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In Memoriam: Cathleen Synge Morawetz (1923-2017)

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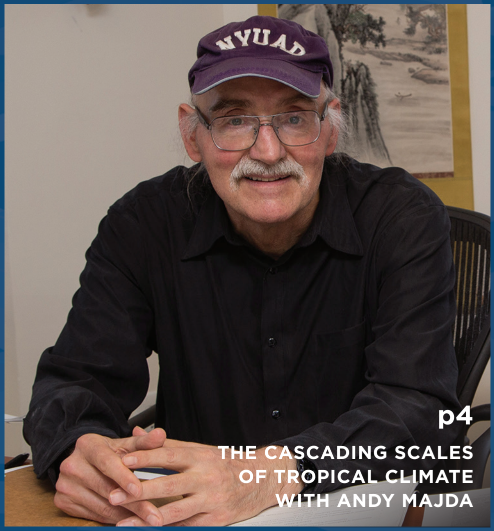

ALSO IN THIS ISSUE:

NYU COURANT INSTITUTE OF MATHEMATICAL SCIENCES

The architecture of intelligence
With Yann LeCun

by April Bacon

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At NYU and Facebook, Yann LeCun is pursuing the most promising edges of research in his long quest to understand intelligence and bring it to life in machines.

Training a machine is a bit like training a person, says Yann LeCun, Silver Professor at Courant and head of Facebook's Artificial Intelligence Research (FAIR) department. "When you want people to operate reliably, you have them go through training. You have them take an exam, you train them some more, and then do an apprenticeship. It's a similar thing for a machine—you have to kind of take it through."

The engine of a machine's learning is provided by neural networks. In a neural net, millions of computational "nodes" are connected to each other, a bit like neurons in the brains of animals and humans. Convolutional neural nets (ConvNets) are a type of neural net whose architecture is inspired by the visual cortex. They make possible much of what we see (and don't see) in ever-more intelligent machines. For example, four ConvNets provide users with the Facebook image experience alone. For every one of the between 1 to1.5 *billion* photos uploaded to the social network every day, one ConvNet filters out objectionable images, another translates image content into words for the visually impaired, a third one analyzes the images to show people content they are likely to be interested in, and a fourth one recognizes your friends' faces.

In the early 1980s, about half a decade before the internet was created, Yann was an undergraduate student at Ecole Superieure d'Ingénieurs en Electrotechnique et Electronique working on back propagation, a learning algorithm for multi-layer neural networks. He ran experiments on medical data sets of a then-enormous 6,000 samples. Only a handful of researchers were working on neural nets at the time. The AI community had moved away from neural net approaches in the late 1960s, focusing instead on logic, reasoning, and so-called expert systems. As the theory goes, the 1969 book *Perceptrons by* Marvin Minsky and Seymour Papert put the last nail in the coffin of a field that was already facing widespread pessimism and a steep decline in funding. In the book, Minsky and Papert laid out perceived limitations of neural nets as a step towards AI.

Yann arrived to the area by way of a philosophy text: *Language and Learning*, the transcript of a 1975 debate between linguist Noam Chomsky and Jean Piaget, the developmental psychologist who laid out the stages of cognitive development in children. In the book, Yann found an article by Seymour Papert himself, praising the Perceptron—one of the first neural networks—and its learning abilities. He was hooked.

His work on ConvNets began in 1987 as a Postdoc at the University of Toronto working with Geoffrey Hinton. The following year he joined AT&T Bell Laboratories and began applying his research to real data sets for handwriting recognition.

As Yann says, intelligence requires understanding the world. We can understand the world because it is compositional—larger and more complex things are made of smaller and simpler things. The architecture of a ConvNet exploits the compositional nature of the world by processing images or sound or text in a layered fashion. In the case of an image, the ConvNet first detects oriented edges, then simple motifs formed by combinations of edges (such as corners or crosses), then parts of objects (such as the tires of a cars), then objects (a car).

It does this in the following way: For each overlapping tile of an image, the machine applies a series of filters each indicating the presence or absence of a particular motif, like an edge at a particular orientation. The filters are applied to all locations in an image, producing a representation of each window as a stack of numbers indicating the presence or absence of each motif. The following layer similarly detects combinations of first-layer motifs over larger input windows. Subsequent layers detect larger and more abstract motifs, until the last layer which represents object categories. The design of the ConvNet architecture allows it to recognize objects regardless of their positions within the image, their size, or their orientation.

Back propagation, or "backprop," is the process by which the ConvNet is trained. For example, an image of a car is shown to the ConvNet, which produces an output. If the output is correct, nothing is done. If the output says "dog" instead of "car," the back-propagation procedure computes how to modify the strengths of each of the connections between all the nodes in the ConvNet so that the output of the network gets closer to the desired one. The process is repeated with thousands, even millions of images, until the strengths of the connections settle to a stable configuration. As part of this learning process, the ConvNet learns the filters, represented by the strengths of connections between nodes, that form appropriate abstract representations of images. It learns automatically that cars have wheels, dogs have legs, and airplanes have wings, and it learns detectors for these concepts.

The decade-long work culminated in the first practical deployments of ConvNets in the mid-1990s for such applications as reading bank check amounts automatically. The system was described in a 1998 paper "Gradient-based learning applied to document recognition" by Yann and collaborators. By the early 2000s, machines using Yann's technology were reliably reading the amounts on 20 percent of all checks in the U.S. At present, this seminal paper has been cited over 10,000 times (and counting). Yann's contributions to the field have earned him awards such as a Lovie Lifetime Achievement Award, IEEE Neural Network Pioneer Award, IEEE PAMI Distinguished Researcher Award, and election to the National Academy of Engineering. And, of course, recruitment to Facebook, which he joined as the head of FAIR in December 2013.

The members of FAIR are located primarily in New York, Menlo Park, Paris and Montréal. Smaller groups are also in Tel Aviv and Seattle. In total, there are about 120 scientists and engineers. The size of the unit grows substantially in the summer, when 75 interns are brought on, many of whom are NYU students.

One of the team's primary goals is prediction, which Yann believes is the essence of intelligence. Prediction requires basic contextual knowledge of how the world works—much like, to refer back to Piaget, a child grasps causality, begins to act towards goals, and learns how objects work (for example, that they still exist when out of sight) at roughly the same time.

We make small-scale predictions every day: If a tennis ball is bouncing down the street, one may predict that a dog may be running after it. If a video displays only one side of a living room, we can approximate the other half because we know that rugs, bookcases, and couches are generally symmetrical. The team at FAIR has worked on machine prediction for these kinds of tasks. For the second task of predicting the future in a video, they have developed a multi-scale convolutional neural net trained with adversarial training. As Yann says: "It has a few tricks in it." Their system can predict video a half a second into the future. In one demonstration, a child in a photo leans closer to blowing out the candles on her cake, getting slightly blurry in the predicted frame, but moving in a fashion very similar to reality.

The reason this machine is such a good student is because it has an adversary—a second neural net, known as a discriminator. Adversarial training was invented by Ian Goodfellow less than half a decade ago, when he was a PhD student at the University of Montréal, and Yann says it's the most interesting thing to happen to machine learning in a decade.

In adversarial training, two neural nets train against each other. A generator pursues a given task (e.g. "predict what happens next") and is constantly trying to fool the discriminator into thinking its predictions are reality. The discriminator is a critic, assessing the quality of the prediction, and telling the generator how to improve its predictions.

While working on the prediction task, the machine learns a little bit of what the world is like. It learns how cars moves, that pedestrians will disappear behind buildings, and that a tree will eventually pass out of the frame if the video is from a car moving forward. It does all of this without any human having to label what is a road, a tree, or a pedestrian. In machine learning parlance, this is the holy grail of the field: unsupervised learning.

With supervised learning, the machine is given the answer. "But when you want to get the machine to predict the future, there is no single correct answer," says Yann. If a pen is set on its end and let go, for example, and a machine predicts it will fall forward, but it falls backwards, the machine isn't entirely right or wrong.

"We need a way to tell the machine, okay, you got it wrong, but in fact it's among a set of plausible futures that are all right and therefore I'm not going to punish you for producing the wrong answer. The problem is that we don't know how to characterize the set of plausible futures. So we train a second neural net to tell the first neural net whether its answer is correct or not. And those two neural nets train against each other."

There have been some impressive demonstrations of adversarial training, says Yann, but "nobody has a completely reliable recipe yet. Sometimes it doesn't work and we don't understand why. But in the examples where it works, it produces amazing results."

In one demonstration, Yann and NYU students have created a system that trains on handwritten samples of the alphabet from several people. Without having the completed alphabet from any one of the writers, the system is able to complete the alphabet in any of the written styles.

"After you've trained a system you can generate any character in any style," says Yann. "And you can do this for video game characters, for faces, for all kinds of things." The system can be trained on faces, and then offer a set of parameters that change the lighting condition, the orientation of a face, whether the person photographed is smiling or not. "You can [swap] the style of one face with the face of another person and kind of mix the two." In another demonstration conducted by Yann and his students, a system has been trained on images of dogs in order to produce totally new photographic instances of the animals. They appear pretty accurate when squinting. As Yann says, they are more like "soft" dogs, or Salvador Dali dogs.

"We're going to make progress on this," he says. "But this is the kind of technique we hope will get machines to learn primitive models of the world, which is an essential part of intelligent systems." Five years from now, Yann expects there to be other techniques that may work even better, but "they'll probably build on the idea of adversarial training," he says.

Artificial Intelligence will continue to have a big impact on our everyday lives. From self-driving cars to personalized medicine and virtual assistants, it offers an extraordinary vision of the near-future. Yann believes that a decade or two from now, the changes will cause a major paradigm shift in human relationships. When they are more seamlessly integrated into our lives, we will be able to refocus our own intelligences away from the machines and back to the human level. "People will, I think, attribute more value to human interaction and less to material goods, because those will be produced by machines," he says. "It will transform society and human relationships. There's no question." ■

The cascading scales of tropical climate
with Andy Majda

by April Bacon

Andrew Majda and Nan Chen

Andrew Majda's cutting-edge approaches to modeling the tropical climate capture its interconnected mechanisms and open new roads to climate simulation and prediction.

Andrew ("Andy") Majda, Professor of Mathematics and The Samuel F. B. Morse Professor of Arts and Science, joined the Courant Institute from Princeton 23 years ago to set up a research center in an area that was entirely new to him. Now, the Center for Atmosphere Ocean Science (CAOS) is a leading program, with 8 faculty members pursuing a wide range of problems at the forefront of climate science.

About his venture into the area, "I was betting on some new stuff," Andy says. "I felt the world was ripe for stochastic statistical models interacting with nonlinear PDEs." His bet paid off for the field. As stated in the citation for the 2015 ICIAM Lagrange Prize, Andy has made "revolutionary contributions to the development and analysis of mathematical models in atmosphere ocean science."

What is breathtaking about climate is also what makes it so challenging. As Andy says, "Everything couples together." For example, the temperature of the ocean, precipitation, turbulence, waves, and cloud formation can all alter developing weather. What happens at the scale of tens of kilometers cascades up, affecting climate at a hundred times that scale—and vice versa.

Large-scale weather phenomena that originate in the tropics can modify weather across the entire globe and cause fluctuations in global warming trends.

Andy and his collaborators have developed breakthrough approaches that master such complexities, unveiling the beautiful mechanisms of our tropical atmosphere and its global reach. Their simplified models for the El Niño-Southern Oscillation (ENSO), for example, match nature and make strong predictions. Even more remarkably, they handle these tasks while being efficient with computing power, outperforming computationally expensive models that produce mixed results even on the world's largest supercomputers.

"Forty years ago, I naively thought El Niño was completely understood as a periodic [i.e. occurring at regular intervals] oscillation," says Andy. "But in some of my interactions with people who do clouds and climate, they told me that the El Niños in the last 30 years don't look like the historical El Niños at all. They're very different, and they profoundly influence climate change."

The model developed by Andy, postdoc and former student Nan Chen (Ph.D. '16), and postdoc Sulian Thual reproduces ENSO systems in all their variety for the first time. Because the work requires selecting the right variables and relationships which will allow a simplified model to represent reality, it demands mathematical rigor, advanced knowledge of geophysical processes, and nimble intuition.

The team began with a model of the ocean-atmosphere system that is linear and deterministic. From this stable foundation, variation develops via a coupled system of stochastic [i.e. randomly determined] wind bursts and nonlinear advection of sea temperature. The model is sensitive to when and how El Niño is developing and will switch states to accommodate the emerging pattern. With explanatory power, the model reproduces the last three decades of the El Niño climate record, including the 1997 extreme "El Niño of the Century," the weak Central Pacific El Niño of the early 2000s that contributed to draught conditions in the western and southwestern U.S., and the 2014-2016 El Niño that was delayed by a year.

In the latter case, conditions were favorable for El Niño in early 2014. In the western Pacific, sea surface temperature was warmed, winds and depth of thermocline (a transition layer between warmer surface water and colder deep water) were increased, and westerly wind bursts were present. But as the weather system propagated east, the westerly wind bursts were counteracted by unusually strong easterly winds, defeating the emerging system. Amenable conditions were once again present at the start of 2015, but in contrast to the previous year, westerly winds dominated, and El Niño emerged.

Andy's model accounts for such subtleties in sophisticated ways. For example, because increased wind bursts usually correlate with warmer sea temperatures, presence of the latter will switch the model into a state of amplified wind intensity, making the model—like nature—susceptible to producing El Niño. The model also captures the effects caused by wind direction being either dominantly easterly or westerly.

The 1997 "El Niño of the Century" was triggered by a large-scale weather pattern known as the Madden-Julian Oscillation (MJO), in a scenario similar to 2015. Unlike El Niño, which is a standing pattern over the eastern Pacific Ocean, the MJO is a traveling wave that originates in the Indian Ocean and moves eastward, cycling back to its point of origin over a period of one to two months. In 1997, an MJO moved in to the eastern Pacific, intensifying the El Niño which was ripe to grow. The model also captures this interaction through its stochastic, state switching system.

After the seasonal effect of the sun, ENSO has the largest influence on our climate across the seasons and MJOs and monsoons have the largest intraseasonal effect. “It’s a cascade of scales,” says Andy.

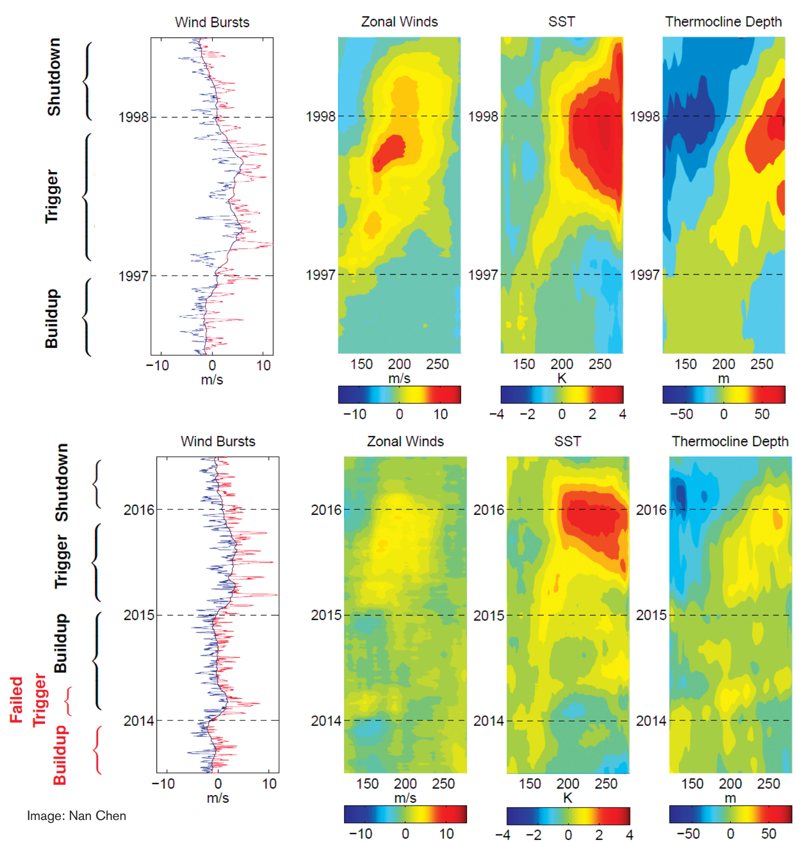
All three of the above weather patterns are responsible for extreme weather across the globe. “You tickle it in the tropics, it rumbles in the poles,” says Andy. As such, simulating the climate in any region of the world is in part contingent upon being able to model these irregular patterns in the tropics and understanding them is tremendously meaningful to society and human lives. Yet, until recently, no operational models succeeded at their prediction.

In 2012, Andy founded an NYU-Abu Dhabi research unit along with co-Principal Investigators and Courant Professors Olivier Pauluis and Shafer Smith. The Center for Prototype Climate Modeling advances research that in part aims to deepen our knowledge of climate and ability to predict it.

Under its auspices, Andy and collaborators have constructed the first accurate climate model simulations of MJOs and monsoons using a novel stochastic parameterization of clouds.

The cloud model originates in work by Andy and Boualem Khouider, a former postdoc of Andy’s who is now at the University of Victoria. In the late aughts, the pair built a multi-cloud model that is computationally cheap to add on to operational models and conceptually illuminating.

Around most of the globe, rotation effects of the planet confine weather systems to a scale of about 1,000 kilometers. This rotation effect, however, disappears exactly at the equator, transforming the equator into a kind of waveguide, with its southern and northern bounds acting on atmospheric waves much in a similar manner as coastlines. Here, giant wave patterns called “convectively-coupled waves” form systems of moisture, gravity waves, and clouds at the weather scale scale of about 1,500 kilometers. There are three types of significant clouds in these systems—congestus (shallow), deep, and stratiform (giant anvils).



El Niño events come in several varieties. Here, observational phenomena for the 1997-1998 classical super El Niño (top) are compared with the 2014-2016 delayed super El Niño (bottom). Wind bursts, zonal winds, sea surface temperatures (SST), and thermocline depth all correlate and impact the emerging weather systems.

Convectively-coupled wave systems contain many smaller-scale storms of about 150 kilometers in size which exhibit the same cloud types as above and “amazingly enough, at 15,000 kilometers [the scale of the MJO], you see the same pattern of congestus, deep, and stratiform,” says Andy. “That’s an example of a turbulent system which has a kind of strange self-similarity. The same kinds of patterns repeat themselves on 1,500, 150, and 15,000 kilometer scales. The ones on 15,000 kilometer scales have the most planetary scale impact. The ones on the smaller scales can create a lot of human suffering.”

Within this self-similar hierarchy, clouds are also randomly “bubbling” everywhere—“that’s where the stochastic thinking comes in,” he says. “You need models that will discriminate when clouds are going to be harmless or when they’re going to have coherent upscale impacts.”

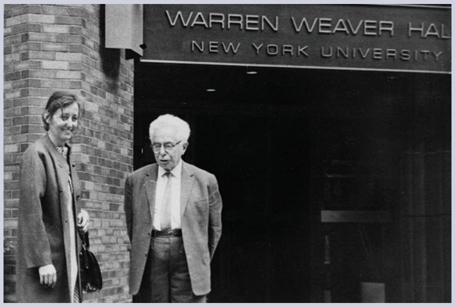
The pair demonstrated that these three patterns are key to understanding and modeling the atmosphere in the tropics. Now, in order to produce the MJOs and monsoon simulations, they and other collaborators (from the University of Victoria, the National Center for Atmospheric Research, and the Indian Institute of Tropical Meteorology in Pune) have made their stochastic multi-cloud model operational in the National Centers for Environmental Prediction’s Climate Forecast System version 2 (CFSv2)—one of the most advanced global models of the ocean, land, and atmosphere, which hourly releases data collected from across the world for almost fifty climate-related variables such as cloud frequency, sea surface temperature, gravity waves, and air temperature.

The multi-cloud model is load-bearing in the CFSv2. The team is still working on refinements to the model, though its sturdy handling of variation in spatial scale and of randomness already yield incredibly accurate simulations of MJOs, monsoons, and convectively coupled waves. It reproduces the mechanisms of these phenomena as well as their physical structure. The simulated weather events match nature in terms of variables such as speed of propagation, location, and severity. The results further validate that the three cloud types and their interactions are a major component to atmospheric convection in the tropics.

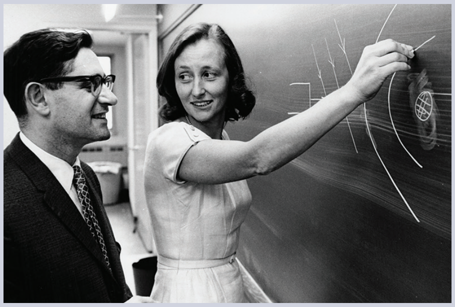
“We have the best results in the world. I know it sounds ego-centric, but it’s true,” says Andy. “This is a huge breakthrough. And it’s because of the interdisciplinary spirit we have at Courant.”

In Memoriam: Cathleen Synge Morawetz (1923-2017)

Herbert and Cathleen Morawetz.



Cathleen Morawetz and Richard Courant outside of Warren Weaver Hall.



Harold Grad and Cathleen Morawetz.

The legacy Cathleen Synge Morawetz left to mathematics is foundational and enduring. She made seminal contributions to partial differential equations, in transonic flow, scattering theory, and other fields. As a leader, Cathleen was generous, visionary, and effective. She brought these traits to many leadership and advisory positions throughout her career, including as the Institute's Director from 1984-1988. In 1945, Cathleen earned her Bachelor's from the University of Toronto, joined M.I.T. as a graduate student, and met and married Herbert Morawetz, a polymer chemist. She arrived to NYU in 1946 and was a colleague, guiding force, and friend for the subsequent 71 years.

Cathleen first visited NYU by invitation of Richard Courant, and her affection for the community was immediate. She "didn't find her home until she first visited NYU," said Cathleen's daughter and NYU Professor of Clinical Law Nancy Morawetz at a memorial celebration held at the Institute in November. "She made lasting friendships beginning in her graduate school days." Cathleen's peers then included Joe Keller, Peter Lax, and Louis Nirenberg.

Richard Courant entrusted Cathleen with editing and rewriting parts of the seminal Courant-Friedrichs text *Supersonic Flow and Shock Waves.* "I had never heard of a shock foil before. That's how I learned," said Cathleen in a 2012 Simons Foundation interview conducted by Marsha Berger. As Director Russ Caflisch said at the event, it was an "immersive learning experience that set the foundation for the rest of her career. By the time the project was completed, she was fascinated by transonic flow and related phenomenon. Over next few years, Cathleen wrote a doctoral thesis and started a family." Cathleen earned her Ph.D. in 1951, became a Research Associate in 1952, and joined the faculty in 1957.

In 1956, she settled an open question in transonic flow. Airplanes traveling at supersonic speeds (above the speed of sound) generate sonic booms which create drag. When nearing supersonic speeds, air flow around the wing is transonic—a mixture of subsonic and supersonic flow. Engineers debated if it were possible to design a wing that would be shockless at transonic speeds. Cathleen proved that even the smallest perturbation will cause shocks, making it fruitless for design. The work had great impact in engineering and yielded important techniques for solving equations of a mixed type. Cathleen continued to make deep contributions in the area over most of her career.

She also made fundamental contributions to the mathematics of waves. In terms of a general understanding of how waves behave when reflected off an object, "Almost nothing was known before Cathleen," said her long-time collaborator Walter Strauss (Brown University) at the celebration. Professor Leslie Greengard drew attention to the many mathematical procedures and objects resulting from Cathleen's work: Morawetz identities, Morawetz multipliers, Morawetz inequalities, the Morawetz bootstrap. "That puts you in a pantheon of the very great mathematicians," he said.

The first female recipient of a National Medal of Science, Cathleen's many honors include election to the National Academy of Sciences, the American Mathematical Society (AMS), and Society for Industrial and Applied Mathematics (SIAM); and an AMS Leroy P. Steele Prize for Lifetime Achievement and George David Birkhoff Prize in Applied Mathematics.

Cathleen was an extraordinary leader. As the 53rd President of the AMS starting in 1995, "she was spectacular," says Math for America President John Ewing, who was Executive Director of the AMS for 14 years. At the time, math was facing many challenges: funding was under attack, jobs for young faculty were scarce, and the web was changing publishing. "She tackled every single one of the problems in a way that only Cathleen could do," John says. Out of an initiative formed by Cathleen came MathJobs. She was on the board of a then-upstart called JSTOR. She was also an advocate and professional mentor for women. "Some of the things that Cathleen did have their profound effect now twenty years later in the mathematics community," says John.

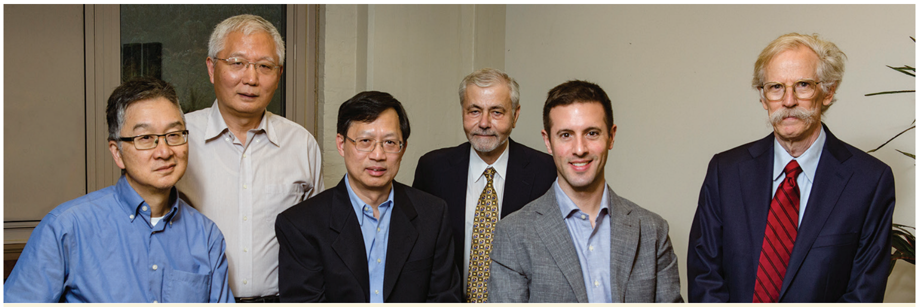
As a leader, "she had vision," he says. "An essential part of that vision was the unity of mathematics." At the time, there was tension between the AMS and SIAM, he notes. But, when Cathleen was President of the AMS, "by some miracle, the president of SIAM was Margaret Wright. The two of them brought people together." The pair fortified a broad view of mathematics within their respective organizations and built a united front for advocating for resources."Cathleen was a master," says Margaret. "I just got to watch her and smile."

Cathleen's presence had a gladdening effect. "When you were with Cathleen, you felt like you were part of something really important," said Russ at the celebration. The event was attended by the broad Courant community, including Cathleen's family, Ernest Courant (Richard Courant's son), Fred John (Fritz John's son), Peter Lax, Louis Nirenberg, and many Courant faculty, administrators, staff, and friends.

"We all miss her," says John. "She changed mathematics. More than many people realize."

Read more about Cathleen's research and achievements at *math.nyu.edu/news/morawetz*

Math departments at Courant and Tandon School of Engineering merge



The Institute integrates six math faculty from the Brooklyn campus and has begun efforts to recast educational programs and open pathways for collaborative research and service.

The Courant Institute and Tandon School of Engineering mathematics departments merged this past September, a big step for the department in completing a transition set in motion in 2014 when Tandon (then the Polytechnic Institute of Brooklyn, widely known as "Brooklyn Polytech") became the engineering school of NYU. As Courant Director Russ Caflisch notes, the 2014 merger completed a circle: NYU had an engineering school at its Heights Campus in the Bronx, which was sold in the early 70s and became a part of Brooklyn Polytech—which is now NYU Tandon. The math merger expands the Courant faculty and holds promise for the Institute's teaching, research, and service missions.

With the merger, Courant welcomes five faculty at the Tandon campus into the fold: Professors Erwin Lutwak (convex geometry, geometric and analytic inequalities), Edward Miller (differential topology), Deane Yang (convex geometric analysis, Riemannian geometry, PDEs), Yisong Yang (nonlinear PDEs, mathematical physics, applied mathematics), and Gaoyong Zhang (convex geometry, geometric analysis). A sixth, Assistant Professor Mike O'Neil (computational PDEs, numerical analysis, fast algorithms), was formerly joint between Courant and Tandon math.

As a whole, the math faculty at both campuses are taking the transition as an opportunity to look at the department's educational programs, starting with a redesign of the B.S. in mathematics. "We are revamping the course offerings to what we deem a modern education in applied mathematics," says Professor Jalal Shatah, chair of a transition committee for the departmental merger. Students enrolled in the B.S. will be required to take five classes that build a substantive and coherent engineering or science elective. "We think of it as a very high level math for sciences degree," he says. The committee has also been constructing coursework for a new M.S. in Engineering Mathematics—though in a preliminary stage, the hope is to launch a degree program that would meet the needs of students in academic, research, or industry career paths.

The B.A. in mathematics will remain at Washington Square under the College of Arts and Science. As math chair Bruce Kleiner describes, unrestricted cross-listed offerings between the two Bachelor's programs means that students will have access to a wider range of faculty and courses, and they will have the benefit of being in classes with their B.A. or B.S. counterparts from just across the East River. Some faculty from Washington Square will teach some courses at the Brooklyn campus, and vice versa. Bruce describes an eventual, natural flow of faculty and students between the two campuses—a flow that also opens an important pathway for collaborative research between math and engineering.

"A lot of the research at Courant is driven by physical problems—physical phenomena that people want to model or understand," says Mike O'Neil. "It'll take a little bit of time to get more interaction between the math and engineering faculty, but it seems like a natural fit. It's been really nice for me to be [at Tandon] because there are a lot of people that care about the same problems that I do."

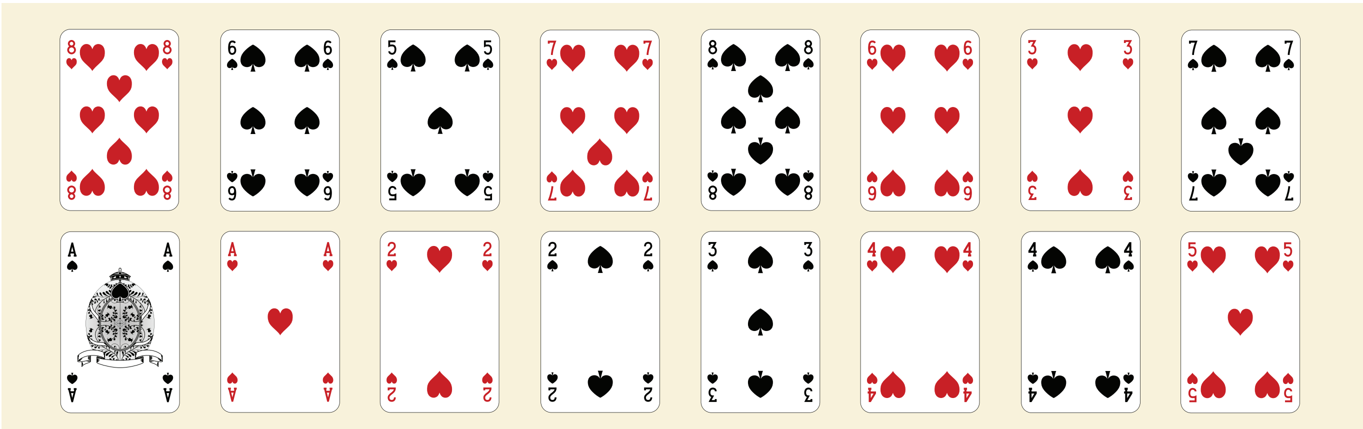
Because the combination of mathematics and engineering is so powerful, the merger offers the Institute opportunities to enrich its outreach programs, says Russ. In service, academia, and research, "five or ten years from now, I'm hoping to see deep and sustained interactions between Courant with the great things that are going on in engineering at Tandon," he says.

To begin that interaction, the best result of the merger would be for an engineer with an interesting scientific problem to walk into a mathematicians office, or vice versa, says Jalal. "I was an engineering undergraduate and I saw it happening a lot," he says. "Having physical proximity is a major asset. I can see down the road some joint grants being written by the faculty that will lead to some very exciting mathematics and engineering ideas." ■

Herbert Morawetz (1915-2017), a polymer chemist and the devoted husband of Cathleen Morawetz, died in October, just a few months after the passing of his wife. Born in former Czechoslovakia, Morawetz went into his family's textile trade before immigrating with them to Canada in 1939 to escape Nazi occupation. He earned his Bachelor's and Master's in Chemical Engineering from the University of Toronto, his Ph.D. in chemistry from the Polytechnic Institute of Brooklyn (now NYU's Tandon School of Engineering), and was a professor at his doctoral alma mater for his entire professional career. In 2003, the Morawetz Lecture Series was funded by former students in recognition of the influential professor. To date, it has brought over thirty distinguished speakers to the Brooklyn campus to give talks across many scientific fields, a breadth which recognizes the wide-ranging intellectual curiosity of the man for which the series is named. Morawetz authored the seminal books *Macromolecules in Solution* and *Polymers, The Origins and Growth of a Science*, served as associate editor for the American Chemical Society (ACS) journal *Macromolecules* for 15 years, and received the ACS's Award in Polymer Chemistry for "outstanding fundamental contributions and achievements" in the field.

Stacking the Deck

By Dennis Shasha, Professor of Computer Science



Consider a deck of 16 cards, consisting of the ace through 8 of hearts and the ace through 8 of spades. You are allowed to arrange the cards in any order you wish. Your opponent chooses a number between 1 and 8. You deal that many cards from the top of the deck and put the last card face up, with a value of, say, k (ace is considered 1). You next deal k cards and put the last card face up, with a value of, say, k'. You then deal k' cards and so on. You continue until the number revealed is greater than the number of remaining cards, in which case your opponent wins, or the last of the 16 cards dealt is an ace, in which case you win.

Warm-Up:
Find an arrangement in which you can win this game.

Solution:
There are many. Here is one possibility:
3 4 5 6 7 8 7 6 5 4 3 2 1 2 8 1

If your opponent chooses, say, 2, you deal the first two cards, so the last card is a 4. Turning over the four cards after the 4 lands on an 8, then eight cards after that lands on a 2. Turning over two more cards lands on the final ace. This will work no matter which number between 1 and 8, inclusive, your opponent chooses.

Now suppose your opponent takes the following eight cards and arranges them like this
5 2 2 3 3 4 4 1

Can you insert the remaining cards among and perhaps before or after these eight and still guarantee to win?

Solution:
Here is one solution, with the inserted cards bracketed
5 2 2 3 3 4 4 1 [7 6 5 6 7 8 8 1]

Consider the same problem, but your opponent starts, as in the Figure, with **8 6 5 7 8 6 3 7**. The remaining cards are **1 1 2 2 3 4 4 5**. Can you intersperse the second set of cards in some order into the first sequence to force your opponent to land on an ace as the final card, based on the rules outlined here?

Solution:
8 6 5 7 8 6 3 [1] 7 [2 5 4 3 2 4 1]

Upstart 1:
Suppose your opponent gets to arrange all cards ≥d. You are allowed to insert the remaining cards anywhere you like. Now find the minimum d that will still allow you to be sure to win and show how you did it.

Upstart 2:
Again suppose your opponent gets to arrange all cards ≥d. You are allowed to insert the remaining cards anywhere you like. But in this game, you win if your opponent ever lands on an ace, whether of hearts or spades, no matter where it is. Find the minimum d that will still allow you to be sure to win and show how you did it.

This puzzle also appeared in Vol. 60 No. 4 of Communications of the ACM.

WELCOME TO THE INSTITUTE'S NEWEST FACULTY!

Joseph Bonneau, Assistant Professor of Computer Science, has a Ph.D. in Computer Science from the University of Cambridge. His research interests are in computer and web security, applied cryptography, cryptographic currencies, and human authentication. Bonneau was previously a Postdoctoral Researcher at Stanford, Technology Fellow at the Electronic Frontier Foundation, and Postdoctoral Fellow at the Center for Information Technology Policy at Princeton.

Corrin Clarkson, Clinical Assistant Professor of Mathematics, holds a Ph.D. in Mathematics from Columbia University. Clarkson's research interests are in low dimensional topology, specifically 3-manifolds, Heegaard Floer homology and mapping class groups. She is also interested in Inquiry Based Learning teaching strategies. Prior to joining NYU, Clarkson was a Zorn Postdoctoral Fellow at Indiana University.

Naima Hammoud, Clinical Assistant Professor of Mathematics, holds a Ph.D. in Applied and Computational Mathematics from Princeton University. Hammoud's research interests include the area of thin film dynamics, with a primary focus on stability. Prior to joining NYU, Hammoud was a research specialist and a lecturer at Princeton.

Suzanne McIntosh, Clinical Associate Professor of Computer Science, joins Courant with affiliation at the NYU Center for Data Science. She has been an Adjunct Professor at NYU since 2013. McIntosh received the Engineer Degree in Computer Engineering from Stevens Institute of Technology and holds Master's and Bachelor's degrees in Computer Science. Prior to NYU, McIntosh developed firmware for DoD mission critical systems. She holds patents in security, virtualization, and the Internet of Things. Her research interests include distributed systems, big data analytics, and security.

Jigarkumar Patel, Clinical Assistant Professor of Mathematics, holds a Ph.D. in Applied Mathematics from the University of Texas at Dallas, where he was a Senior Lecturer II before joining NYU. He holds graduate degrees in Mathematics/Science Education and in Pure Mathematics from Gujarat University. His research interests include numerical solution of PDEs, operation research, optimization, dynamic contact, and impact analysis..

Anirudh Sivaraman, Assistant Professor of Computer Science, holds a Ph.D. and a Master's in Computer Science from MIT and a Bachelor of Technology in Computer Science from IIT Madras. He is broadly interested in computer networks, with a current focus on fast and programmable routers.

Shenou David Cai

10/11/1963-10/21/2017

We are deeply sad to report the passing of our friend and colleague David Cai at the age of 54. An obituary article will appear in our spring newsletter.

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