The Day of the DATACATS

A small UNH graduate program offers new ways of looking at teaching, the campus and the world

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Outside a nondescript office on Madbury Road in Durham sit eight parking spaces, appearing unremarkable to hundreds of passersby each day. In fact, they are part of a trial run, a data collection and analysis experiment, if you will, the eventual success of

which could accomplish nothing less than solving the university's parking challenges once and for all. For those of you all too familiar with the university's perennial parking headaches, you also know that a Nobel Prize (for peace?) would be a fitting award.

The office is the UNH Connectivity Research Center, and the trial run involves a series of hockey puck-sized sensors placed beneath the asphalt of each parking space. Using wireless communication technology, the sensors record, in real time, not only when a space is open or occupied, but also, in concert with a handy algorithm we'll call "The Parking Space Algorithm," the likelihood of it being available at any given time, based on general usage patterns.

One need only imagine this capability expanded campus-wide to begin to see its transformational potential. Using their UNH app, for example, thousands of students, faculty, staff and visitors would be able to enjoy real-time updates about every parking space on campus as classes and work shifts changed over. They also could know when to expect the Campus Connector or Wildcat Transit to be available anywhere on campus to whisk them off to lecture hall or office during peak commuting hours, no matter where they parked.

When this brave new world of transportation arrives, says Robert McGrath, director of the analytics and data science master's degree program, "we'll have fewer people sitting in their cars and reading before business hours, idling until a spot opens, or playing the meter game, and more people finding a place to park and getting where they need to go on time, saving on fuel emissions and, who knows, maybe even getting more exercise."

Next stop, Stockholm?

Well, we're not there yet . . . but these kinds of small-scale projects with large-scale implications are growing in number as, sensor by sensor, fiber optic cable by fiber optic cable and student by student, a network of scientists and researchers are setting the table for the smart campus and smart world of tomorrow.

How large-scale a future are we talking about?

The world is going to change so fast and dramatically in the coming years that nobody will quite be ready for it.

McGrath offers the wry smile he has smiled many times before when discussing this topic with newbies. "When people think of the next big thing, they're usually not thinking nearly big enough," he says. "The world is going to change so fast and dramatically in the coming years that nobody will quite be ready for it."

An Agile Education

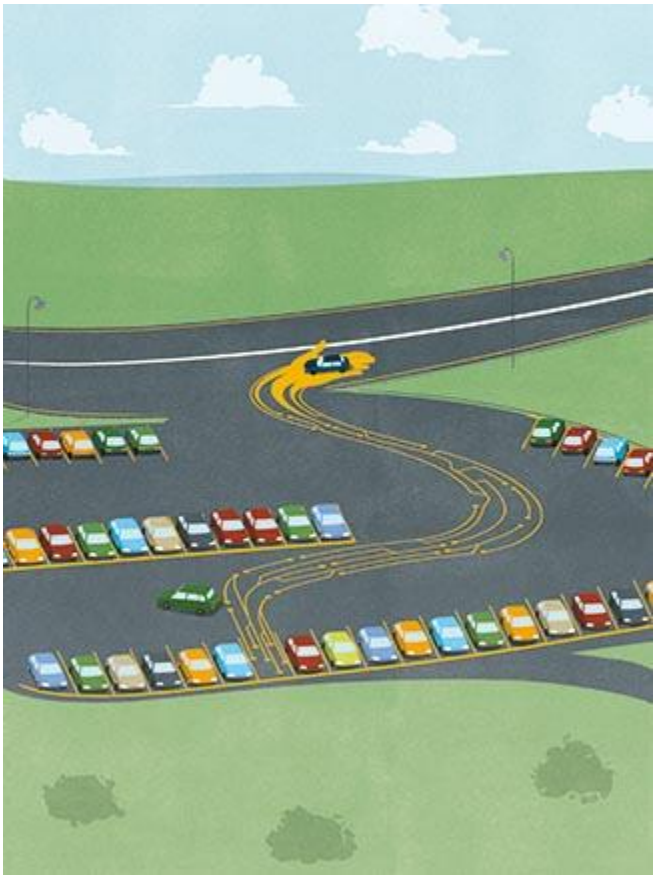
Whether we're aware of it or not, we are all familiar with the world being created through the collection, analysis and application of data — lots of data — in every corner of our daily lives. Data analytics governs Google's and Facebook's selection of ads served up to you when you visit their pages and following you when you leave. It allows scientists to model molecular activity in the quest to understand and speed up the application of

lifesaving medical procedures (see “Deep Learning”). It allows some airports to simulate and coordinate the movement of huge jets safely to and from their gates (See “Algorithm”).

It also threatens to undermine our privacy and freedoms and will surely require a massive retooling of the workforce, a concern that McGrath and his small but influential team are working practically around the clock to address. “We’re coping with the speed of change by trying to educate our workforce without knowing what kind of workforce we need,” he says.

Four years ago, there were 14 academic programs in data science in the U.S. Now, there are more than 200. “It’s the fastest growing industry in the world, and some countries (including Australia and Norway) have created entire universities around the subject,” McGrath says. With some of New England’s heavy-hitting private campuses ramping up, it will be difficult for UNH to stay on top, says McGrath. “But people may be surprised to know that we’ve kind of owned the Northeast.”

Provost Wayne Jones Jr. believes that in an era where big data is everywhere, “the analytics program at UNH has filled a niche for students from all majors interested in gaining these new skills to advance their career.”



With well-established programs in computer science, mathematics, engineering, business, health policy and economics, the university didn’t get serious about analytics until 2012, when Lisa MacFarlane, then provost, appointed McGrath and College of

Health and Human Services Dean Michael Ferrara to create a presence at the university for this cutting-edge field. Her charge to the group, recalls McGrath, was to centralize the program rather than “having six different colleges doing six different things” and to focus on an educational mission.

The result was a master’s degree program in analytics and data science — colloquially known as DSA, and modestly set up at 10 Pettee Brook Lane in Durham. There used to be a pizza place next door that went bottoms-up. But lunch is not foremost on DSA’s menu of priorities. What is on the menu at DSA is hard work, which comes in the form of a yearlong boot camp featuring an “agile” approach to graduate study that has no exact comparators at UNH or, seemingly, any other university.

For those unfamiliar with the Silicon Valley mantra of “agility,” it refers to the practice of fearless experimentation, finely tuned responsiveness to the needs of stakeholders and adeptness at pivoting on a dime to meet these needs as they change. Agile organizations may write up multi-year strategic plans, but they feel comfortable scrapping them in a heartbeat to address emerging technologies.

If anyone embodies the agile mindset at UNH, it’s Prashant Mittal, DSA’s clinical assistant professor. Mittal came to UNH from the University of Southern Maine Muskie School of Public Service, where he labored in frustration at what he dubs “the huge disconnect between what business schools were teaching and what industry needed.”

“Faculty become comfortable with a course and stick with it, year after year,” says Mittal. “Industry, on the other hand, is constantly solving new problems requiring new tools and skills.” By Mittal’s estimation, universities typically lagged about seven years behind industry in terms of student preparation.

McGrath and Mittal were determined to close the gap by seamlessly integrating classroom work with industry relevance — not through capstone or standalone projects but by baking experiential learning into the fabric of their program.

Over the course of one summer and two semesters, each master’s degree cohort — whom McGrath calls “Datacats” — takes classroom-based modules that run concurrently with two practicums with various industry partners. Explains DSA lecturer Phani Kidambi, “If you look at data science programs at many universities, they are basically made up of existing courses packaged as data science. Real data science isn’t a collection or sequence of courses but a dynamic field that constantly changes.”

Far from a “sequence of courses,” UNH’s DSA classes are densely interwoven tapestries typically involving up to half a dozen faculty members from around the university. A course on data architecture or visualization techniques, for example, may draw on Paul College’s Billur Akdeniz Talay to teach marketing analytics or Tevfik Aktekin or Burcu Eke to teach optimization. Computer scientist Arvind Naray may come in from the College of Engineering and Physical Sciences (CEPS) to teach a module on programming using the powerful Python tool, and colleague Adam Boucher may be called on to teach mathematical foundations and linear algebra.

“Data science evolved at the intersection of mathematics, computer science and an area of application, such as health care, transportation, space travel, the environment and so forth,” McGrath says.

The “application” phase is where the second pillar, the practicums, really shine. Practicums operate like consultancies, in which UNH student teams, advised by faculty, de- vote large numbers of hours to devising ingenious solutions to problems brought to them by several dozen industry part- ners. Recent partners have included Martin’s Point Health Care, Lindt Chocolate, Amazon Alexa, the Boston Red Sox, Planet Fitness, Walmart, Unum Insurance, CA Technologies, Granite State College and other local and national firms.

The Stanford of the East?

We’ve already indulged in some good-natured, Nobel Prize hyperbole. Here’s another one: UNH analytics is the “Stanford of the East.”

Unlike hackathons and similar events, DSA’s practicums focus on real problems the partner lacks the time or re- sources to take on. In one practicum, the UNH team worked with Martin’s Point Health Care to develop a tool to predict who their next high-cost users would be. Mittal was de- lighted to learn that data scientists at Stanford University ar- rived at a similar approach to their work with insurance giant Kaiser Permanente. “I was very proud that although we are far from Silicon Valley and working with a smaller client, we are doing the same kind of thing on a relative scale.”

DSA’s rigorous format not only stands out at UNH, but nationally as well. Just ask Joanna Gyory ’19G. Gyory came to DSA with a bachelor’s degree in biology from Cornell University, a master’s degree in marine and atmospheric science from SUNY Stony Brook, and a Ph.D. in biological oceanography from the joint program between MIT and the Woods Hole Oceanographic Institution. After a career in academia and a couple years of maternity leave, she wants her next career to be in industry.

“I enjoyed the theory and research focus of academics,” Gyory says, “but now I’m really interested in the applied, methods focus of analytics. One great strength of the pro- gram is the diversity of people it draws. They come from sports, music, IT, biology — you name it — so I’m exposed to people with different ways of looking at problems.” Gyory says another difference between her earlier degree work and DSA experience comes from the focus on group projects rather than solitary scholarship. As a result, she says, “I’ve strengthened ‘soft’ skills such as conflict resolution, communication and thinking on your feet.”

Soft skills such as communication come in handy during a nerve-wracking rite of passage that has quickly become a hallmark of DSA: Mittal’s regular “team oral exams.” In addition to written assignments, Mittal regularly devotes class time every week or so to grilling students on current topics, tools and applications. Recent alum Steve Glover ’18G recalls these sessions with startling clarity: “With the class seated around the conference room table, Prashant grills us one-by-one. He starts out easy, and then asks harder questions, taking the student ever deeper into a problem until, finally, the student simply can’t answer a question. Then, he moves on to the next person who may have to pick up where the previous one left off — if they can!”

“The key to this kind of assessment,” says Mittal with a twinkle in his eye, “is not only to know your business but to know how talk about it to other people who may not be experts in the subject. If you can’t do this, your great ideas aren’t going to be useful.”

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Sound cruel? Don’t worry about these students. The agile mindset is one that embraces failure. “I like to say we are in the business of failure,” explains Mittal, “and that humility is the most important virtue for successful data scientists.” To illustrate what he means, Mittal says he typically teaches his students as many as 75 algorithms to solve a given problem. Students’ ability to try one, fail fast and move on to the next option makes or breaks their project.
“The wisdom lies in figuring out when the pathway you’re taking isn’t working,” Mittal says.

And when it comes to self-correction, DSA practices what it preaches, changing roughly 25 percent of its master’s degree and certificate content each year to reflect the intro- duction of new tools and, indeed, career pathways. From its humble beginnings of 14 students in 2015, DSA has gradu- ated more than 100 students and also offers online certifica- tion for those who don’t want to devote a year to boot camp. At this point, the program boasts a 100-percent placement rate for graduates, most of whom enjoy higher salaries and more rewarding work.

The success of the graduate program also has led to the development of a bachelor of science joint degree program between UNH Manchester and CEPS where students can take an analytics track in Manchester or Durham, or a data science track (more foundational math, statistics, computer programming and less applied) through CEPS in Durham.

Innovation and Economic Engine

When most people think of campus planning and master plans, they think bricks and mortar, pedestrian walkways and so forth. What they think less about, says Scott Valcourt, director of IT strategic technology at UNH and adjunct lecturer in computer architecture, “are all the things we might learn about what goes on around us and the uses to which we might put this information.”

Valcourt’s talking about a “smart campus.” One of the hallmarks of smartness involves the breaking down of data silos, which enables the larger organization to connect the

dots and open the lines of communication between, or among, formerly isolated offices. We saw what might happen with UNH parking and transportation services, but the potential for new and productive configurations is virtually endless.

Consider just a few examples. In the not-too-distant future, campus lighting could be entirely motion-detected, saving enormous sums on energy. Further up the mission-critical food chain, analytics could drive the university's innovation and economic engine even more than it does now. McGrath's team is already working with a number of university centers, including the new John Olson Center for Advanced Manufacturing — which engages with New Hampshire's manufacturing industry to modernize their technologies and groom the next generation of skilled workers — and the UNH Connectivity Research Center (CRC), the site of the parking project noted earlier.

CRC's founding director and associate professor of elec- trical engineering Nicholas Kirsch and research program manager Christina Dube are helping the UNH greenhouses develop a wireless application that can measure pH, mois- ture content and other values without expensive infrastruc- ture. "If it works, the application could be used across hun- dreds of university research acres and be commercialized for wider use," says Kirsch.

McGrath says UNH is "poised to become a world leader in environmental analytics" through the collaborative efforts of environmental scientists, data scientists, statisticians and computer scientists who are developing the capacity to build a nationwide network of sensors monitoring streams, waterways and adjoining land areas, with sensors transmit- ting up to 20 data points every 15 minutes.

"The university has sought national funding to build out the work and develop a doctoral program in watershed infor- matics," he adds, "the first of its kind to bridge what we do in data science with environmental science."

As with the university's educational side of analytics, Provost Jones points to the timeliness of the university's "traditional strength in the connectivity of devices and interoperability" as the building blocks for more such industrial partnerships.

An Eye on Ethics

While the upside to such achievements appears endless, some applications of analytics, machine learning, and big data have certainly had a Who's Who of critics. Not the least of these involved the late physicist Stephen Hawking, who warned that humans were "entering a new phase of what might be called self-designed evolution, in which we will be able to change and improve our DNA." Hawking worried that such capabilities would be available mostly or exclusively to the wealthy, creating nothing less than a "super-human" race.

In a similar vein, The New York Times best-selling historian Yuval Harari, author of "21 Lessons for the 21st Century," argues that science fiction's fear of artificial intelligence, captured in films such as "The Matrix," is misguided. What we ought to fear more, writes, Harari, is "conflict between a small superhuman elite empowered by algorithms and a vast underclass of disempowered Homo sapiens."

McGrath and his team are well aware of the ethical implications arising from the uses and abuses of machine learning. That's why they've brought in professor of philosophy Willem deVries to perform the critical role of gadfly, lecturing to every master's degree cohort about the existen- tial nexus between human and artificial intelligence, people and robots.

"We can do all kinds of things we couldn't do before, but that doesn't mean we should," deVries cautions students.

DeVries believes that invasion of privacy tops the list of the dangers posed by the "Internet of Things." "As human beings, we're both a physical body and a set of information," he says. "As our information becomes digitized, it becomes available for commercial, political and other uses — and abuses." To illustrate, deVries points to the 2016 case of Target. The big box chain captured the public's fascination and fear of corporate intrusion on private life when its marketing department used the purchasing history of a teenage girl to figure out she was pregnant before her own family knew. The tip-off came when Target mailers began pitching diapers and baby bottles to her at home. This kind of practice rankles the lifelong Kantian in deVries, who says one formulation of Immanuel Kant's categorical imperative places respect for other people at the top of the ethical pyramid. "Kant believed we should never treat others as a means to our own ends but rather as ends in themselves," deVries says. "This applies to our bodies and our 'information.'"

Count deVries, therefore, among those who remain skeptical about another technology, driverless cars, that touches on a project currently underway between the CTC and the city of Dover. UNH and Dover are trying to tackle the Garrison City's gridlock problem along its main thoroughfares by making the sequencing of stop lights more responsive to traffic volumes.

While Kirsch and his colleagues are in the early stages of installing sensors to measure traffic patterns, the long-term goal is to install wireless communication devices in traffic lights and cars alike. Cars could communicate their presence to the lights and, eventually, to one another, ultimately replacing the human decision-making, with all its flaws, involved in tasks such as braking for lights, avoiding people and other cars, finding alternative routes to destinations and staying in one's lane, a feature that is already appearing in new automobile models.

What do you think? Are you ready — will you be ready in your lifetime — to cede control of your driving skills to an algorithm?

Or, do you find yourself nodding in agreement with deVries, who argues, "Driving is very difficult, and it would be, in practical terms, impossible to test thoroughly a system as complex as a driverless traffic control system would have to be. Do we really want to adopt a life-critical system that isn't thoroughly tested?"

It seems Sheen Estevez wasn't entirely right after all: you *can* argue with the data. What you can't do any longer is ignore it. It's there by the gigabyte, terabyte, petabyte, and, yes, the yottabyte for us to gather, analyze and apply in an effort to make our world a better place. We can only hope.

No wonder the folks at 10 Pettee Brook Lane are working so hard!

You Know Me Al(gorithm)!

Algorithms are step-by-step procedures for performing calculations according to well-defined rules. Because algorithms describe general truths that work every time, we can use them to perform highly complex, repetitive tasks without having to reinvent the wheel. The Greek philosopher Euclid is cred- ited with inventing the first algorithm in his treatise “Elements” (300 BCE). The Euclidean Algorithm offers a technique for quickly finding the largest common denominator of two positive integers.

For much of their existence, algorithms were known mostly to mathematicians and computer scientists. Lately, we’re learning how influential these ingenious tools are in our daily lives.

In the 2015 documentary “The Secret Rules of Modern Living: Algorithms,” an Oxford University mathematician considered the ubiquitous smartphone. Every time we take a selfie, an algorithm breaks down the data that comes in through the phone’s camera aperture and puts a box around our faces to focus on. Hold up a well-composed “fruit face” using a banana smile, cherry nose, and oranges for eyes, etc., and the camera still picks out the real face.

Algorithms seem simple — once experts explain them. Their power emerges when we see them applied to problems of staggering complexity. At London’s Heathrow Airport, for example, data scientists and aviation engineers devised an algorithm to simulate the entire outward-bound operation of its planes — from their initial pushback from the gate to taxiing and takeoff. The Heathrow Sequencing Algorithm aims to cut two minutes of taxiing time per plane per year, saving nearly $20 million per year in fuel costs. Now, imagine the reduction in costs and emissions if the world’s 1,200 international airports followed suit.

Dedicated to Deep Learning

Clinical trials are expensive and valuable parts of the pharmaceutical drug devel- opment process that companies, investors and, most of all, patients want to succeed. They’re also long and arduous undertakings often involving patient, disease and treatment profiles that produce enormous amounts of data to sort through — often compiled in different languages.

It’s what Chris Bouton, co-founder of Vyasa in Newburyport, Massachusetts, would call a “complex information system.” Vyasa has developed a deep learning platform that helps firms make sense of such systems and, in this case, turn data into successful drug treatments. “Deep learning refers to creating algorithms that enable machines to learn and adapt more or less like people do, only many orders of magnitude faster,” says Bouton.

In 2017, Bouton hired Justin Greenberg ’12, ’16G to create an algorithm called Chem Vector, which allows clients to find novel lead molecules to aid in the development of

new medicines and treatments. Explains Greenberg, “Rather than rely on hundreds of scientists to try to randomly mutate a molecule using test tubes and microscopes, Vyasa’s algorithm simulates testing in a fraction of the time.” Ultimately, a drug will have to be developed and tested on people, but Greenberg’s algorithm should help Vyasa’s client get to that critical stage faster.

Like many DSA grads, Greenberg counts himself among his profession’s “data for good” adherents, motivated primarily by a passion “to help those in need in order to pioneer humanity towards a better future.” Before coming to Vyasa, Greenberg worked in a hotbed of applied analytics — healthcare — helping Elliot Hospital’s Center for Clinical Excellence successfully design and implement a predictive model for identifying patients most likely to be readmitted within 30 days of discharge.

Greenberg credits DSA with turning his life around. “I doubled my income, bought a home and am finding fulfillment in a way I didn’t think possible,” he says.

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