Newsletter of the **Department of Mathematical Sciences** @ University of Delaware

RECKONINGS

SUMMER **2021**

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UNIVERSITY OF DELAWARE

Message from the Chair

MARK GOCKENBACH

As I write this, UD and society at large are preparing to return to a more normal way of operating and I am completing my first year at the University of Delaware and as the Chair of the Department of Mathematical Sciences. For many faculty and students, it has been a difficult year, but there is still a lot of good news to report.

Since the pandemic began, faculty have devoted countless hours to teaching their courses in an online format. They have had to become familiar with various forms of technology, learn how to engage students online, and learn new ways to assess student learning. The department has held several seminars about different aspects of online teaching and there have been many more conversations among colleagues inside the department and across the university.

Although there may not be many students who prefer online classes to learning face-to-face, I feel that departmental faculty rose to the occasion and delivered instruction in a professional, effective, and compassionate manner. This is not just my opinion, either; student evaluations of the department's instructors in Fall 2020 and Spring 2021 were noticeably higher than in the recent (pre-pandemic) past.

At this point, we are all looking forward to returning to face-to-face classes in Fall 2021, and I expect the department's teaching to be better than ever. We have all had to re-examine our instructional practices, and I think we will be better teachers as a result.

I am pleased to be able to report that research in the department is thriving. To give an idea of the scope of research activity: In calendar year 2020, departmental faculty authored or co-authored 86 papers that were published in refereed journals, along with one textbook, 11 conference papers, five book chapters, and five other articles (editorials and reviews). In addition, faculty members edited or co-edited five volumes.

The Department of Mathematical Sciences is well funded, with departmental faculty directing 25 active grants (total value is more than nine million dollars). Research expenditures average about $1.1M each year.

The department continues to graduate well-prepared students; over the past year, 76 students have earned a bachelor's degree in one of the mathematical sciences and twelve have earned a graduate degree (three MS, nine PhD) in Mathematics or Applied Mathematics. Of these nine doctoral graduates, three accepted postdoctoral positions, one landed a faculty position and three more accepted visiting faculty positions, and one took a position in the Department of Defense. Several more students will defend their dissertations in Summer 2021, and at least four of them have found postdoctoral positions.

Looking to the future, the department is planning a number of initiatives. I will just mention one here: we intend to increase opportunities for students at all levels to apply their mathematical skills to the field of Data Science (one of the fastest-growing occupations in the U.S., according to the Bureau of Labor Statistics). The university already has a successful interdisciplinary Master of Science degree in Data Science (MSDS) (created with strong support from the Department of Mathematical Sciences and especially through the efforts of founding director Professor Rich Braun). We are in the process of creating dual degrees to allow our graduate students to earn the MSDS along with the PhD in Mathematics or Applied Mathematics. Our graduates already have considerable success in the job market, but the dual degree should open even more doors to them. The department is also considering creating a bachelor of science in Data Science, adding to the six degree programs that we already offer (eight, if you count BA and BS variants): Actuarial Sciences, Applied Mathematics, Mathematics, Mathematics and Economics, Mathematics Education, and Quantitative Biology.

Thank you for your interest in UD's Department of Mathematical Sciences. If you are inclined to support us with your charitable giving, I can assure you that your contribution will be used to advance mathematics through original research and innovative teaching, and above all to encourage UD students in their mathematical studies. I wish you all the best in all of your endeavors, mathematical and otherwise.

Mark S. Gockenbach
Professor and Chair

Cuisine Based Methods in Machine Learning

DOUGLAS P. RIZZOLO

Suppose you have a collection of text documents that you want labeled by the topics they cover, but the collection is too large to label by hand. How would you do it? This is an important problem in machine learning and many popular approaches are based on nonparametric Bayesian statistics.

The premise of Bayesian statistics is that one can use Bayes' formula for conditional probability, that $P(A|B) = P(B|A)P(A)/P(B)$, as a rule for updating beliefs based on data. If one has the prior belief that, in some experiment, the outcome A occurs with probability $P(A)$ then, after observing D, one should believe that outcome A occurs with probability $P(A|D)$.

To see how this can work in practice, it is best to see an example. Suppose we have a coin and we want to learn the probability p that it lands on heads when flipped. We can treat the probability of the coin landing on heads as a random variable, call it U. If we have no belief about the value of U we might initially assume that every possibility is equally likely, so that U is uniformly distributed on [0; 1], i.e., for $0 \le a < b \le 1$, $P(a < U < b) = \int_a^b 1dx = b - a$, or equivalently the probability density function of U is $P(U = x) = 1$ for $0 \le x \le 1$. If we flip the coin once, and it comes up heads (say $X_1 = h$), how should we update our believes about U? The Bayesian approach is that we should now believe that

$$P(U = x|X_1 = h) = \frac{P(X_1 = h|U = x)P(U = x)}{P(X_1 = h)}.$$

Since U is the probability that the coin lands on heads, we know that $P(X_1 = h|U = x) = x$ and $P(U = x) = 1$, we find that we should believe that $P(U = x|X_1 = h) = 2x$, where the constant 2 can be found either by computing $P(X_1 = h)$ directly or using that $\int_0^1 P(U = x|X_1 = h)dx = 1$. We can keep flipping the coin to learn more about the probability p, and it is not too hard to show that as the number of flips tends to infinity our beliefs about the value of U concentrate around p in a suitable sense. The key points that make this procedure useful are that $P(X_1 = h|U = x)$ and $P(U = x)$ are easy to compute.

But how can this be applied to assigning topics to documents? It turns out that one of the central ingredients is choosing the appropriate prior distribution, the analogue to our initial belief about U being uniformly distributed in the coin flipping example. In this case, where one is observing a large amount of data with complex relationships, two of the most important aspects of the prior distribution are that it be easy to work with computationally and that it be sufficiently "spread out" that the large amounts of data will be able to force the procedure to concentrate around the correct result. To see what "spread out" means, observe that if, in the coin flipping example, we initially believed that U was uniformly distributed on [0; 1/2], but in fact $p = 3/4$, then no amount of coin flipping could change our belief that $U \le 1/2$ and we would never get close to the correct answer.

One idea that has proved adaptable for creating prior distributions suitable in many contexts is a stochastic process called the Chinese Restaurant Process. The Chinese Restaurant Process originated as a way to study the cycle structure of random permutations. The process can be imagined as follows: customers enter a restaurant one at a time. Customer 1 enters the empty restaurant and sits at a large round table. Customer 2 then enters and sits to the left of Customer 1 with probability 1/2 or sits at a new table with probability 1/2. In general, when Customer n enters the restaurant they either sit immediately to the left of Customer i, $1 \le i \le n - 1$ or start a new table, each with probability $1/n$. In the figure, the first 8 customers have been seated and Customer 9 can sit in the locations the arrows point to, each with equal probability. The tables in the restaurant after n customers have arrived naturally correspond to a permutation by treating the tables as the cycles of the permutation. In this correspondence, i maps to the number of the customer sitting to the left of Customer i. The restaurant in the figure corresponds to the permutation, in cycle notation, (1473)(285)(6). Amazingly, if Π_n is the permutation generated after n customers have been seated, then Π_n is a uniformly random permutation of $\{1, 2, \ldots, n\}$ and the nature of the construction makes it straightforward to answer many interesting questions about cycles in random permutations.

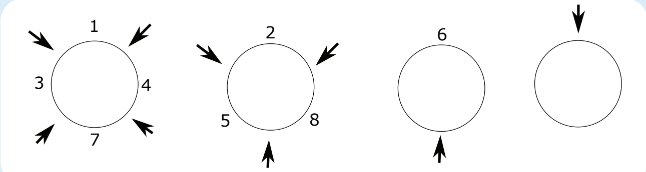


Figure 1. The restaurant after the first 8 customers have been seated. The arrows point to where Customer 9 can sit, and Customer 9 chooses each possible seat with probability 1=9.

In machine learning applications, such as topic modeling, the tables after n steps are considered as defining a partition of $\{1, 2, \ldots, n\}$ rather than the cycles of a permutation. The sequential nature of the construction makes it easy to let n tend to infinity, resulting in a random partition of the natural numbers. In the most simplistic application, one might use the distribution of this random partition as a prior distribution for topic modeling with the interpretation that documents are customers and sitting at the same table means being about the same topic. This, however, is overly simplistic for application. In practice, the Chinese Restaurant Process (or a generalization thereof) is typically used as part of a larger hierarchical or mixture model where the tables correspond to latent parameters in the model from which observations are generated. The sequential nature of the Chinese Restaurant has (at least) two important features in this setting. First, it is a very clean and adaptable heuristic that makes models easy to understand and, second, it provides a reasonably efficient method for doing inference.

Interestingly, in machine learning, the Chinese Restaurant Process served as an off-the-shelf tool that could easily be used because of its convenient statistical properties. Having been developed in the early 1980s, before being adopted in machine learning, it was extensively studied and extended in pure probability due in large part to its connections to theoretical population genetics, exchangeable processes, and diffusion processes. The Chinese Restaurant Process continues to inspire substantial work in pure and applied probability and is a rich source of problems for a broad group of researchers.

EXPOnential Analysis emPOWERing Innovation (EXPOWER) *EU Horizon2020*

MIAO-JUNG YVONNE OU

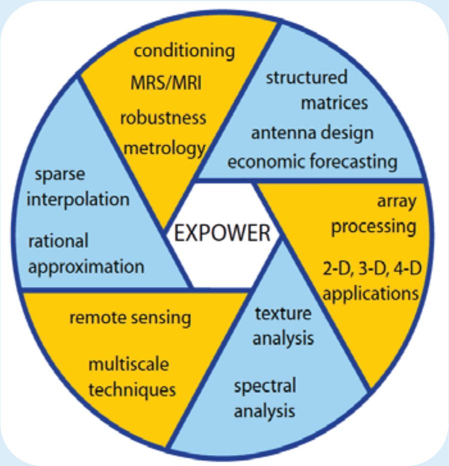
I am excited and honored to be part of the team which receives a prestigious EU Research and Innovation Staff Exchange (RISE) award in mathematics under H2020 program Marie Skłodowska-Curie Actions. The project, titled EXPOWER, is coordinated by Prof. Annie Cuyt (University of Antwerp, Belgium) and connects 8 universities, 3 research institutes and 7 companies from 9 countries. University of Delaware is participating as a third country (i.e., outside the EU) academic partner. The project will run from 2021 till 2025 with awarded funding of €777,400 (USD 922,575) on the subject of multi-exponential analysis (MEA).

Exponential analysis might sound remote, but it touches our daily lives in many surprising ways, even if most people are unaware of how important it is. Multi-exponential analysis is fundamental to magnetic resonance and infra-red spectroscopy, antenna design, satellite navigation, radar imaging, induction-motor fault diagnosis, automotive radar, solving Schroedinger equations and monitoring of Alzheimer's disease, to name just some of the obvious examples. The ubiquity of exponential analysis arises from the fact that almost all mathematical functions can be constructed by using the exponential function as a building block with its base being the famous Euler number 2.71828… . When the exponent takes on real values, it represents a function that monotonically grows or decays exponentially in size. It can also represent oscillating functions if we allow the exponent to take complex values. Roughly speaking, exponential analysis is the process of breaking a function object apart in order to see what exponents and combinations are driving the behavior of the given function. This process is highly non-trivial, especially in the multivariate scenarios.

The MEA of a function *f*(*t*) in 1-dimensional space is to approximate the function by a sum of exponential functions with unknown (complex-valued) coefficients α_i and ϕ_i exponents. More specifically,

$$f(t) \cong \sum_{i=1}^{N} \alpha_i \exp(\phi_i t), \alpha_i, \phi_i \in \mathbb{C}$$

A closer look at it reveals that the approximation can be regarded as a special case of the Laplace transform with the measure being a finite-term linear combination of Dirac measures. Similar to the inverse Laplace transform, this approximation is an ill-posed problem in terms of the numerical stability. In my own research, this type of approximation emerges in the design of numerical schemes for wave equations with memory terms. Also, a variation of this problem plays the central role in the study of Alzheimer disease by using NMR measurements of brains, which is a collaboration with Drs. Richard Spencer and Chuan Bi at the National Institute on Aging of NIH. MEA for dimensions higher than one is a crucial tool in handling high dimensional numerical integration encountered in computational chemistry. These are just three of the many examples where MEA plays an essential role. As is stated in the description of EXPOWER at http://expower.eu, "…, a substantial amount of effort in signal processing and time series analysis is essentially dedicated to the analysis of multi-exponential functions. Multi-exponential analysis is also fundamental to several research fields and application domains that are the subject of the EXPOWER proposal: remote sensing, antenna design, digital imaging, testing and metrology, all impacting some major societal or industrial challenges such as energy, transportation, space research, health and telecommunications." The breadth of applications is sketched in the figure.



Many challenges of the planned research are summarized in the project description: "The network is interdisciplinary, intersectoral, unconventional and ambitious. It is unconventional in the sense that it connects stakeholders from seemingly separately developed fields: computational harmonic analysis, numerical linear algebra, computer algebra, nonlinear approximation theory, digital signal processing and their applications, in one and more variables. It is ambitious because the consortium stretches from mathematics to computational science and engineering and industry." With this EU grant, a deeper and broader mathematical understanding of MEA and better numerical algorithms tailored for specific application problems will be pursued through the group effort on staff exchanges and training/mentoring of the younger generation of mathematicians. For mathematics at the University of Delaware, this serves as a great opportunity to further enrich and broaden our well-established inverse problems program.

More information can be found at **http://expower.eu/members**.

Math Sciences Faculty Awarded $2.6 Million NSF Grant on Problem-Posing Research and Development

MICHELLE CIRILLO

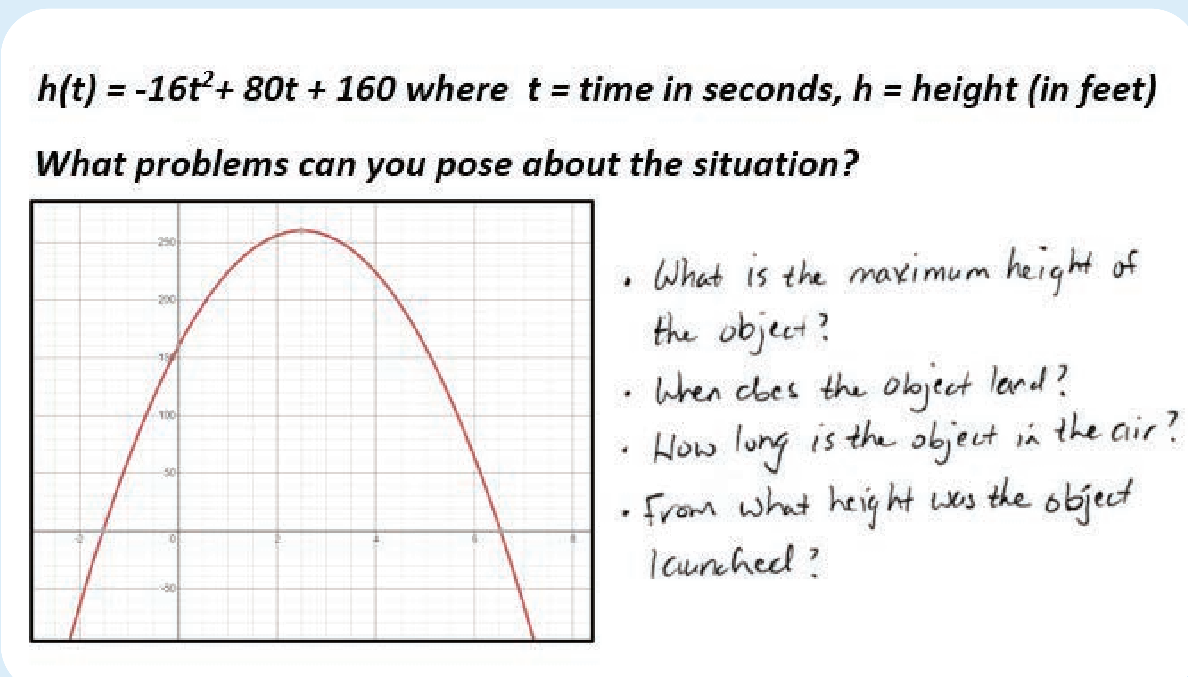
Murray Klamkin, an American mathematician known worldwide as a prolific proposer of professionally challenging mathematical problems, once noted that formulating a problem well is often more difficult than solving it. Yet, despite the fact that generating problems to solve, conjecturing theorems to prove, and identifying situations to model are central to mathematical thinking and learning, historically, there has been little emphasis on these kinds of mathematical activities in school mathematics. In fact, research has revealed that widely used curriculum materials fail to incorporate problem posing in a substantial and consistent way, leaving teachers with sparse resources to enact this process.

To solve the problem of problem posing in school mathematics, mathematics education faculty in the Department of Mathematical Sciences proposed a 4-year longitudinal research project to the National Science Foundation. In March, 2021, Professors Jinfa Cai and Michelle Cirillo, along with Dr. Faith Muirhead from UD's Professional Development Center for Educators, were awarded $2.55M for the project: Supporting Teachers to Teach Mathematics through Problem Posing: An Early Stage Longitudinal Study. Dr. Stephen Hwang will serve as the Project Coordinator.

Problem posing refers to both the reformulation of given problems and the generation of novel problems. Theoretically, there are many benefits of engaging students in problem posing. For example, problem posing can foster students' positive mathematics identities and dispositions, as engaging in problem posing sparks curiosity, increases interest in mathematics, and develops agency by empowering and positioning students as explorers of mathematics. Second, engaging students in mathematical problem posing is a powerful approach to teaching and learning mathematics that fosters reasoning and sense-making. Third, through its flexibility, problem posing offers students of all abilities access to sense-making opportunities.

Empirically, there is a need to generate longitudinal data confirming the promise of problem posing. There are two major goals of the project. The first goal is to support teachers to teach mathematics through engaging their students in mathematical problem posing (problem-posing-based learning, or P-PBL). The second goal of the project is to longitudinally investigate the promise of supporting teachers to teach with P-PBL with respect to teachers' instructional practice and students' learning. The team will collaborate with local middle school teachers to engage students in mathematical problem posing. Through the ongoing partnership, a networked improvement community of teachers and researchers will integrate problem posing into daily mathematics instruction and continuously improve the quality of P-PBL through iterative task and lesson design. A quasi-experimental design coupled with design-based research and improvement science will be used to understand how, when, and why P-PBL works.

The intellectual merit of this project is in its contribution to research on supporting teachers to teach mathematics through problem posing. The broader impact of the project is in the generation of 20-30 research-based P-PBL cases of high-quality, problem-posing based, middle school algebra lessons that include critical details about implementation of P-PBL and the "lessons learned" from the lesson development process. In particular, this project will generate valuable scientific research findings about teaching through problem posing for district administrators, mathematics teachers, teacher educators, professional development providers, and researchers, as well as curriculum developers and policy makers.



Learning by Teaching Online during the Pandemic

EIRINI KILIKIAN

On a Wednesday in March 2020, I was chatting with a group of students in my MATH353 class—my last for the day. They were stressed over a high-stakes exam they had on the next day in another course. "I hope we close for a couple of days because of this virus" one of them exclaimed hopefully. Word had already spread that such a move was possible, because of the increasing number of cases in the U.S. at the time. Sure enough, later that day we received the official announcement from the University administration that Spring break would start early, and that we wouldn't be coming back to campus in two weeks' time.

LEARNING (AGAIN) HOW TO TEACH

After the initial shock, educators had to prepare for a mostly unknown mode of instruction: teaching remotely. I knew that I didn't have any experience of that kind whatsoever, but I had to come up with a plan that would allow me and my students to complete our coursework. Realizing my knowledge gaps, I turned to the source of all things, the World Wide Web. It didn't take long to feel even more overwhelmed by the amount of information available. Every day, a plethora of new ideas, platforms, techniques, checklists, tools were emerging, and it was impossible to keep track of all of them.

It was then that I decided to look at the situation as a math problem: "What do I want to achieve?", "What can I achieve?", "What am I given?", "What tools do I need to get to my end goal?". My answers to these and more guiding questions played a major part in keeping things in perspective and making decisions as the semester went on.

In the months that followed, remembering some common advice I heard as a new instructor a couple of years ago, I decided to try to incorporate one thing at a time. The influx of information, tips and tricks of remote teaching did not stop, but my commitment to not get carried away into multiple new territories helped me stay grounded and only try a handful of things, and only with a true purpose.

THE TOOLS

Fortunately, in Spring 2020 I had started using Top Hat, a student response system, similar to clickers, that required a phone app or a browser to respond. Students created accounts for a small fee in the beginning of the semester, and I used it for attendance and polling, even before COVID hit. Having that form of student engagement and participation proved valuable after the transition, which happened almost seamlessly. Since then, I have adapted the activities to other platforms, like Poll Everywhere or Zoom polls.

In my Calculus sections in Summer and Fall 2020, I explored the Teacher Desmos platform, after reading about it from members of the "Math Mamas" Facebook group. I started using it as an active learning tool and to provide more means for practice to my students—with good success. I started by using short activities prepared by other instructors who made them available to the public, and slowly built up my expertise by editing existing activities and (finally) preparing my own. Despite the significant amount of prep time this took, it was certainly an empowering and stimulating experience.

For open-ended activities, I used various other suggestions, like Google Jamboards and Google Docs. Even though these tools are not as convenient for in-depth work on a problem, they are great for getting an overall sense of the class and gathering broad facts for review. For example, I used a Jamboard in my Calculus class, asking groups to list all facts they know about exponential functions; and again to list everything they know about the shape of a given function using derivative tests. Google Docs worked well for questions with smaller output, for instance having groups calculate different finite difference approximations and record them in a shared doc, which we then reviewed in a whole class discussion.

I should also mention that no matter how confident I was and how much I planned in advance for in-class activities, it always felt like a shot in the dark. I am grateful for the openness and honesty of my students who shared feedback, either formally or informally. From timing the activities appropriately to linking them better to the course material, and from varying the type of activities to creating challenging but achievable tasks, their thoughts were of great help for me in this new teaching format.

THE BRIGHT SIDE

I am proud to say that my Project NExT cohort picked the moniker "Savvy" Silvers, due to our ability to learn to use technology in a way that few of us had before, and be comfortable doing so. More than surviving a couple of unconventional semesters, I like to think that we acquired skills and broadened our worldviews, in ways that will stay with us for years to come.

In a format that hindered direct communication with our students and hands-on practice, the part of my teaching philosophy that says that one learns math by doing—and not by watching—was reinforced. Preparing activities in different ways has been a helpful pedagogical exercise: "What will my students get out of this?", "Is there a better way to cover this topic?".

Since the closings of March 2020, teachers around the globe came together as a collective hive mind to solve big and small problems with teaching remotely. Advice was shared beyond the borders of departments, campuses and nations. As corny as it may sound, we *are* all in this together, meaning that it also falls upon us to face and solve our problems. And I think that the educators' communities responded beautifully to this call.

Finally, a not-so-bright side to the matter is that deeper issues of human society have come to the surface: inequality of access to what we might take for granted, like a stable internet connection, a printer, a safe housing and family environment. In the time that both we and our students combine the workplace with home, these issues can cause frustration, feelings of inadequacy and lead to mental health problems. I cannot help but think how these problems existed before but remained out of sight when we only met our students in a classroom. This added dimension of awareness and visibility will hopefully last long after the pandemic ends, as a way to remember and act on our benevolent instincts.

FACULTY REMINISCENCE

The Origin of the Graduate Program in the Department of Mathematical Sciences

DAVID COLTON

Before 1970, the Department of Mathematics (as it was known at that time) had no graduate program and concentrated on the teaching of undergraduates. Faculty members were expected to be able to teach any course in the Department, regardless of whether or not it was in their area of expertise. This situation changed dramatically in the 1970s and, by the time I arrived in Delaware in 1978 from the University of Strathclyde in Glasgow, Scotland, the Department had converted itself into one with a rising international research reputation. This short article is to describe how this happened. However, in telling this story, I remind the reader that there are no true stories; there are only facts, and the stories we tell ourselves about those facts. Nevertheless, I will try to be as truthful as memory allows.

The catalyst that changed everything was the arrival of a new provost, Leon Campbell, in the early 1970s. His view was that the School of Engineering was a particular strength of Delaware and a strong engineering school required a strong mathematics department. He therefore proposed that the Department strengthen its research mission and establish a graduate program with particular emphasis on applied mathematics. To that end, he pledged the necessary resources to accomplish that mission.

Needless to say, the Department welcomed this initiative, but with some reservations as to its effect on the mathematical cohesion and morale of the Department, which then consisted not only of an active group of applied mathematicians (in particular George Hsiao and Ralph Kleinman) but also faculty members in complex analysis, algebra and topology among other disciplines. Indeed, it was quickly recognized that there are in fact two different types of applied mathematics. One of these, which I will write as "Applied mathematics," is primarily interested in the application whereas the second type, although motivated by applications, is primarily interested in the mathematics. I will write this second type as "applied Mathematics." Given this situation, the decision was reached to focus on applied Mathematics and, to make sure that there was no ambiguity on this issue, the area was called "applied analysis." Not surprisingly, simply renaming the area did little to reduce the underlying tension between these two orientations in applied mathematics, a tension which persists until today in the Department. For an informative discussion on the conflicts that can arise in this rather arcane mathematical dispute, I refer the reader to the interesting interview with Harvey Greenspan in "Recountings: Conversations with MIT Mathematicians" edited by Joel Segal.

Having chosen to focus on building the Department's strength in applied analysis, Bob Gilbert was hired from Indiana University as UNIDEL Professor and Ivar Stakgold from Northwestern University was hired as the new Chair of the Department. As part of his negotiations, Ivar obtained not only a commitment to hire three more full professors in applied analysis, or related areas, but also to move the Department from Sharp Lab, where it had shared space with the Physics Department, to new quarters in what is now known as Ewing Hall. To symbolize the new direction of the Department, the name Department of Mathematics was changed to the Department of Mathematical Sciences. I was one of the three new professors hired by Ivar, the other two being Zuhair Nashed and Adi Ben-Israel. By the time I arrived in Delaware, the sudden resurgence of the Mathematics Department at Delaware was the "talk of the town" among my friends and colleagues in Scotland and Germany as well as at the conferences that I attended at that time.

The issue of course arose as to what kind of graduate program to create. It was quickly realized that to follow the traditional graduate curriculum of major American mathematics departments was not a good idea since Delaware would then have no "label" to distinguish itself from other more established departments. At the same time, the Department wanted to train students broadly in mathematics, not only in applied mathematics. The outcome was to establish first- and second-year graduate courses in ordinary and partial differential equations, measure theory, complex and functional analysis as well as algebra and topology. As the 1980s progressed, junior faculty members were hired in discrete mathematics, probability and numerical analysis, all of which were considered important to the applied mission of the Department, and graduate courses were established in these areas.

The results of all these efforts were phenomenal! Graduate students, who were undecided as to what area of mathematics they were interested in but did know that they did not want to be separated from applications, applied to Delaware and we began to recruit excellent graduate students. Postdoctoral students most, but not all, in applied analysis started coming to Delaware on a regular basis, funded either by grants in the Department or, in the case of foreign students, by their government. This trend continued well into the 21st century. It is noteworthy that most of these postdoctoral students did not come to Delaware to work with a specific person, but were free to work with whomever they chose. In particular, the view of the Department was that postdoctoral students were at Delaware to benefit from the faculty, not the other way around! This influx of postdoctoral students was central to my academic career. In particular, I mention my postdoctoral students Andreas Kirsch (recently retired as Professor of Mathematics from Karlsruhe Institute of Technology in Germany), Fioralba Cakoni (currently Distinguished Professor of Mathematics at Rutgers University) and Houssem Haddar (currently Professor of Mathematics at Ecole Polytechnique in Paris). Without these three students, together with my Delaware colleague Peter Monk, my mathematical life would have been entirely different. Looking back at my life, I feel that there was no better place in the world for me to be than at Delaware and I continue to be profoundly grateful to the wisdom of Leon Campbell which made all of this possible by his decisions back in the 1970s.

IT HAPPENED IN 2020-21

Mathematical Modeling Camp

ADAM KAMRAS

In June, the department hosted 23 graduate students from 16 states to participate in the 16th annual Graduate Student Mathematical Modeling Camp (GSMMC) followed by the 37th annual workshop on Mathematical Problems in Industry (MPI). After learning about mathematical modeling with hypothetical problems at the camp, the students remained at UD to put the lessons to work over the next week on real-world, research-level problems in the much larger, virtual MPI workshop, conducted by the University of Vermont.

According to GSMMC co-organizer professor David A. Edwards, the camp experience equips students with the confidence to actively participate on MPI teams with faculty and postdocs. In return, MPI benefits by having a cadre of well-trained, energetic students to collaborate with the other academic participants. “Though there are other summer student training camps like GSMMC and other industrial study groups like MPI, GSMMC-MPI is the only program that ties the two together,” said Edwards.

Edwards’ co-organizer Lou Rossi, professor of mathematical sciences and dean of UD’s Graduate College, added, “Private industry and government agencies have real mathematical needs that can be met by graduate students and faculty who can cross disciplinary lines and communicate effectively in teams. This program has long been a successful model for providing needed career preparation as well as a fertile recruiting ground for the sponsors.”

The participants relished the opportunity to work with other students in person and do some socializing. “The overall experience was great,” said UD student Linsey Jacobs. “The other students were all very nice, so I felt very comfortable right from the start.”

Participants quickly found out that math proficiency was only part of the problem-solving equation that could not be completed without social skills and team effort. “My biggest takeaway is that communication is key when working on a team,” said Jacobs.

“It’s also important to not be shy and speak up if you do not understand something and to help others struggling if you can.” Wyatt Rush, a student from George Mason University, added, “Just getting a broad idea of how people take different approaches to the same topic is really helpful.”

Students were also reminded of the importance of interacting with subject matter experts from other disciplines. Rush, who described his overall experience as a lot of intense problem-solving,” said, “I had to learn about tree biology the first week and COPD [chronic obstructive pulmonary disease] the second week, so there was a lot of interdisciplinary learning.

“Anyone who has the opportunity should definitely try to do a camp or conference like this. Go meet people, learn about the industry, learn what is being talked about and researched, and just go learn and have a good time.”

The MS in Data Science Continues to Grow

R.J. BRAUN

The Master of Science in Data Science (MSDS) began in Fall 2018. As founding director of the program, I worked with a large group of enthusiastic faculty to launch it. The executive committee runs the program, and includes faculty from a variety of departments and colleges around campus. The affiliated faculty includes representatives from a wide variety of departments and come from all of the colleges on campus. A number of faculty from Mathematical Sciences are affiliated with the program and have helped mentor students in projects and in the degree program. Our steering committee, comprising representatives from local industry and commerce, have given us valuable suggestions and advice.

Despite the pandemic, the program has grown steadily, and its students have shown remarkable resilience and determination to earn their degrees. Our first three graduates earned their degrees in Spring and Summer 2020, after the pandemic closed the campus. The graduates included Jon Clifford, who was previously an undergraduate applied mathematics major at UD. Our fourth graduate finished in December 2020 after finishing in just one calendar year, all during the pandemic. The total number of graduates has risen to nine through the summer of 2021, and this number is expected to rise steadily as the program grows. We are very proud of these graduates!

Beginning with the 2019-20 academic year, MSDS is offered in combination with the Bachelor degree options in a 4+1 format, where two courses (6 credits) from the graduate level are shared between the undergraduate and MSDS degrees. This sharing of credits allows the student to complete both degrees with lower time to degree and tuition cost. The combined 4+1 Bachelors/MSDS options are available from the Department of Mathematical Sciences, the Department of Computer and Information Sciences, the Department of Electrical and Computer Engineering, the Department of Mechanical Engineering, and the Department of Physics and Astronomy. Each department has multiple majors at the undergraduate level, and these can be combined to shorten the time to obtain both degrees. Our first three graduates from the 4+1 combined program graduated in May 2021. Dominick Sinopoli, an actuarial sciences major from our department, was one of those first three graduates. There is another half dozen in the 4+1 programs currently, and steady growth is expected.

Beginning in the Fall 2021 semester, new dual degree programs have been launched combining the MSDS with the PhD degrees from the Department of Mathematical Sciences. Each combined PhD, either in applied mathematics or mathematics, is considered a new program by the Graduate College. These new programs will admit student who are qualified for the PhD programs, but will allow students to share graduate credits and earn the combined degrees much faster than they could otherwise. Including the MSDS together with the PhD will give the graduates knowledge and skills that are highly sought after in academia, industry, commerce and government. The future will be bright for those graduates!

The students have also had an impact on the faculty. Several MSDS students worked on a project that combined deep learning, mathematical modeling, parameter estimation and tear film imaging on the surface of the eye; that project is supervised by Tobin Driscoll and me. That group included Dominick Sinopoli. Another 4+1 student, Kaitlin Canalichio (Quantitative Biology undergrad), worked with Chad Giusti, Tobin Driscoll and me on topological methods and tear film imaging. Peter Monk worked with an MSDS student on a project that used finite element methods. These are just a few of the examples from our department and around campus.

In an effort to compete with more established programs, the MSDS worked with an outside consulting firm to analyze tuition charges from our competitors. As a result, the MSDS lowered its tuition by about half. Potential applicants noticed, and applications increased.

Subsequent to this move, the Graduate College streamlined and lowered tuition costs for nearly all programs on campus, with the MSDS tuition becoming the standard rate. The program also hired a graduate coordinator, Tiffany Harrison, to help run the program. Despite challenges getting the international students to campus, these and other moves have helped us grow the program. Support from the Deans of the Colleges of Arts and Science, Engineering, and Agriculture and Natural Resource, as well as from the Chairs of Mathematical Sciences, Computer and Information Sciences, and Applied Economics and Statistics, was essential to get the program this far.

More information and news about the program can be found at **www.msds.udel.edu**. We are excited to see what successes the future brings for our students!

Coming Soon: BS in Data Science

TOBIN DRISCOLL AND DOMINIQUE GUILLOT

The department of mathematical sciences is currently preparing a new Bachelor of Science degree in Data Science. This interdisciplinary degree will provide training across mathematics, statistics, and computer science as preparation for a career or advanced study in this burgeoning field. The curriculum will include two new undergraduate courses in Data Science that will cover foundational topics such as data representation and visualization, supervised learning, unsupervised learning, and deep learning, all accompanied by practical training in the Python language. The department is planning to add a minor in data science as well that includes the new courses. Pending College and University approvals, the department hopes to start admitting students into the program and minor in 2022.

Winter Research Symposium

PHILIPPE GUYENNE

The 11th annual Winter Research Symposium (WRS) of the Department of Mathematical Sciences was held virtually on Friday February 26th 2021 via Zoom. Dr. Mark Gockenbach, the department's Chair, opened the symposium by noting the important contributions of our graduate students to this event. A big crowd was in attendance, including faculty, graduate students, family, friends and potential recruits for the coming year. About twenty prospective students from the US and abroad were invited to a virtual visit of the department and to attend the WRS.

Unfortunately, due to COVID-19, no AWM travel awards were given this year. Dr. Mark Gockenbach awarded the Wenbo Li Scholarship Prize, in memory of Dr. Wenbo Li. This cash prize recognizes an outstanding paper that is primarily authored by a graduate student. This year's winner was Ms. Rayanne Luke for her paper "Parameter estimation for evaporation-driven tear film thinning" which has been published in the Bulletin of Mathematical Biology.

There were seven talks on a wide range of topics given by graduate students. Of

these, six were senior students (Gautam Aishwarya, Michael Bush, Li-An Chen, Hansen Pei, Kelvin Rivera-Lopez, Nicholas Russell) as well as the prize recipient (Rayanne Luke). Due to COVID-19, no poster competition was organized this year. Two graduate students (Dheer Desai and Melinda Kleczynski) volunteered to present virtual posters on their research.

In addition, there was an invited alumnus talk. This year's speaker was Dr. Samuel Cogar who is currently a Hill Assistant Professor in the Department of Mathematics at Rutgers University, New Brunswick. He received his Ph.D. in Applied Mathematics from our department under the direction of Drs. David Colton and Peter Monk in 2019. He conducted his doctoral research as a National Defense Science and Engineering Graduate Fellow, and he presented some of his work in the Wenbo Li Prize talk at the 2019 Winter Research Symposium. His thesis topic was new eigenvalue problems in inverse scattering. He will begin a permanent position at the John Hopkins University Applied Physics Laboratory in June 2021.

This event made a good impression on the recruits. One recruit commented "I'm very impressed by the faculty I spoke to at Delaware ... I think Delaware had the best virtual recruitment event I have attended". We would like to thank Ms. Daytonia Campbell as well as all the graduate students and faculty who helped make the WRS a successful event again this year despite the special circumstances.

AWM Expanding a Network of Support in Unprecedented Times

EMILY ROSS RUSSELL

In the last year, UD has faced unprecedented changes in the face of halting all on campus activity due to the national lockdown. Despite these changes, however, the UD chapter of the Association for Women in Mathematics (AWM) has strived to overcome these changes in continuing our mission in the Department of Mathematical Sciences and beyond.

Specific to the graduate program, AWM has spearheaded the Mentorship Program, which is going on its fourth consecutive year this upcoming fall. The goal of the mentorship program has been to pair older graduate students with incoming first years in an effort to foster a supportive network of people newer graduate students can turn to in order to help ease their transition into the program and help give them a greater chance at success. In addition to this, AWM helped facilitate the first Faculty Mentor Program this year where incoming first year students were also paired with faculty members interested in mentoring, supporting, and helping new students find their way both academically and professionally in the department. With the University shifting to being entirely online, we felt these programs were particularly important to implement and maintain this year so that there was still a place that new students could organically find roots and build support systems in the department.

Beyond the graduate program, it was a priority of the AWM this year to expand our chapter to include and support undergraduate students. With the addition of three undergraduate students to our E-Board, these members played a vital role in helping us curate events centered around undergraduate outreach and professional development, including a virtual LaTeX Workshop held this past Fall. Moving forward, we hope to continue expanding our undergraduate outreach efforts with more events centered around professional development and continuing to bridge the gap between undergraduate and graduate students with the continuation of undergraduate inclusion on the E-Board and events like the UD Mathletics Competition.

Over the course of the last year and a half, we have faced novel socio-economic shifts as the COVID-19 pandemic and calls for political and social change have touched every aspect of our lives personally, professionally, and academically. Given that it has always been the mission of the UD chapter of AWM to support and empower underserved and minority groups in STEM, this year posed both unique opportunities and challenges for us to overcome in carrying out this mission. In addition to the programs and events already mentioned, AWM also held some social events, such as virtual Game Nights and bi-weekly Snack Breaks. These social events were especially important to our mission in that they created a space where people could escape the stress of the semester and this last year and spend time making and catching up with friends, which is an integral part of building a network of support. Specifically, our bi-weekly Snack Breaks have long been a staple in our efforts to create a network of support in our department and often involve discussing and reading articles about the professional, academic, and societal hardships faced by women and minority groups in STEM. In light of the events of the past year, we used our Snack Breaks to talk in particular about the topics of systemic racism and racial injustice both broadly and in mathematics, as well as how the pandemic was specifically affecting women and minority groups in STEM. These meetings drew people of different ethnic, academic, and socio-economic backgrounds together in an effort to cultivate an environment where people feel safe to talk about issues pertaining to personal hardships and/or social injustice. These discussions were especially important in informing how we, both as individuals and as members of the UD community, could come together to make the department a safer and more welcoming place for everyone.

This last year has taught us that despite any distance, we are still able to come together as a community to grow and support each other. As we forge into this next semester, the AWM hopes to continue this growth through our professional and community outreach in order to promote the continued intersectional inclusion, retention, and advancement of underrepresented groups in STEM.

UD Student SIAM Chapter

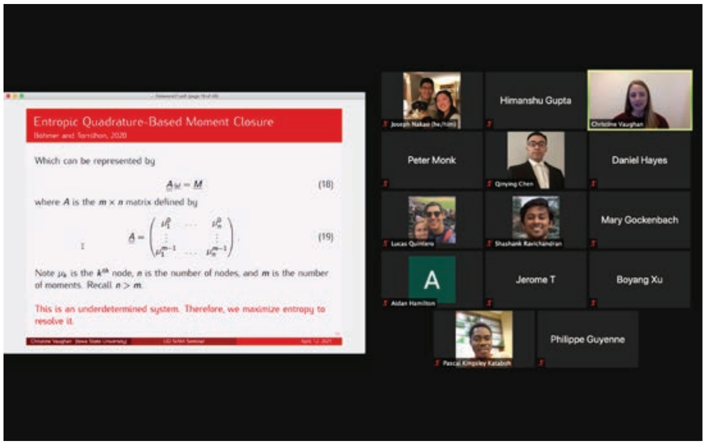
HIMANSHU GUPTA SIAM UD CHAPTER PRESIDENT, 2020-2021

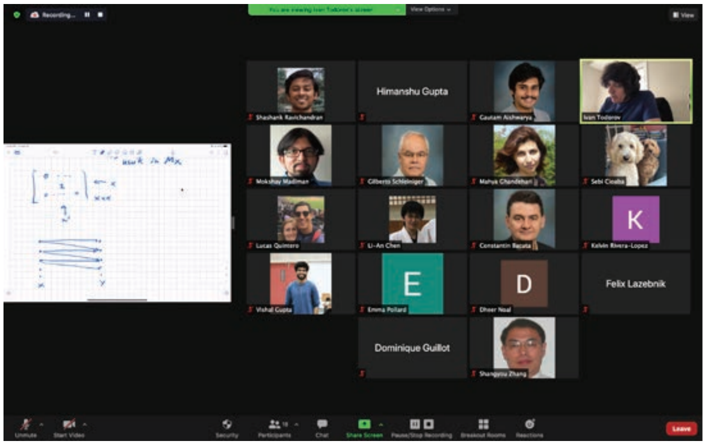
The University of Delaware chapter of SIAM is one of the active chapters of SIAM all through the previous decade and a half. It has a rich history of putting together various academic and social events. This year was different since a challenge was to conduct all the events online. We are delighted that the SIAM community at UD came together in these difficult times and made all the events fruitful.

The main feature was the SIAM Seminar Series. Setting to promote inter-disciplinary collaboration among graduate students we invite PhDs and postdocs to give a talk. The online format allowed speakers from across the country and globe to present their research.

We continued with the Special Topics Lectures that began two years ago. The objective is to organize three-lecture series on topics that are of interest to graduate students but are not usually covered in the regular coursework. This year we conducted two series. Prof. Rakesh and Prof. Ivan Todorov kindly delivered amazing lectures on Differential Forms and Quantum Information Theory respectively.

We started a new seminar series called *SIAM Invitation to Industry.* The goal is to invite a speaker from industry to talk about career opportunities outside academia. The first talk featured Dr. Nitsan Ben-Gal, Data science specialist at 3M. She talked about her experience as a mathematician in the industry and expanding into new skill domains. Along with a Q&A session, we got an expert's insight about how to build a similar career trajectory in industry.





Throughout these challenging circumstances, the SIAM community at UD maintained in touch. We arranged virtual social meetings using the website gather dot town to engage with fellow graduate students. In May, we hosted a Math Meet-up and dinner at the beautiful Newark Reservoir. We look forward to exciting and productive events next year!

Math Alliance at UD

NICHOLAS RUSSELL

During the past year, it has become clear that significant change is necessary to combat racism, to become anti-racist, and to dismantle the policies and status quos that have allowed the United States to continue to disenfranchise minorities. There is a great need to do a much better job to promote diversity, which includes eradicating the racial discrepancy that exists throughout UD and more specifically in our department. 5.3% of graduate students enrolled in the College of Arts and Sciences identified as Black or African-American in 2020, while the percentage of Black residents in Delaware (23.2%) and the United States (13.4%) are markedly larger. There are several underrepresented groups in the STEM disciplines, including Black, Hispanic, first-generation college, and low socioeconomic status students. The faculty and graduate students in the Mathematical Sciences are committed to diversifying our student population and welcoming new, talented individuals from underrepresented groups.

In 2019, the graduate committee proposed joining the **Math Alliance**, an organization that assists minority undergraduate students in applying to and succeeding in graduate programs in the mathematical sciences. Alliance faculty would be involved in activities such as mentoring, developing collaborations with REU programs, and attending the annual Field of Dreams Conference. They would also build and maintain an Alliance Graduate Program Group, which has the "goal of ensuring that underrepresented students who wish to pursue an advanced degree in these departments will thrive, and they have committed themselves to a set of best practices." In just a few months, several graduate students worked alongside UD faculty to submit a successful application to join the Math Alliance.

Several faculty members have joined the Alliance Graduate Program Group who will mentor first and second year students. They will be a channel of communication between students and faculty in the department. This mentoring plan contains several pillars, derived from fruitful conversations between faculty, graduate students, and the AWM chapter at UD:

1. To help new graduate students make connections in their first several weeks/months in the department;
2. To guide graduate students as they navigate various aspects of graduate school, and particular University and departmental rules and regulations;
3. To help students optimize their educational experience, and to assist their socialization into the disciplinary culture; and
4. To ensure that graduate students struggling in their academic work or personal lives receive the attention and intervention needed to help them overcome difficulties.

This is an opportunity for the University of Delaware to show support for marginalized groups and to help them succeed in mathematics, while showing that we are committed to promoting and valuing racial diversity.. All members of the community will experience more diverse viewpoints and a sense of community that reflects the demographics of the world. To change the status quo, we all need to take initiative and have hard conversations that lead to systemic change. It is of utmost importance that we in this department act and not sit idly by, and joining the Math Alliance is a worthy first step. We must continue to look at our departmental policies to prevent disenfranchisement and promote success for all students, while relentlessly pursuing equality in our department, community, and world.

ALUMNI SPOTLIGHT

My Life at UD & Beyond

KAIJING KEVIN WANG ‘13 BSC MATHEMATICS, DATA, ANALYTICS & AI STRATEGY & OPERATIONS CONSULTING LEAD AT ERNST & YOUNG UK

I still remember the first day I moved into George Read Hall in Laird Campus—a new country, a new school, a new home, and a new life. It was a ‘dream come true’ with freedom and happiness in the air, but I wouldn’t have imagined what those four fruitful years could mean for my future. Fast forward 12 years later, looking at the number of years passed in disbelief, I have since graduated from UD, worked in Management Consulting for 8 years specialising in data, analytics & AI across industries, and lived in New York, Toronto, and now London pursuing my professional and personal passions. I have witnessed my fellow graduates and friends from Department of Mathematical Sciences chasing their own dreams, and my experience is only one of the possibilities that the family of blue hens have created.

The flexibility of exploring and changing majors at UD led me to mathematics, a major I never thought I would end up studying with utmost interest. Starting at UD as an Economics major, I gained exposure to various arts, sciences & engineering knowledge through required and elective courses, and was fascinated by mathematics, and how it is integrated into other subjects and eventually utilised to tackle real world problems. The journey wasn’t an easy one, but I was helped by numerous mentors along the way, my professors who worked in and out of their office hours to help me make the most of my time on campus. From them I learnt lessons of a lifetime, ones that have continued to push me to explore with curiosity, learn with passion, analyse with critical thinking, and challenge myself and coach others where I can.

One cannot understate the importance of peers and alumni, without whom I wouldn’t have some tremendous life opportunities today. Before embarking on a consulting journey, I considered actuary as an option, and reached out to alumnus Matt Surles ’03 who I found on LinkedIn for advice. He couldn’t be more gracious and patient in promptly responding to my queries with incredible details regardless of how busy he must have been. It broke my heart to learn his passing when I tried to catch up and express my gratitude again years later, but needless to say he left his mark on all the people he had helped through the years. It was my accounting friends who put Big 4 on my radar, and introduced me to UD’s Career Services Centre with a world of effective resources. That was also where I found the data analytics internship job post by Deloitte New York Office, in the spring semester of my junior year at a time when Big 4s were not actively recruiting for Consulting positions at UD. And the reason they were looking at UD, along with Harvard, Duke, Brown and Carnegie Mellon, was precisely because the Practice Leaders / Partners were both UD alumni. I was overjoyed when I received an offer as one of the two, they extended nationally after rounds of interviews both on the phone and on site in World Financial Centre in New York. This internship was a gateway to landing another Consulting job at PwC in my Senior year and eventually leading me to EY, a company that gave me an opportunity to work and live in three countries so far.

The university life was nothing short of fun, and this was aided even further by being in close proximity to major cities like Philadelphia, New York, and DC. I joined student organisations, planned & executed student events, performed classical piano in multiple occasions, and started my fitness journey. The good friends I’ve made will always be my brothers and sisters regardless of our physical distance these days. If there was anything else I could have done, I would have pushed my boundary even further and engage in more campus activities including sports, meet more friends, and take advantage of so much more that UD had to offer. As a Blue Hen, I am truly proud of the developments of the school over the years, and the achievements of its graduates. This includes the increasing opportunities at campus recruitment due to UD's improved recognition by leading employers, and the Data Science Programme that Department of Mathematical Sciences offers in response to a highly demanded capability across business industries around the world.

Last but not least—dare to be a blue hen; dare to be first.

My UD Experience

NATASHA GUREVICH '21 BSC APPLIED MATHEMATICS, QUANTITATIVE BIOLOGY

As a recent graduate from the math department, my time at UD has quickly come to a close. Reflecting on my time here and remembering my worries about selecting the right school, I now know I could not have made a better decision than choosing to study quantitative biology at the University of Delaware.

In high school, I really enjoyed biology, but I was particularly drawn to genetics and the data driven sides of biology. I loved the problem-solving aspect of genetics, and I was able to use my math skills to work through the problems. Biology is a large field, and I began to realize that focusing on the computational applications was exciting to me.

UD's program in quantitative biology is really unique; I don't know of any other schools that offer an undergraduate degree that combines math and biology in the same way. It was the perfect way to focus on the specific aspects of bio that I cared about. Ultimately, I chose UD because it just felt right. I could see myself as a student here and it had everything I wanted: a major that excited me, all the extra curriculars I wanted to be involved in, and a beautiful and welcoming campus and community.

When I got here and started taking classes, I realized more and more how strong the connection between math and biology is. After taking some computer science courses that I greatly enjoyed, I saw how perfectly that field fit into my interests, and I added a bioinformatics minor. A lot of the courses for my major, while they are math courses, gave me opportunities to explore my specific interests in biology. I completed a project exploring linear algebra applications in genetics, and in my senior fall semester, I developed a system of differential equations to model COVID-19 to analyze the effectiveness of various mitigation strategies. I realized how versatile math is, and how easily I could tailor it to support and complement my passions.

I also chose UD for the plethora of research opportunities for undergraduate students. I knew I wanted to get involved in research, but it was something that always intimidated me. But, as a math major, I had a lot of options. Not only is there research happening in the department, but the skills I had from my math courses made me an asset to other fields as well. I joined the Gleghorn biomedical engineering lab my junior year, and I recently completed a senior thesis project that was entirely my own. I was not just an assistant doing busy work for graduate students—I was running my own project. Still, my advisor and the graduate students in the lab helped me develop the idea and were always there to provide guidance and feedback.

Throughout my time as a member of the lab, I developed code to reanalyze existing gene expression datasets for sex differences. There are a lot of public databases filled with data from gene expression experiments, where scientists study if there is differential gene expression between several groups. For example, are genes expressed differently in individuals with a specific disease versus those without? I created a tool that will access data that is already publicly available and reanalyze it to see if there is differential expression between males and females. This will help gain a better understanding of why certain diseases disproportionally affect males or females. The project involved a lot of statistics and data processing, but it was all biological data, so it perfectly integrated my interests.

I had a difficult time choosing a college four years ago, and I worried that I would arrive at UD and wish I made a different decision. Each semester, I became more and more confident that I made the right choice. I know now that UD was the right place for me, without a doubt. My education from the math department and all the opportunities UD provided make me excited for what the future holds. I will be pursuing my PhD in Bioinformatics at Boston University this coming fall, and I am so grateful for the UD math department for making me feel so ready and capable for this next chapter of my life.

My Time as a PhD Student at UD

NICHOLAS RUSSELL '21 PHD APPLIED MATHEMATICS

The concept of mathematical research never even crossed my mind until I took a differential equations course as a sophomore at Marist College. I was enamored by how my professor, Dr. Glomski, presented how simple equations could explain how epidemics could spread throughout a society and how mathematics can admit such beautiful representations of the world around us. That influential moment led me to research the Ebola Outbreak in West Africa with that same professor, to an REU in Chattanooga to research difference equations, and ultimately to our department at the University of Delaware to pursue a PhD in Applied Mathematics.

While at UD, I had the pleasure of working with Dr. Louis Rossi to model and analyze the movement and pattern formation of phytoplankton to understand the underlying causes of harmful algal blooms. In our first two summers, we conducted our own experiments in the MECLab in the basement of Ewing Hall to explore the various mechanisms governing planktonic motion. Working with two undergraduates and collaborating with marine biologists at UD, we concluded that plankton form aggregations due to two main mechanisms: their run-and-tumble swimming motion and autochemotaxis, where plankton release a chemical to signal others and then move towards the chemical. Our model captures these mechanisms, and by varying parameters, we are able to glean how each parameter affects planktonic aggregation patterns in the absence of fluid flow.

I have been extremely fortunate to participate in several other research experiences in my five years in this program, many in interdisciplinary environments. In 2017, I collaborated with biologists and mathematicians at the Mason Modeling Days, where we constructed a model of the HIV transcription process and ultimately published that research. In 2018, I went to Oxford University to collaborate with other graduate students at the InFoMM Graduate Camp to optimize battery output for electric currents to prevent brownouts and blackouts. Lastly, I was a NSF Mathematical Graduate Student Intern (MSGI) at the US Army Corps of Engineers in Vicksburg, Mississippi where I collaborated with a chemist and physicist to use techniques from information theory and statistical mechanics to deduce how flocks of birds and schools of fish move collectively.

Outside of research, I am an incredibly passionate educator and ardent community activist. My teachers, advisors, friends, and family have provided me with incredible support, and I want to be that catalyst and support system for others who have not had that luxury. At UD, I was the SIAM Student Chapter president in 2018-2019, on the executive board of AWM for two years, and the graduate student liaison on the Graduate Committee in the math department for the past two years. I received the Baxter-Sloyer Graduate Teaching Award both in 2019 and 2020 for my teaching and the SIAM Student Chapter Outstanding Efforts and Accomplishment award in 2019. Outside of UD, I have taken several volunteer positions, most notably on the Board of Directors for the Delaware Science Olympiad. Assisting this middle school and high school competition along with the help of several other graduate students was such a pleasure, as we watched students foster their love for science.

In my free time, you can find me at the gym, hiking various trails, watching and playing sports, and playing music on my trumpet or euphonium. I have accepted a postdoctoral position at the Max Planck Institute for Plant Breeding Research in Cologne, Germany under the direction of Dr. Pau Formosa-Jordan, where I will be studying the dynamics of cellular patterning of various plant developmental processes. I am extremely grateful for the friends and mentors that I have made while at UD, and I cannot thank them enough for their tireless, unwavering support of me.

RAYANNE LUKE '21 PHD APPLIED MATHEMATICS

I grew up in apple country on the shore of Lake Ontario in Williamson, New York. I always liked math and was good at it, but assumed I'd become a high school teacher. In my junior year of college at SUNY Geneseo, I had the opportunity to join a research team with three other students and a professor to study matrix analysis. I felt unqualified, but my mom still encouraged me to apply, and I'm glad she did! It took a lot of work to get comfortable not knowing the answer all the time and realizing that's precisely what research is. The next summer I did research with a cancer image analyst at Rutgers University. This sparked my interest in medical applications of math, which continued into graduate school.

I was attracted to the math department at the University of Delaware by the strong applied math faculty contingent and its built-in support systems for grad students, namely a review program and guaranteed first year summer funding. After my first summer working with Dr. Richard Braun on numerical discretization methods for models of human tear film dynamics, he became my advisor. Since then, I've worked with a range of collaborators, including optometrists and data scientists. I use our models to analyze videos of human eyes in order to understand the underlying causes of dry eye disease.

I've been able to present my work both virtually and in-person, including at the 2020 (Vancouver) and 2021 Association for Research in Vision and Ophthalmology annual meetings and 2020 Society for Industrial and Applied Mathematics (SIAM) Annual Meeting. I have also attended workshops at UC San Diego and the Institute for Mathematics and its Applications at the University of Minnesota. My honors include the 2018 Baxter-Sloyer award for excellence in teaching and the 2021 Wenbo Li award for excellence in research.

UD's chapter of the Association for Women in Mathematics (AWM) interested me, so I joined right away my first semester. I served as president for the 2019-2020 year. We are committed to diversity efforts for all underrepresented groups in math, and I'm especially proud of our work coaching a local Title I school's 7th grade math league team and reincarnating the department's peer mentoring program for grad students. Through our SIAM chapter, I designed and ran a competition section on geologic mapping for high school students at the Delaware Science Olympiad. I also organized our department grad student seminar series for two years.

When I'm not doing math, you might see me out on a run on the roads or trails of Newark, sometimes with a fellow math grad running buddy. I also enjoy reading, playing the piano, and cooking delicious vegetarian dishes. I am grateful for many memorable moments made with my cohort over problem sets and dinners on Main Street, and for advice and support from Dr. Braun and the rest of the Tear Film Research Group. In July I will begin a joint postdoctoral fellowship at Johns Hopkins University and the National Institute for Standards and Technology, working with Dr. Paul Patrone in the area of flow cytometry.

RECENT PHD GRADUATES

2019

Kevin Aiton
Applied Mathematics, (Advisor: Dr. T. Driscoll)

Chuan Bi
Applied Mathematics, (Advisor: Dr. M-J Y. Ou)

Patrick Cesarz
Mathematics, (Advisor: Dr. R. Coulter)

Seth Cowall
Applied Mathematics, (Advisor: Dr. P. Cook)

2020

Emily Bergman
Mathematics (Advisor: Dr. R. Coulter)

Benjamin Civiletti
Mathematics (Advisor: Dr. P. Monk)

Mingchang Ding
Applied Mathematics, (Advisor: Dr. J. Qiu)

Shukai Du
Applied Mathematics, (Advisor: Dr. P. Monk)

Hasan Huseyin Eruslu
Applied Mathematics (Advisors: Dr. P. Monk & Dr. F. Sayas)

Kristopher Hollingsworth
Mathematics (Advisors: Dr. M. Ghandehari & Dr. D. Guillot)

Lorinda Leschock
Mathematics (Advisor: Dr. F. Lazebnik)

Navid Mohammad Mirzaei
Applied Mathematics, (Advisor: Dr. P-W. Fok)

Benjamin Nassau
Mathematics (Advisor: Dr. F. Lazebnik)

Hanlin Zou
Mathematics (Advisor: Dr Q. Xiang)

2021

Melissa Fuentes
Mathematics (Advisor: Dr. F. Lazebnik)

Kelvin Rivera-Lopez
Applied Mathematics (Advisor: Dr. D. P. Rizzolo)

Ryanne Luke
Applied Mathematics (Advisor: Dr. R. Braun)

Nicholas Russell
Applied Mathematics (Advisor: Dr. L. Rossi)

NEW HIRES IN 2020-21

CHRIS COX

Chris Cox is returning to UD for his second stint as a temporary Assistant Professor. After earning his BA from Williams College and his MS from Northwestern, Dr. Cox worked as a faculty member at Illinois Central College from 1998 to 2011. He then entered the doctoral program in Mathematics at Washington University in St. Louis, where he studied dynamical systems and earned his PhD in 2016. After a year as a Postdoctoral Teaching Fellow at Washington University, he came to UD for a year as a temporary Assistant Professor and then went to Tarleton State University, where he taught for the past two years. In Fall 2020, he will be teaching Math 230 and Math 243.

DIEGO PENTA

Diego Penta joins the department as an Assistant Professor (Continuing Track). Dr. Penta received his MS in Mathematics from Rutgers University in 2010 and his PhD, also in Mathematics, from SUNY-Binghamton in 2016. His research, in Kac-Moody Lie algebras and their representations, resulted in two papers in the *Journal of Physics A: Mathematical and Theoretical* and one in the *Journal of Combinatorics and Number Theory*. Following his doctoral studies, Dr. Penta was a Lecturer at The Ohio State University and a visiting researcher at Hebrew University of Jerusalem.

Before "seeing the light" and deciding to pursue mathematics, Dr. Penta earned a BS in Materials Science and Engineering in 1996, after which he worked in industry for nine years.

Dr. Penta's professional interests lie in teaching introductory and intermediate level collegiate mathematics, and particularly in the use of class-based discussion and other active learning techniques. He joins the Mathematical Sciences Learning Laboratory (MSLL) team, which implements such strategies in key introductory courses.

MIN RANABHAT

Originally from Nepal, where he earned an MA in Mathematics, Min Ranabhat came to the US in 2014 and earned an MS in Applied Mathematics from the University of Alabama-Birmingham. In 2020, he earned his PhD in Mathematics from Kansas State University, obtaining a Graduate Certificate in Applied Mathematics in the process. His dissertation research focused on inequalities in PDEs, specifically on the Poincaré and Sobolev inequalities in the Monge-Ampére quasi-metric structure. During his graduate studies, Dr. Ranabhat taught numerous courses: precalculus, calculus and linear algebra, elementary differential equations, and introductory statistics. He has experience as a course coordinator, and he is now looking to start a teaching-oriented career. His initial assignment is Math 114.

GANGOTRYI SORCAR

Gangotryi Sorcar earned her BSc and MS in Mathematics in her home country of India, after which she came to the U.S. to pursue doctoral studies at SUNY-Binghamton, where she earned her PhD in 2015. Her doctoral research focused on differential topology and geometry. After earning her degree, Dr. Sorcar spent three years at the Ohio State University as Ross Assistant Professor, and she then spent the past two years as a Postdoctoral Fellow at the Einstein Institute of Mathematics at Hebrew University of Jerusalem. In past positions, she has taught calculus and linear algebra repeatedly, and has also taught courses on the geometry of curves and surfaces and on general topology and knot theory. Her initial assignment at UD consists of Math 241 and Math 349.

ALFREDO VILLANUEVA

Alfredo Villanueva earned his BSc at the University of San Marcos in Peru, his MS in Mathematics from the University of Puerto Rico, and then his PhD, also in Mathematics, from the University of Iowa. His doctoral studies, completed in 2007, focused on differential geometry and differential equations. Since earning his PhD. Dr. Villanueva has held faculty positions at the University of Puerto Rico, Savannah State University, and the University of Saint Francis. He has taught numerous college mathematics courses, ranging from college algebra and quantitative reasoning to abstract algebra and advanced calculus, plus differential manifolds and differential geometry at the graduate level. At UD, his initial assignment consists of Math 113 and Math 351.

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