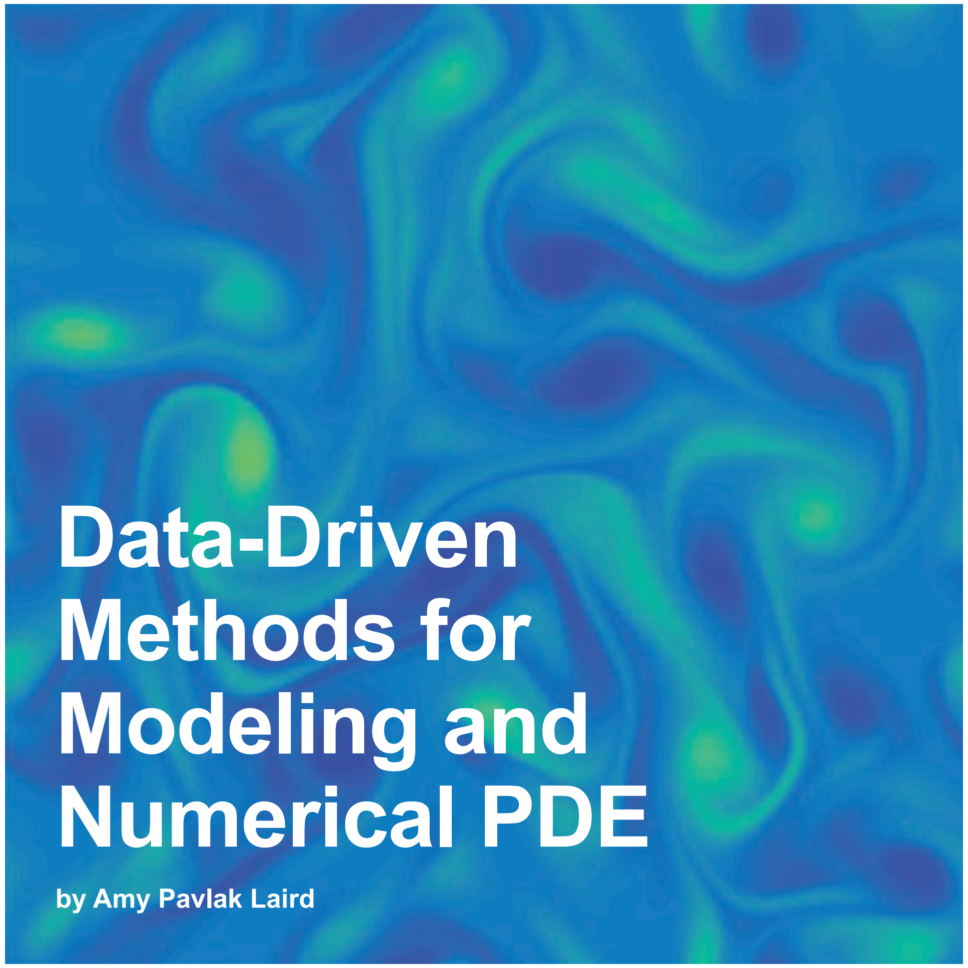
Doerge completed a Ph.D. in statistics at North Carolina State University with a focus on agricultural genetics and a postdoctoral fellowship at Cornell University in the Department of Biometry and Plant Breeding. When she applied for a faculty position at Purdue University, the university embraced her unique background and offered her a joint appointment in Statistics, which was in the College of Science, and Agronomy, which was in the College of Agriculture. At Purdue, she built a research program focusing on understanding new biotechnologies that are producing data that require computationally-based novel analytic approaches. The Doerge research group develops novel statistical methods that, with the help of sophisticated computing, solve the Big Data problems found in biotech, human cancer and global food issues.

Doerge holds a joint appointment in Biological Sciences (Mellon College of Science) and Statistics (Dietrich College of Humanities and Social Sciences) at Carnegie Mellon. She was attracted to CMU because of its strengths in foundational science and the reputation that CMU has for embracing transdisciplinary teams working on hard problems. At a ceremony on October 6 marking her official installation as the seventh dean of MCS, Doerge wrapped up by saying:

"As we prepare to celebrate the 50th anniversary of the merger of the Mellon Institute with the Carnegie Institute of Technology, it is an honor to lead the Mellon College of Science into the next 50 years of history."

Read more about Doerge's appointment as dean at

cmu.edu/news/stories/archives/2016/may/doerge-mcs-dean



Data-Driven Methods for Modeling and Numerical PDE

by Amy Pavlak Laird

Turbulent Winter, 2016

There's an art and a science to imaging that piques Hayden Schaeffer's curiosity. For the new assistant professor, it's the subjective nature of human vision and imaging paired with the more rigorous possibilities for mathematical models that make it intriguing.

"When we perceive something, there is so much happening in our brains that we don't yet have the ability to mimic computationally," Schaeffer said. "Imaging science is exciting for me because it is at the intersection of what we experience, what we interact with, how we communicate, and what we can model or even mathematically understand."

Take texture, for example. Our brains can easily pick out textures like mottled colors in a carpet or black and blue checks on a pair of pants. But it's not so easy to describe mathematically. To distinguish something that's a texture from something that's not is the difference between something being very patterned and something being almost random. Yet even random objects can be textures. A wood dining room table offers a good example. It has a regular aspect—rectangular and brown. It also has textures and patterns in the grain, which are distributed everywhere. Humans can easily distinguish between the two and use each to identify and assess the object. We have learned these patterns from years of visual experiences, but textures cause issues numerically because they can often look random like noise. Noise is very small-scale, just like texture is, but is essentially more unstructured.

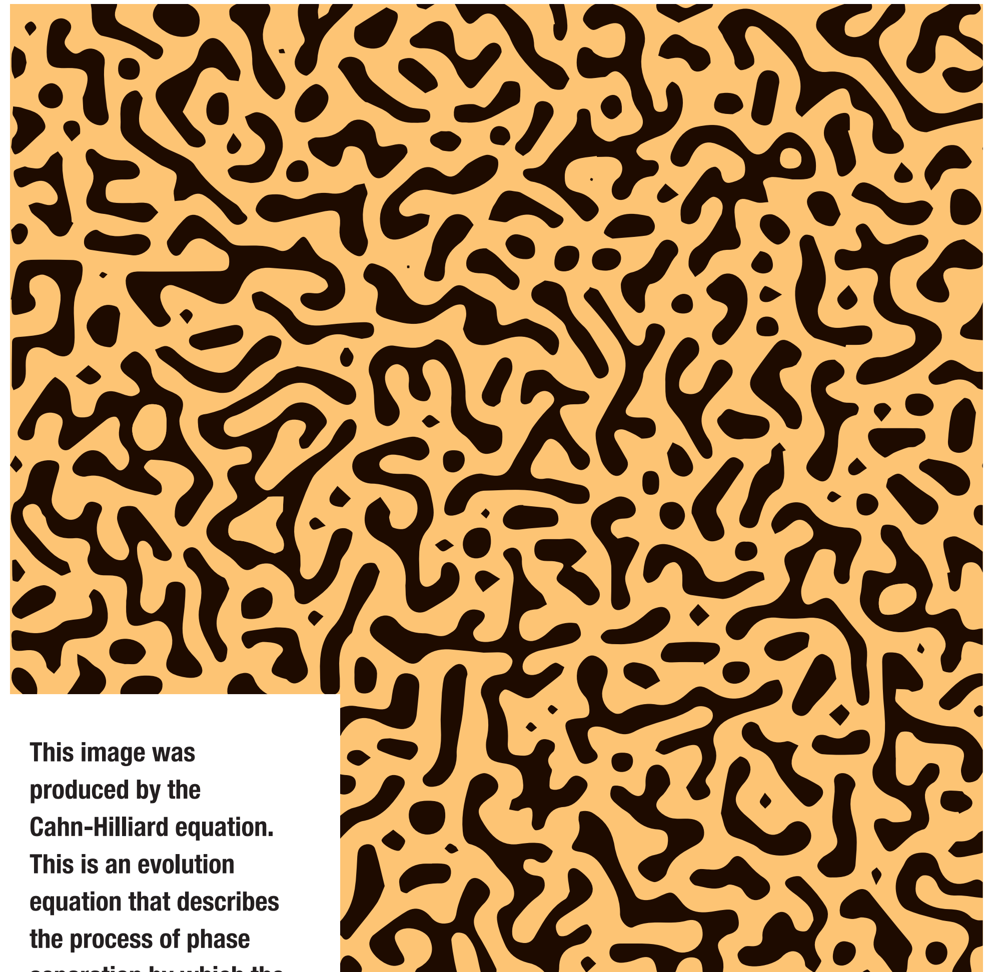
For his thesis work, Schaeffer used a combination of machine learning, partial differential equations and sparse optimization to create a model to compute the actual separation between large-scale visual geometries, textures and noise.

"Imaging science is exciting for me because it is at the intersection of what we experience, what we interact with, how we communicate, and what we can model or even mathematically understand."

Recently, drawing from his experiences with imaging and pattern recognition, Schaeffer has turned his attention to partial differential equations and data-driven modeling. "We are in a time with an abundance of data, from pictures to experiments. There is a need for mathematical methods and models that can use this data for analytics and predictions." Take, for example, a laboratory experiment, where many samples are taken over several days or even weeks. How can we use this data to describe the fundamental behavior (typically by putting an equation to the system) when we do not have a complete physical theory yet? How can we predict the outcome of small changes to the laboratory conditions? According to Schaeffer, the key is to find a small collection of influential patterns in the data. But computationally, this can be very challenging. As a recipient of the Air Force's Young Investigator Program award, Schaeffer will receive support to further explore these and other problems related to sparse modeling and machine learning for nonlinear partial differential equations. (For more on these topics, please see pages 16-17.)

No matter the research project, Schaeffer's goal is always on the computational aspects. "How do I come up with a scheme that better solves a problem in the scientific community? How do I make things more efficient? How do I make things more rigorous?"

Turbulence, Color Block 2016



This image was produced by the Cahn-Hilliard equation. This is an evolution equation that describes the process of phase separation by which the two components of a binary fluid separate.

Cahn-Hilliard, 2016

Sparsity, Compressive Sensing and Data-Driven Modeling

by Hayden Schaeffer

Suppose we would like to solve an evolution equation of the form:

$$u_t = F(x, u, u_x, u_{xx})$$

where the time-derivative only depends on a function of space and the spatial derivatives. For an example, consider the Swift-Hohenberg equation, which models pattern-formation related to thermal convection (see sidebar). Since analytic solutions are difficult to construct, numerical methods are needed to compute approximations to evolution equations. One common technique is to solve the evolution equation using a spectral method (or a related approach), which transforms u into a basis (typically the Fourier basis) and solves the equation in the coefficient domain. In recent years, there has been a signicant amount of interest in data-driven methods, which improve on the classical spectral methods by directly incorporating data.

Data-driven modeling is related to and often inspired by methods from signal processing, machine learning and compressed sensing. Classical sampling of discrete signals are often limited by the famous Shannon sampling theorem, which states that the sampling rate for a discrete signal must be at least two times larger than the largest frequency in the signal. This condition is referred to as the Nyquist sampling rate and is a limiting factor for which an imaging or signal device can acquire data.

Compressive sensing (CS) is a new paradigm shift from conventional sampling methods. The main mathematical technique used in CS theory is sparsity — the theory that the information encoded in the data or the number of degrees of freedom in the data is smaller than the total amount of data. In particular, there exists some representation in which the amount of terms needed to accurately express the entire dataset is very small.

The CS approach involves both forward sampling strategies (data acquisition and compression) and the inverse problem (data reconstruction from compressed measurements). In CS, the data is undersampled in the sense that the amount of measurements is much less than the total size of the data. Let $A \in \mathbb{R}^{m \times n}$ be the sampling matrix with respect to a certain representation and $b \in \mathbb{R}^m$ be the data vector, with the assumption that $m < n$. Suppose that the coefficient vector is denoted as x, then the data acquisition process can be written as $Ax = b$. Since $m < n$, the linear system has many solutions.

The key to recovering the underlying data (i.e., the coefficient vector x) is sparsity. The problem can be formulated as finding the solution of $Ax = b$ with the least number of non-zero terms in x. This is a combinatorial problem and is (generally) an NP-hard. The convex relaxation to this problem is:

$$\text{minimize } ||x||_1 \text{ subject to } Ax = b$$

and it can be shown (assuming that A satisfies a restricted isometry property or coherence condition) that the solution of the convex minimization agrees with the sparse problem. In practice, the data is corrupted by noise, thus the solution to the linear system is inexact. In the noisy case, the problem is formulated as:

$$\text{minimize } ||x||_1 \text{ subject to } ||Ax - b||_2 \leq \varepsilon$$

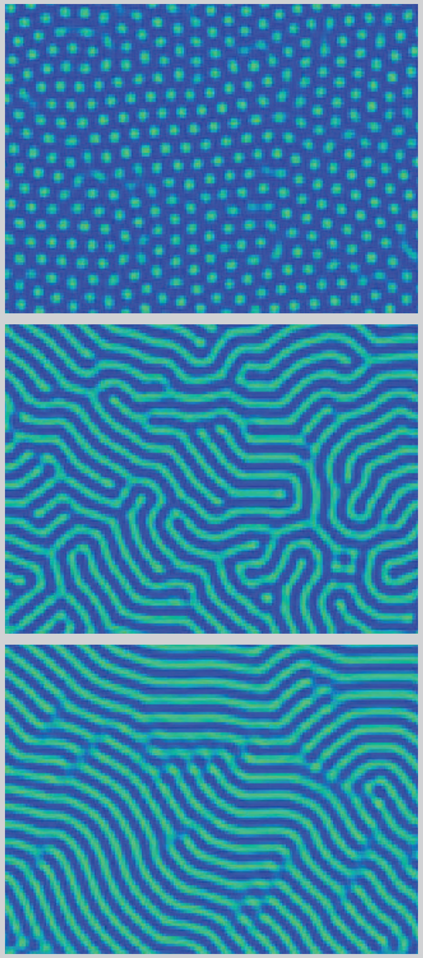
with some appropriate noise constant $\varepsilon > 0$. Many CS-inspired models are based on this least-squares fitting. Applications of the CS framework include medical imaging, seismology, radio signals, facial recognition, video compression and more.

Returning to evolution equations, ideas from CS, in particular that the coefficient domain can be compressed, has led to improvements in the computational efficiency of different numerical methods. Larger gains can be achieved when the basis is generated by the data itself — leading to a growing body of research in data-driven modeling. Also, the incorporation of sparsity directly in the differential equation has led to some very recent advances in computational math, in particular, for learning equations from data and/or enforcing properties in the solutions.

For more on CS see:

E. Candes, J. Romberg, and T. Tao, "Robust uncertainty principles: Exact signal reconstruction from highly incomplete frequency information," IEEE Trans. Inform. Theory, 52(2): 489-509, 2006.

E. Candes, and T. Tao, "Near optimal signal recovery from random projections: Universal encoding strategies?" IEEE Trans. Inform. Theory, 52(12):5406-5425, 2006.



The Swift-Hohenberg equation is a scalar evolution equation with fourth order derivatives:

$$u_t = -(1+\Delta)^2 u + \alpha u + \beta u^2 - u^3$$

This equation models thermal convection, which forms various patterns depending on the choice of two parameters: α and β. Visually, these patterns can resemble curves and coral-like and hexagonal structures. By using the data itself without prior knowledge of this equation, we are able to extract one governing equation that models seemingly different phenomena.

Training Olympic Hopefuls

by Jocelyn Duffy

Mathematical Olympiad Summer Program Held at Carnegie Mellon

Po-Shen Loh is known for attracting some of the best young mathematicians to study at Carnegie Mellon. For the last two summers, those students have been younger than your average first-year. Seventy of the world's best high school math students have spent three weeks on Carnegie Mellon's Pittsburgh campus as part of the Mathematical Association of America's (MAA) Mathematical Olympiad Summer Program (MOSP).

Loh leads the program, and is the coach of the U.S. International Mathematical Olympiad (IMO) Team. Under Loh's leadership, the team placed first in the IMO for the second year in a row. Getting to the IMO is difficult. In fact, just getting asked to participate in the MOSP — affectionately referred to as MOP by the program's attendees and alumni — is a significant accomplishment. To score an invite, students must be among the top of the more than 340,000 who participated in the MAA's American Mathematics Competitions program, a series of school-based mathematics competitions. Only six are chosen to be on the U.S. IMO team, but the rest eagerly come to the program to learn and spend time with other students who share their passion.

"I've always dreamed of going to MOP since the beginning of high school," said Rionna Flynn, a senior from Cupertino, Calif. "MOP has always been a holy grail. It's something people who are great at math get to go to, where you can learn about math and be with people who are as passionate as you."

During the program, the students learn advanced math concepts and techniques with a focus on developing problem-solving skills. They also attend seminars that show them the different ways math is used in the real world and the variety of career options for math students.

"The short-term goal is that the students have so much fun, they don't want to leave at the end of the program," said Loh, an associate professor of mathematical sciences. "For the long term, I want to focus on the 20-year trajectory of the success of all these students."

" We have a responsibility to help these people not only succeed in the competition, but to be as productive as possible in their future careers and leave an impact on the country and the world."

Linus Hamilton (SHS 2016), who participated in MOSP while he was in high school, now comes back to the program as an instructor. He says what he learned during the program not only helped him to succeed as an undergraduate at CMU, but has helped prepare him for what's next.

"Math is about creatively solving problems and finding truths. MOP is about the creative side," said Hamilton. "It's not about winning a competition at the end. It's about these skills that you gather and can use later on."

This year the program was enriched by adding international students. Loh, who was a silver medalist in the 1999 IMO, says that one of his favorite things about participating in the IMO was getting to meet students from other countries and seeing how they learned math.

This year, under the sponsorship of the Carnegie Mellon University President's Office and supported through funds provided by the Hillman Foundation for the Henry L. Hillman President's Chair and the Benter Foundation, Loh was able to bring this experience to all of the MOSP students, not just the team traveling to the IMO. Ten international students, the most ever, participated in the MOSP.

Michelle Chen, a senior from Melbourne, Australia, had a fantastic experience in Pittsburgh. "It was great to meet students from around the world, and learn about their different perspectives," she said.

Po-Shen Loh also teaches CMU's Putnam seminar to prepare students for the William Lowell Putnam Mathematical Competition, an annual contest for college students established in 1938.

Carnegie Mellon's team, which consisted of **Josh Brakensiek**, **Linus Hamilton** and **Thomas Swayze**, placed second in the 2015 competition. All three members of CMU's official team are Knaster-McWilliams scholars. This was the fifth top-five performance in a row for CMU.

In addition to the team's success, 41 CMU students placed among the top 470.

(Breakdown of students in top 470)

88 Massachusetts Institute of Technology

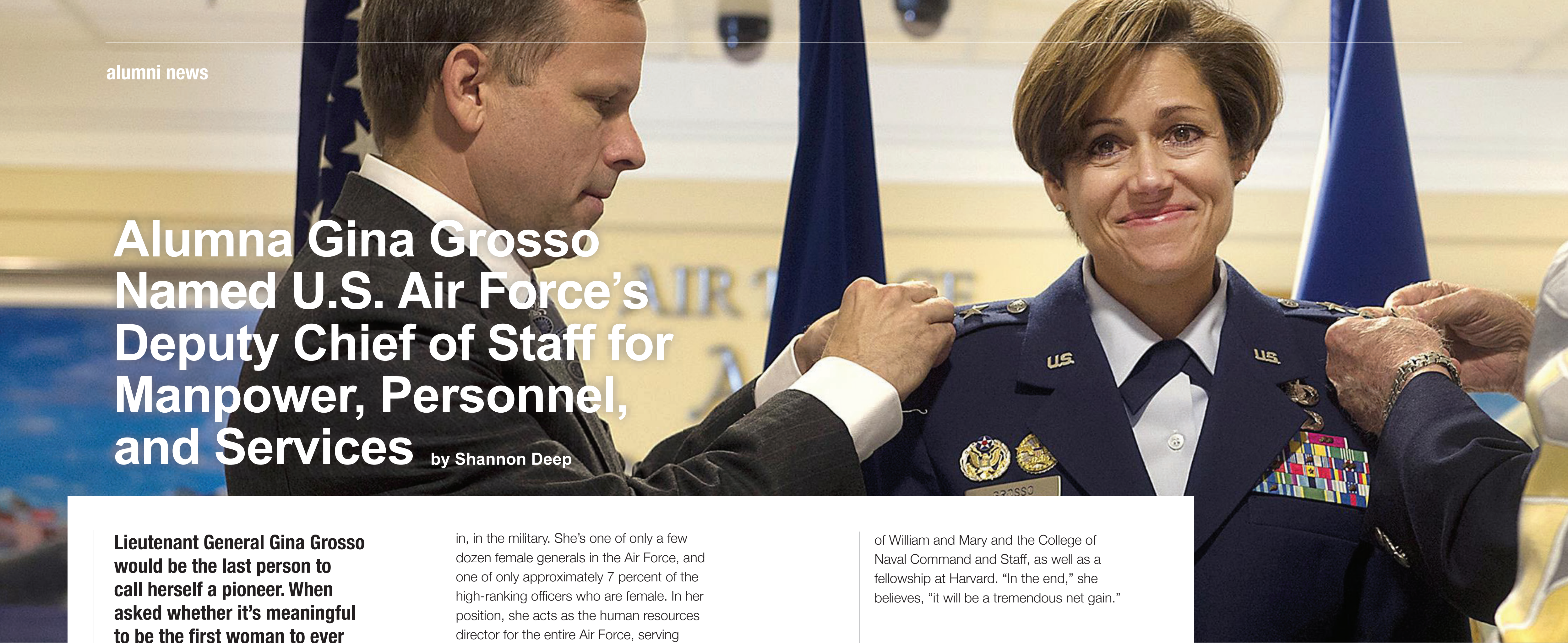
41 Carnegie Mellon University

23 Harvard

22 Waterloo

21 Princeton

21 Stanford



Alumna Gina Grosso Named U.S. Air Force's Deputy Chief of Staff for Manpower, Personnel, and Services

by Shannon Deep

Lieutenant General Gina Grosso would be the last person to call herself a pioneer. When asked whether it's meaningful to be the first woman to ever hold her position as the U.S. Air Force's Deputy Chief of Staff for Manpower, Personnel and Services — a position created nearly 50 years ago — the three-star general pauses thoughtfully before offering a cheerful and pragmatic, "No."

She clarifies: "I feel like I'm an airman just like any other airman. It's not at all meaningful to me that I'm the first woman. It's really an honor to be promoted to this grade no matter what your gender is." She attributes her successes to hard work, good luck and a knack for problem-solving that she honed as a math and business major at Carnegie Mellon University, where she earned a B.S. in applied math and industrial management in 1986.

But Grosso, whether she considers herself to be or not, is pioneering, helping to establish a precedent for jobs women can hold and thrive in, in the military. She's one of only a few dozen female generals in the Air Force, and one of only approximately 7 percent of the high-ranking officers who are female. In her position, she acts as the human resources director for the entire Air Force, serving more than 680,000 military and civilian airmen, not to mention their families. She loves that her job allows her the daily opportunity to do good for those who, as she put it, "have chosen to serve their country at a pretty tumultuous time and deserve the best that we can give them."

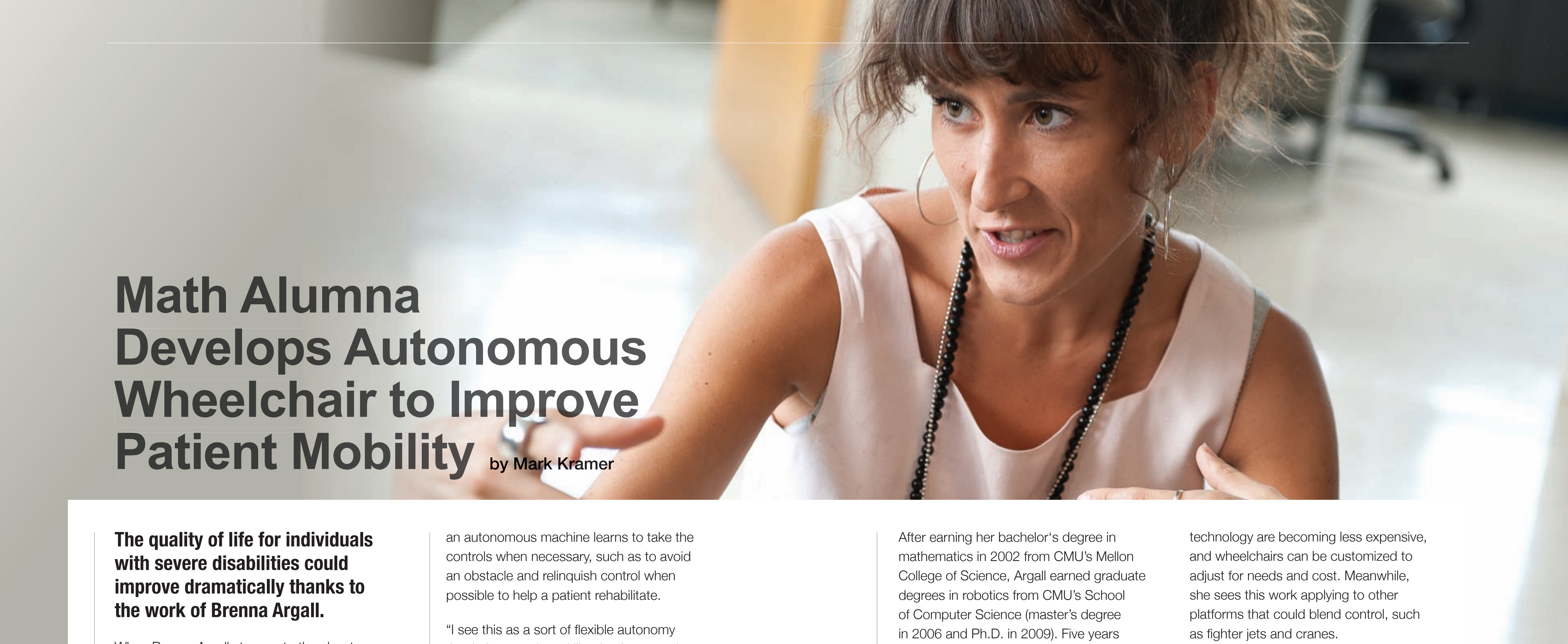
Her promotion to lieutenant general and her assumption of duties happened on October 15, 2015, just 48 days before another pioneering move for the military, albeit on a much grander scale and wider scope: opening all combat positions to women. Though Grosso's personal career trajectory isn't affected by the decision, she praises its dedication to inclusion — inclusion being a strategic imperative of the Air Force that she takes to heart. "If you're seen as a place where women can thrive, I think it will open up a great pool of talented people," says Grosso, who — after earning her undergraduate degree at CMU — completed master's degrees at the College of William and Mary and the College of Naval Command and Staff, as well as a fellowship at Harvard. "In the end," she believes, "it will be a tremendous net gain."

"If you're seen as a place where women can thrive, I think it will open up a great pool of talented people," says Grosso.

Grosso started her career in the Air Force in ROTC while at CMU, but she says that she was motivated more by the scholarship opportunities than any particular affinity for the force. In fact, she planned to serve her time, get her MBA and become a "corporate mogul."

"It wasn't really my plan to stay for this long," she says, now entering her 30th year as an airman, "but I was really happy."

This story is excerpted from "Call to Arms" published by Carnegie Mellon Today at cmtoday.cmu.edu. It is reprinted with permission.



Math Alumna Develops Autonomous Wheelchair to Improve Patient Mobility

by Mark Kramer

The quality of life for individuals with severe disabilities could improve dramatically thanks to the work of Brenna Argall.

When Brenna Argall steps onto the elevator each morning on her way to the 17th floor of the Rehabilitation Institute of Chicago (RIC), she's reminded why she's developing the first autonomously operating wheelchair for people with severe disabilities. She watches patients struggle to manipulate wheelchair joysticks or sip-and-puff controls, colliding into doorways and other people.

Argall, a research scientist and Carnegie Mellon University alumna, believes that by melding robot technology with rehabilitation science, her team at the RIC — ranked "Best Hospital for Rehabilitation" by *U.S. News & World Report* — can help people gain control of their machinery and their lives.

Wheelchairs, robotic arms and other assistance technologies can be difficult to maneuver. Worse, as patients' conditions deteriorate, their ability to manipulate these supports lessens. Argall's work enables a human and robot to share the "control burden" as circumstances change. Over time, an autonomous machine learns to take the controls when necessary, such as to avoid an obstacle and relinquish control when possible to help a patient rehabilitate.

"I see this as a sort of flexible autonomy that helps people feel like they're operating the machine on their own, but also, as they regain ability, that support might also disappear," Argall said.

It was a CMU undergraduate mathematics course that launched Argall's interest in robotics. Under the guidance of James Greenberg, now professor emeritus, Argall led a student team to design and complete a traffic modeling study. She delegated tasks and served as lead writer.

The group submitted findings to one of the field's leading journals, which accepted the work. As an undergraduate, Argall had published her first refereed paper. Furthermore, the editor said no further changes were necessary.

"I haven't had that happen in my whole career," Greenberg said. "That was impressive. In terms of organization, and coming up with a deliverable, Brenna was clearly the best."

After earning her bachelor's degree in mathematics in 2002 from CMU's Mellon College of Science, Argall earned graduate degrees in robotics from CMU's School of Computer Science (master's degree in 2006 and Ph.D. in 2009). Five years ago, she came to the RIC, where she also has appointments with the schools of engineering and medicine at Northwestern University. And she continues to work at CMU's Robotics Institute.

"Brenna serves as an indispensable bridge between roboticists like me and doctors and occupational therapists," said acclaimed CMU roboticist Siddhartha Srinivasa.

Argall hopes to bring an affordable autonomous wheelchair to market within five years. Making that happen will require more bridge-building with manufacturers and insurance companies. Fortunately, she said sensors and related technology are becoming less expensive, and wheelchairs can be customized to adjust for needs and cost. Meanwhile, she sees this work applying to other platforms that could blend control, such as fighter jets and cranes.

At the RIC, Argall is uniquely positioned to advance this project. She conducts tests with patients just down the hall from her lab. "It's easy to keep motivated when the motivation is right outside your door," she said.

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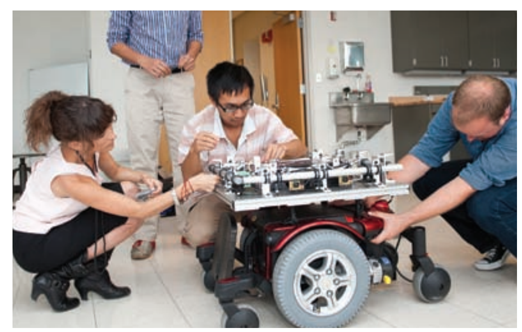
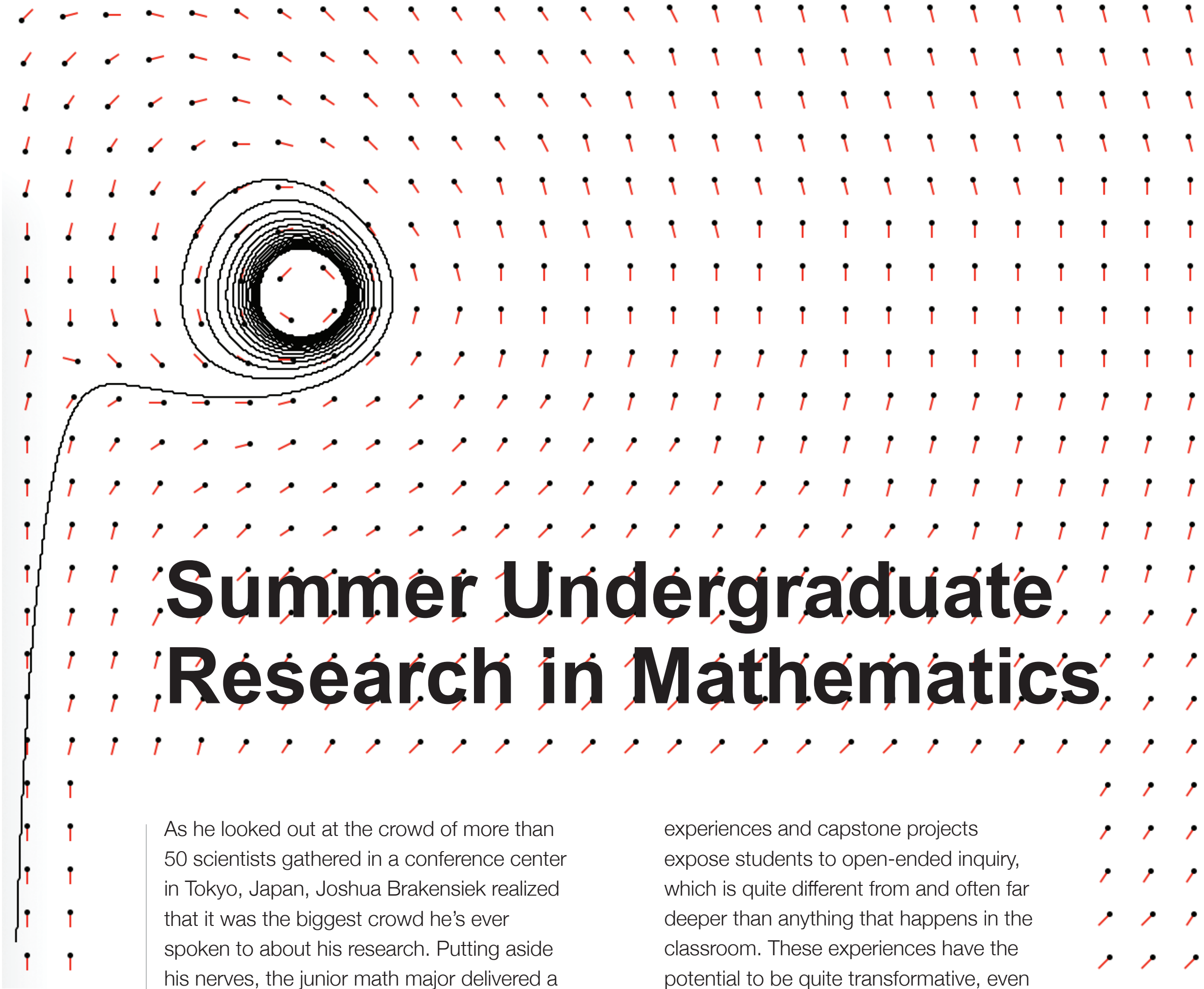




Summer Undergraduate Research in Mathematics

As he looked out at the crowd of more than 50 scientists gathered in a conference center in Tokyo, Japan, Joshua Brakensiek realized that it was the biggest crowd he's ever spoken to about his research. Putting aside his nerves, the junior math major delivered a well-received talk about new hardness results for graph and hypergraph colorings, part of the theoretical computer science research he's doing with CMU Computer Science Professor Venkatesan Guruswami. He's also conducted research with faculty working in statistics and cosmology. For Brakensiek, the opportunity to conduct research has been eye-opening.

"There's kind of this art to it," he said. "Once you learn those basic rules—it's like learning to speak or learning to write—then you have a huge amount of freedom to explore. And that's kind of what the research is. You're exploring a bit."

Brakensiek is one example of the many math students who have shown an increasing eagerness to conduct research. As the interest in mathematics at the undergraduate level grows at CMU, the Department of Mathematical Sciences is endeavoring to create more possibilities for undergraduate research for our students. Research experiences and capstone projects expose students to open-ended inquiry, which is quite different from and often far deeper than anything that happens in the classroom. These experiences have the potential to be quite transformative, even for students who decide not to pursue a graduate degree.

In the summer of 2016, 10 CMU students received Summer Undergraduate Research Fellowships (SURFs) and pursued math research projects. Some of the details from these projects are listed to the right.

The financial support for these SURFs came from alumnus and CMU trustee Larry Jennings (S 1984, TPR 1987), from David (S 1987) and Jacqueline Martin, from CMU's Undergraduate Research Office and from the endowed Innovation Fund for Mathematical Sciences. We hope to continue and even grow this program in the years to come; this will be the primary use of funds from the Innovation Fund for Mathematical Sciences in the near term.

Summer 2016 Math SURF Research Projects

Jiaping Bian and Jingyi Chen

On Optimal Assets Allocation of Retirement Portfolio

Advisor: William Hrusa

Manuel Fernandez

Online Purchasing of Trees with Uncertainty

Advisor: Wesley Pegden

Liuyu Jin

Existence, Uniqueness, and Asymptotic Behavior of Solutions to a Linear System of PDEs with Weak Viscoelastic Damping

Advisor: William Hrusa

Timothy Li

L1 Regularization for Compact Support

Advisor: Giovanni Leoni

Hang Liao, Cameron Montag and Jacob Neumann

Continuous and Discrete Time Multi-Species Population Models

Advisor: William Hrusa

Gidon Orelowitz

A Combinatorial Interpretation for Super Catalan Numbers T(3,n)T(3,n)

Advisor: Irina Gheorghiciuc

Samuel Zbarsky

Linearized Navier-Stokes with Free Surface and Fractional Surface Tension

Advisor: Ian Tice

Mathematical Sciences Students Participating in Meeting of the Minds 2016

First Place:
Mathematics Poster

Jackson Bahr (2017)

"Subrings of C Generated by Angles"

Honorable Mention:
Mathematics Poster

Keven Chionh (2018)

Liuyu Jin (2018)

"Brachistichrone Problem in Non-uniform Gravitational Fields"

Weichen Yin (2016)

"Twinning conditions in Austenite-Martensite Phase Transitions"

Honorable Mention:
Statistics Oral Presentation

Qiulei Bao (2016)

Zhehao Yu (2016)

"Comparison of Community Detection Methods"

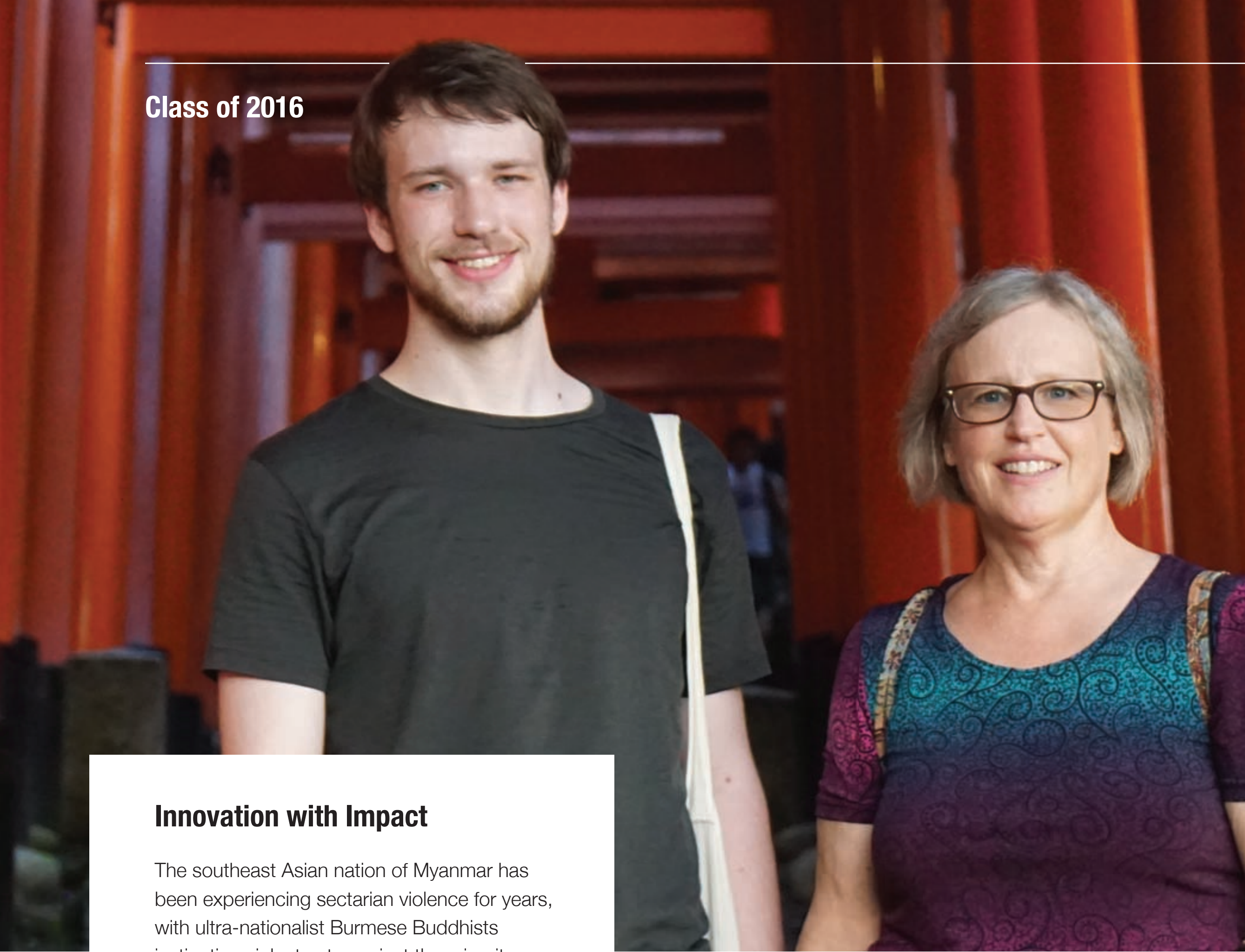
Early Research:
Statistics Oral Presentation

Joshua Brakensiek (2018)

"Galaxy Morphology and Synthesis: Application for the Large Synoptic Sky Telescope"

Other Participants

Eric Alpert (2016)
Evan Bergeron (2017)
Yunwen Cai (2017)
Ethan Gruman (2019)
Kimberly Hsieh (2016)
Ruohui Li (2018)
Timothy Li (2018)
Kabir Mantha (Science and Arts) (2017)
Patrick Mead (2016)
Liyunshu Qian (SHS) (2017)
Sonica Saraf (2016)
Yangjun Sheng (2018)
Moqing Shi (2018)
Zachary Singer (SHS) (2018)
Abigail Smith (2016)
Vijay Viswanathan (2016)
Sijie Wei (2018)
Guru Yerramilli (2016)
Benjamin Zhang (2016)
Kevin Zhou (SHS) (2018)
Xiaofan Zhu (2018)



Innovation with Impact

The southeast Asian nation of Myanmar has been experiencing sectarian violence for years, with ultra-nationalist Burmese Buddhists instigating violent acts against the minority Muslim Rohingya population. Math alumnus Philip Garrison is working with the Center for Diversity and National Harmony in Myanmar on one way to potentially curb the conflict. As a research assistant at the United Nations University's Institute on Computing and Society (UNU-CS), Garrison (S 2015) is developing a piece of software that aggregates public social media, enabling their partners in Myanmar to monitor dangerous speech. Such speech on social media has fueled the flames of violence in the country.

"There are people in Myanmar who think it is important to monitor what's being said online and to do something about it," Garrison said. "The organizations that would be using this tool must be involved in designing this technology."

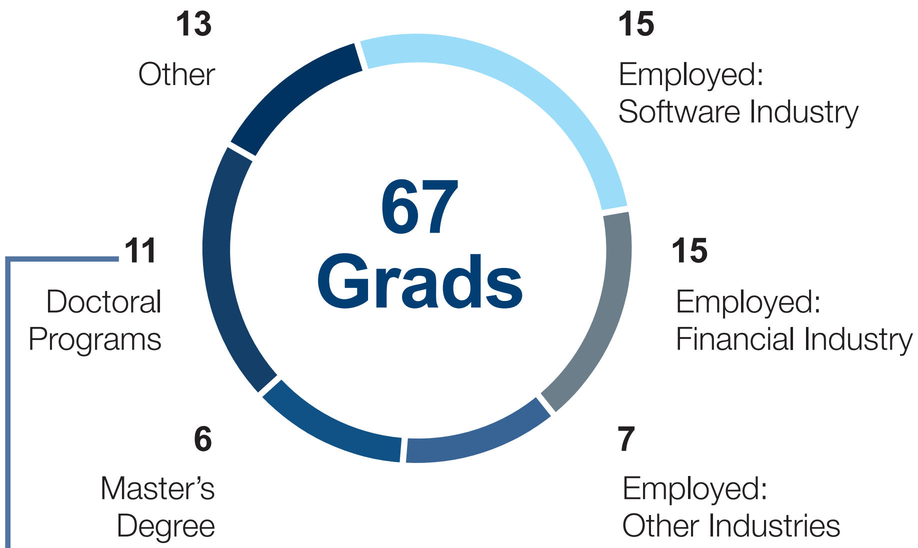
Garrison's project is in line with the UNU-CS's focus on information and communication technologies for development (ICT4D), a field that aims to develop high-impact innovations in computing and communication technologies to deal with the key challenges faced by developing societies. It is a burgeoning field with only a few dozen universities around the world offering ICT4D programs.

After graduating from CMU in December with a double major in math and computer science, Garrison packed his bags and headed to Macau, where the UNU-CS is located. It's not his first stint living abroad. As an undergrad he participated in the Budapest Semesters in Mathematics program. The work he did there led to his winning the Mathematics Poster Competition, sponsored by alumnus David Simmons (S 1986, TPR 1986), at CMU's Meeting of the Minds for his poster "Good Graph Hunting."

Garrison plans to work at the UNU-CS for another year before entering a Ph.D. program to pursue research in the ICT4D field.

Pictured above: Philip Garrison and his mom, Sherri Morgan, in Kyoto, Japan.

Mathematical Sciences Class of 2016



Ph.D. Destinations and Programs

Brown University, Neuroscience

Carnegie Mellon University, Computer Science

Carnegie Mellon University, Machine Learning

Johns Hopkins University, Computer Science

Massachusetts Institute of Technology, Applied Math

Ohio State University, Mathematics

University of California-Berkeley, Theoretical Physics

University of Chicago, Mathematics

University of Chicago, Computer Science

University of Michigan-Ann Arbor, Mathematics

University of Wisconsin-Madison, Philosophy

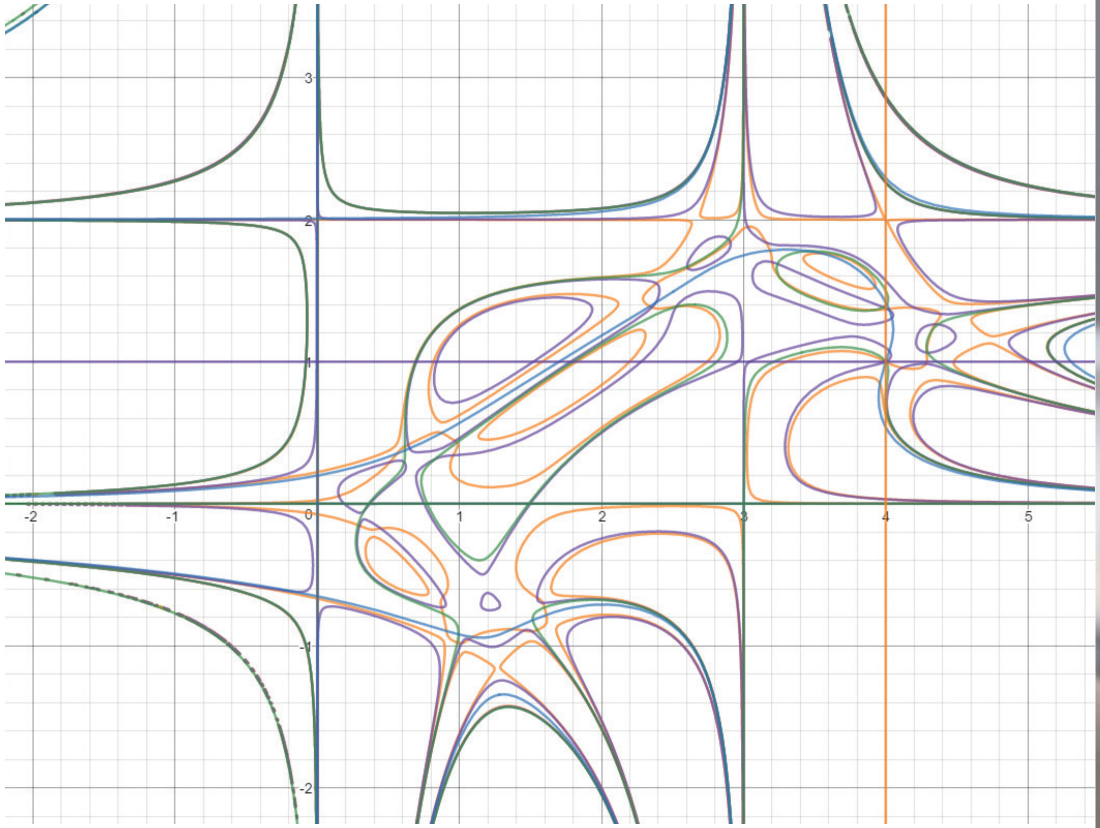
$

Median starting salary for graduates in industry:

$82,500

(of 29 salaries reported in the exit survey)

Carnegie Mellon University
Mathematical Sciences



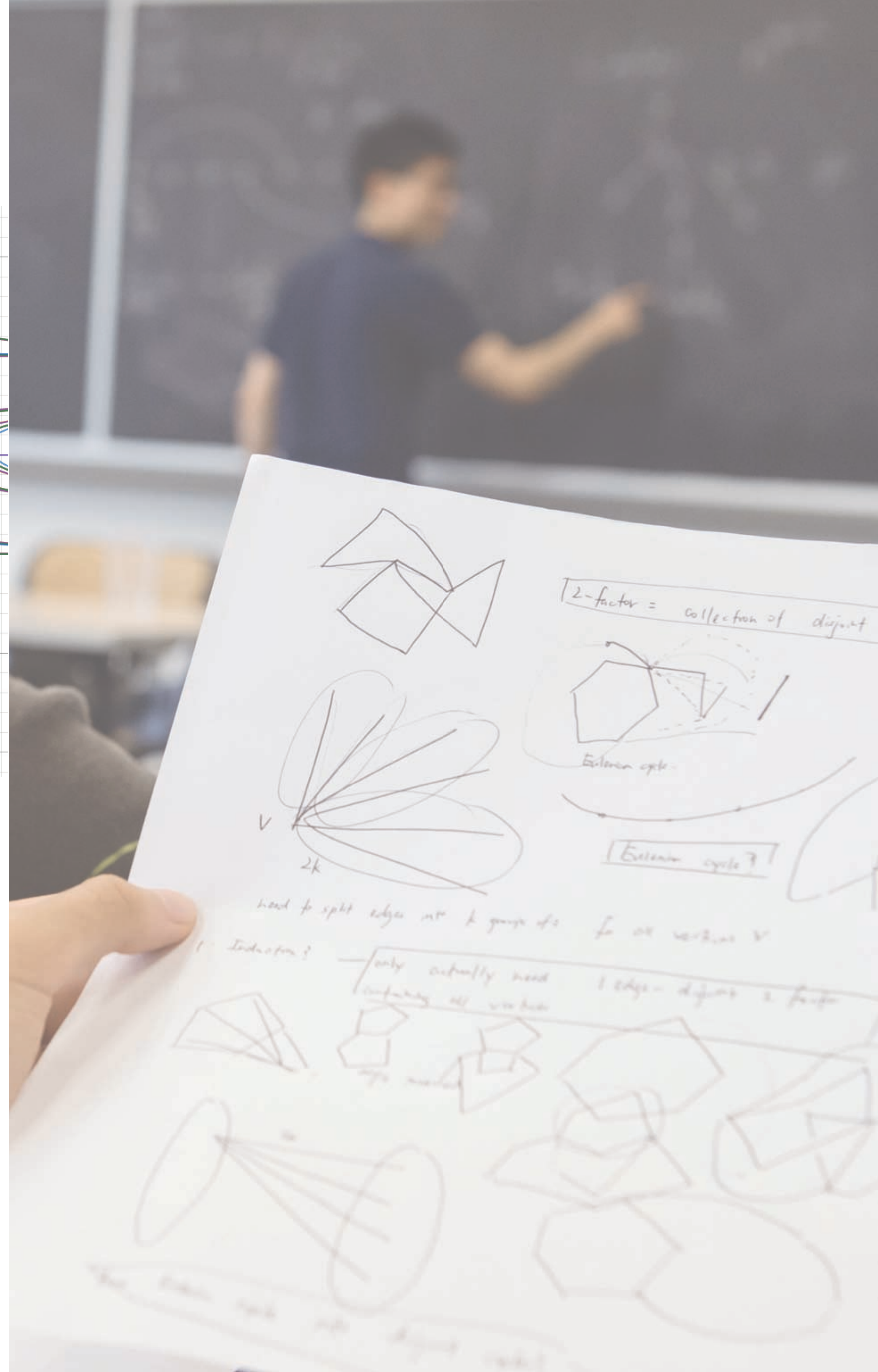
Innovation Fund for Mathematical Sciences

This endowment fund supports:

- Undergraduate research and capstone projects in mathematics
- Math Club and other activities that enrich the CMU experience for math majors
- Mathematics faculty recruiting

To support us, visit

math.cmu.edu/alumni



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