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The BIG Notebook

A Newsletter of the MAA Special Interest Group for Mathematics in Business, Industry & Government

Real Math, Real Fun

Thomas Hoft, Tufts University

In mathematics, I find myself repeatedly drawn to problems that combine modeling, algorithm development, computing, and real-world applications. Usually these tend to be inverse problems in imaging, a topic I got turned on to somewhat by chance. My undergraduate advisor (Matt Richey) suggested an independent study and gave me two seminal papers: Metropolis et al. and Geman & Geman. He also got me up and running with a parallel computing environment and set me to the task of coding a Markov Chain Monte Carlo (MCMC) method for image denoising. This was the first time I used real math, real probability and statistics, and real computing to solve a real non-textbook problem. And it was real fun! Who knew that mathematics could be used to extract information from images? Well, lots of folks, but it was new and exiting to me.

As an undergraduate at St. Olaf College, I majored in Physics and Mathematics and minored in Computer Science. Knowing that I wanted to take my education through the Ph.D. level, I looked at grad schools in both physics and mathematics, hoping to combine my three undergraduate disciplines. I quickly realized that while most programs required choosing one of the two fields, applied mathematics offered the chance to combine them in a meaningful way. I ended up at the

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Thomas Hoft

Inside:

University of Minnesota, drawn by its graduate program in Industrial and Applied Mathematics.

At Minnesota, I did three internships in industry: with 3M designing a homogenizing optical element, with General Motors developing an inverse problem method for nondestructive evaluation of spot welds in cars via thermal images, and with Coherent Technologies Inc. (CTI) investigating polarized laser radar for early-launch missile detection. The first two led to M.S. and Ph.D. theses under Fadil Santosa and were done in collaboration with mathematicians at the host companies, but I did not spend time on-site living the life of a mathematician in industry. The third internship, while not related to my dissertation and possibly delaying graduation by a few months, offered this on-site experience plus a location just outside Boulder, CO.

When I finished up grad school, CTI (by then acquired by Lockheed Martin) offered me a full-time job, which I accepted. I'd always wanted to try both ``sides" of the academic-industrial divide, and this was a chance to go for the industry side. My wife and I moved to Boulder, and spent much of our spare time hiking the foothills adjacent to town, and higher in the mountains in Rocky Mountain National Park.

CTI specializes in custom laser radar (ladar) systems for aviation safety and military applications. My role there, as one of two Ph.D. mathematicians in a research and development group that grew from 50 to 80 folks, was largely in image processing. Ladar signals are corrupted by various sources of noise, but one of the most limiting is distortion caused by transmission of the laser through turbulent atmosphere (this is the same effect as star twinkle and hot parking lot shimmer). We refined existing methods that maximized an image-quality metric after decomposing the aberration into a representation in terms of a

Editor's Note

The profile article is by Thomas Hoft, who has worked on imaging problems both in and out of academia. Now at Tufts, he is also the new NeXt liaison for BIG SIGMAA.

Michael Dorff of Brigham Young University describes how his successful ``Careers in Math'' speaker series came about. He offers a roadmap for others to create similar programs for Mathematics undergraduates looking for career models.

David Carhart of Bentley University shares his experience as a judge for SIAM's Moody's Mega Math (M3) Challenge. We are very fortunate to have this inside look. Thanks also to Lee Seitelman and others at SIAM for the approvals and for working on this with Dave.

We are also very fortunate to have a contribution by Rick Cleary, another Bentley professor, who is also a BIG SIGMAA member and MAA financial manager extraordinaire. He offers an overview of the business-oriented Mathematics curriculum at Bentley University.

The puzzle poem in this issue is by Benjamin Banneker, a free black man born in the English colony of Maryland in 1731. Initially a tobacco farmer, he cut a trajectory that suggests a significant interest and ability in Mathematics and Astronomy. He may have been the first American to build a clock (made mostly out of wood, it gave perfect time for at least 55 years), published Maryland's first Almanac, was the first black presidential appointee (to a six-member team for laying out the boundaries of the District of Columbia, in 1791), and predicted a solar eclipse in 1789. For more, and for classroom ideas, see http://apcentral.collegeboard.com/apc/members/courses/teachers_corner/34224.html.

convenient orthogonal basis. Real math solving real problems! Even better, we used not only simulated and laboratory data but also data acquired at a field test site just north of Boulder. Real data!

The most fun and most rewarding project was developing a fast, robust, and automatic image formation algorithm for a 3-D face imaging system with applications in biometric identification. We started with a group of three doing a proof-of-concept laboratory demonstration of Fourier transform profilometry, an imaging method that extracts, via the Fourier transform, depth information from the deformation of sinusoidal fringes projected onto a surface. While developing algorithms, if I wanted more data I could call over to one of the other two and walk down the hall to the lab and get fresh data in a matter of minutes -- what a great environment for developing real solutions! Over eighteen months this grew to a team of over a dozen with software, electrical, mechanical, and optical engineers and a partnership with an outside company. The end product was an engineering demonstration unit, a prototype of a possible production unit that operated fully unattended. This unit went on a mini-tour to Washington DC for demos to government agencies and higher-ups within Lockheed. And an applied mathematician was involved from start to finish!

Eventually, with the company focus shifting away from R&D and with growing frustration at not being able to use advanced mathematical techniques (of potentially greater utility but certainly longer development time), I decided to make a change.

I spent a summer at the National Institute of Standards in Technology's (NIST) Boulder laboratory working with Brad Alpert on a project in molecular dynamics simulation. One component of a large MCMC code, used by a chemistry group to determine properties of materials, involved computing electrostatic interactions between molecules suspended in fluid. We applied a fast multipole method to reduce computation time, which can be up to one week. This project is ongoing, and while it has no connection to my work on inverse problems in imaging, it is a perfect example of combining mathematics, physics, and computing to solve interesting problems with real-world impact.

Fortunately, a (temporary) position at Tufts University came up with a research focus in inverse problems, offering both teaching experience and the opportunity to work with recognized leaders in my field. So we've traded the mountain trails for the beaches of Cape Cod, where our young kids dig in the sand. I've spent the last two years figuring out how to teach, and developing an academic research program, in inverse problems.

Quotation Corner

The greatest reward lies in making the discovery; recognition can add little or nothing to that.

Franz Ernst (1798-1895)

There is no branch of mathematics, however abstract, which may not some day be applied to phenomena of the real world.

Nikolai Lobatchevsky

"Time is a great teacher, but unfortunately it kills all its pupils."
Hector Berlioz

".. and gladly wolde he lerne and gladly teche .."
Chaucer (the Clerk of Oxenford)

BIG Contributed Papers at JMM Boston, January 2011

James Fife, Educational Testing Service, ``Cubic Splines, Local Extrema, and the Harmonic Mean: An Application to Graph Editors.''

William P. Fox, Naval Postgraduate School, ``New Metrics to Detect Suicide Bombers.''

Ananthnarayan Hariharan and Lauren Keough, University of Nebraska at Lincoln, ``Math in the City.''

Ellina Grigorieva, Texas Womens University, Evgenii Khailov and Andrei Korobeinikov, ``Reduction of the Operation Cost via Optimal Control of an Industrial Wastewater Biotreatment Process.''

Thomas Hoft, Tufts University, ``Optimization in Fourier Imaging for Laser Remote Sensing.''

William S. Barfield, ``Using Regression to Determine Cost Estimating Relationships for Costing of FAA Software.''

Michael Dorff, Brigham Young University, ```Careers in Mathematics' speakers series.''

Emilie Hogan and Cliff Joslyn, ``Visualizing Semantic Data Through the Use of Partially Ordered Sets.''

John Ramsay, College of Wooster, ``Tires, Insurance and Clutches: Applications of Undergraduate Consulting.''

The Puzzle of the Hound and the Hare
by Benjamin Banneker (1731-1806), from his Almanac

When fleecy skies have Cloth'd the ground
With a white mantle all around
Then with a grey hound Snowy fair
In milk white fields we Cours'd a Hare
Just in the midst of a Champaign
We set her up, away she ran,
The Hound I think was from her then
Just Thirty leaps or three times ten
Oh it was pleasant to see
How the Hare did run so timorously
But yet so very Swift that I
Did think she did not run but Fly
When the Dog was almost at her heels
She quickly turn'd, and down the fields
She ran again with full Career
And 'gain she turn'd to the place she were
At every turn she gan'd of ground
As many yards as the greyhound
Could leap at thrice, and She did make,
Just Six, if I do not mistake
Four times She Leap'd for the dogs three
But two of the Dogs leaps did agree
With three of hers, nor pray declare
How many leaps he took to Catch the Hare.

(Answer)

Just Seventy two I did Suppose,
An Answer false from thence arose,
I doubled the Sum of Seventy two,
But still I found that would not do,
I mix'd the Numbers of them both,
Which Shew'd so plain that I'll make Oath,
Eight hundred leaps the Dog did make,
And Sixty four, the Hare to take

Swirl Crown, by Collin Carbno

Careers in Math Speaker Series at BYU

by Michael Dorff, Brigham Young University

Six years ago we discovered something puzzling. We had students who were excellent in mathematics but did not want to be math majors. We asked them why. Their response was that they did not want to be a teacher or a professor. We told them that there are many non-teaching careers using mathematics such as being a cryptographer, a financial analyst, and an actuary. Yet, later we found that these students still did not end up being math majors. So, we decided we needed to more effectively get the message to students that there are many non-teaching careers for mathematics majors.

To do this, we created a "Careers in Math" speaker series. The series has gone on every fall semester for the past four years. Throughout the semester I bring in 5-7 speakers who have a strong background in mathematics and who can show how mathematics can be used in the real world. The idea is to show students that mathematics is used in many careers and that taking math courses is beneficial. Speakers come from various careers: engineering (Raytheon, General Dynamics, Bell Helicopter), programming (Epic Systems, MathWorks, Word Perfect), operations research (Lawrence Livermore Labs, Department of Defense, Level 3 Communications), finance (Goldman Sachs), medical fields (Center for Disease Control, Pharsight Pharmaceuticals), actuarial sciences (The Hartford, Regence), NSA, law, and even movies (Pixar, independent CGI technical director). Typically, 100-150 students attend each presentation.

An example audience from the ``Careers in Math" Speaker Series audience.

When I mention our speaker series to math faculty at other institutions, one question that often arises is "How do you fund this?" Funding has been an unstructured aspect based upon the successful model of starting small and promoting successes to help you grow, and I have had a bit of luck. When I first proposed the idea, the department chair liked it and was able to find some departmental funds to help us start the speaker series. The first year our expenses were small since I used local speakers and alumni who were visiting campus. However, I did have one main speaker whom we knew would give an excellent presentation. I made sure that a lot of students would be attending (offers of extra credit in classes and free donuts worked like magic). Also, I invited the dean. This presentation was fabulous and the dean was so impressed that he offered me some additional funds for the next year to support the speaker series. During the second year, we received an internal grant to support internships among majors and adapted our speaker series by bringing in speakers from organizations that had summer internships for students. Also, we learned that some larger organizations have specific recruiters who want to visit campus to give a presentation and will pay their own expenses. The next year, one of our previous speakers was involved in an NSF TUES grant proposal to promote applications of math in the real world. This led to our "Careers in Math" speaker series becoming part of a collaborative NSF TUES grant funding us for $30,000 for several years (NSF grant DUE—1019594).

Another question that I am asked is "How do you find speakers?" I am a theoretical mathematician working in geometric function theory and who has been a teacher my entire career. When I started the "Careers in Math" speaker series, I did not know a lot of non-teaching careers, let alone people who worked in non-teaching careers. So, first, I got hold of a copy of our alumni list which in some cases included alumni's email addresses and where they worked. I picked a few alumni who seemed like good candidates and I blindly emailed them. I explained what the "Careers in Math" speaker series was, that we were doing this to create awareness of career opportunities for math students, and invited them to be one of our speakers. I was amazed by the positive response from alumni whom I did not know but who were eager to talk about their mathematics and their careers. From there, things just grew. I mentioned to colleagues and people I met at conferences what I was doing, and occasionally they would tell me of a contact who would be a good candidate for a speaker. Now, I have more recommendations for speakers than I have spots available.

Speaker from Goldman Technology

It is helpful to do some work before the speaker arrives. Besides all the normal logistics such as reserving a large room that a lot of students walk by and giving the speaker directions to the room, there are two aspects that are important but which people sometimes don't consider. First, it is helpful to prep the speaker. I let the speaker know of the goals of the series. I tell the speakers I want them to talk about their career but also I want them to talk about how math has helped them in their career. Also, it is good to let them know the type of audience they will be speaking to. In our case, I tell the speakers that the audience will consist of about 100 undergraduate students and that they can assume that the students have only had calculus 1. Second, it is essential to advertise the speaker series and to advertise it well. We send emails to professors asking them to tell their students. We send emails to math majors. We print out a large 2-ft-by-3-ft poster announcing all of the career speakers for the semester and display the poster during the entire semester on a tripod in the walkway building by the vending machines through the math building. Then we create a separate poster, again 2 ft by 3 ft, for each specific speaker promoting their career and display that during the week leading up to that speaker's presentation. For some speakers we get an article in the university paper or on the college website.

Another component of the speaker series is food. This is a great motivator for students. During the second year, when we had some money from the dean, we started placing a large table in front of the presentation room and ordered cookies and donuts to be setup 15 minutes before the presentation. We have someone manning the table with a sign stating the food is reserved for those attending the "Careers in Math" presentation. But there is something even more effective than the donuts and cookies. We organize a dinner for the speaker and a group of about 10 students after the presentation. This is to allow students who are interested in the career to ask the speaker more in depth questions and to network with the speaker. At first, we arrange to go to dinner at a restaurant. But with that large of a group it is difficult for everyone to talk with the speaker. So, we changed the setup. Now we order food from two restaurants (usually pizza, a favorite of students, and Indian food, a favorite of mine and of many of the speakers), bring it back to campus, and have an informal buffet in the math department. It has been great for the students to interact with the speaker and to have the speaker give additional insight to these students.

The speaker series has been a tremendous success. We are doing many activities to encourage more students to take math courses and become a math major including the WeUseMath.org web site, the IMPACT lab that funds undergraduate students to work on problems provided by business and industrial partners, the creation of paid summer internships for our math majors, and a new "applied and computational math" emphasis connected to industry for math majors. But since we have started emphasizing career options in math, we have had an 89% increase in the number of math majors at BYU.

BYU students at one of the post-talk dinners.

It has been interesting to hear employers tell students that they want to hire math students. They want to do this, because of students' problem-solving skills, their attention to detail, their ability to abstract, their methodical approach, and their diversity (they bring to a group a different approach to attacking a problem than an engineer, a physical scientist, a programmer, or a statistician). However, just majoring in math is not enough to guarantee a job. Students have asked these speakers "What should we do to better prepare ourselves for these careers?" Employers recommend the following. Students need to know how to program. Also, they should develop good communication skills (i.e., speaking and writing). It would be beneficial to have a minor in some other STEM field such as statistics, computer science, chemistry, or biology. And students should have an experience working intensively on a hard problem. Such an experience could come from an internship with a company or through undergraduate research on an unsolved problem. It would be great if more students and math professors hear this message.

The Rewards of Being an M3 Judge!
by David Carhart, Bentley University

So what is an M3 judge? Each year, teams of high-school students gifted in mathematics are invited to participate in the Moody's Mega Math Challenge. They are given a challenging problem at 7am on a Saturday morning and have until 9pm that evening to submit their anonymous report/solution. In March, 2012, almost 1000 submissions were received, and since the best papers receive substantial cash awards, someone has to determine which papers are the best! And that's where the M3 judges come in.

The sponsorship comes from the Moody's Foundation, a charitable foundation established by the Moody's Corporation (more famous for providing credit ratings). Committed to supporting education, especially in the fields of mathematics, finance and economics, the Foundation also funds specific initiatives like the M3 Challenge. In 2012, the prize monies will total $115,000 (see www.m3challenge.siam.org for more information).

But prize money alone is not sufficient to run a Challenge. The organization and administration is provided by the Society for Industrial and Applied Mathematics (SIAM), headquartered in Philadelphia. Employing mathematicians, scientists and engineers, SIAM is most noted for advancing the disciplines of applied mathematics and computer science by publishing books and research articles along with hosting conferences. Many of their activities focus on providing opportunities for students; hence, their involvement in the M3 Challenge (see www.siam.org for more information).

So how does the M3 Challenge work? Once the submissions are collected, the goal is to identify the best six student submissions and invite these teams to New York City to present at the Moody's Headquarters Building. That team judged the best after the oral presentations receives $20,000, with the other teams receiving between $15,000 and $2500. In addition to these six teams, approximately 50 more teams are identified as either semi-finalist or honorable mention and awarded $1500 or $1000, respectively.

So why be a judge? I believe I can speak for my entire team when I say it's not for the modest honorarium, but rather for the opportunity to give something back to the discipline, and along the way, we get to see what talented high-school students can do when given an interesting and timely problem. Consider the problem for 2012: Participants were asked to develop a mathematical model(s) to determine which of 10 specified regions, or corridors, could best support high-speed railroad lines. Student teams made analyses based on estimates of future ridership and construction/maintenance costs to investigate the possible revival of the High-Speed Intercity Passenger Rail (HSIPR) Program. Finally, students were asked to predict what (if any) effect such a new rail network would have on the country's dependence on foreign oil.

Vanishing Point, by Collin Carbno

So how was this done in 14 hours? The students analyzed geographic and demographic data, compared construction/maintenance/travel costs, incorporated transportation metrics, and ultimately provided a 1-10 ranking of the 10 rail corridors identified in the HSIPIR.

Or consider the problem from the 2011 Challenge: Students were asked to estimate the impact of the 12-year water deficit on the Colorado River Basin. Many of the Southwestern states (and part of Mexico) depend on the water resource for drinking/bathing, crop irrigation, and hydroelectric power generation. So the student teams had to identify the effects of a long-term drought not only on water supply and demand, but also on the financial and political implications – especially for the seven Basin states that signed the Colorado River Compact in 1922.

The solutions submitted keyed on increasing the water supply:demand ratio by using alternative energy sources, water reclamation, different irrigation techniques (e.g., drip), desalinization, new regulations for industries, community involvement, and of course – changes in the pricing structure for water.

Speaking of politics, in the previous year, students were asked to "Make Sense of the 2010 Census." Every 10 years, the apportionment of the US House of Representatives changes based on the population of the various states as determined by a census. But in 2000, there were significant undercounts in the census figures in many places. Because of the political ramifications, there was considerable interest in how 2010 undercounts would be adjusted.

Students had to decide if the census should be adjusted for undercounts, and if so, how. They were also asked to provide recommendations to Congress for the "best" apportionment of the House of Representatives and to defend why they thought their proposal was superior. Finally, they were asked to make recommendations at the state level to ensure that Congressional districts were fairly drawn.

For each Challenge, each 3-5 person team, under the guidance of a single teacher/coach, prepares a written report not to exceed 20 pages. All submissions are read twice, so each judge ends up reading about 30 or so papers. The scoring is done on-line using a 0-14 scale (0 = insincere effort; 14 = truly outstanding) and the SIAM organizers suggest that each judge spend about 20 minutes per paper. Then, each judge prepares about a paragraph of feedback for the submitting team. I found that an average of about 30 minutes is more realistic for me, partly (mostly?) because I am in such a relaxed mode when reading (I do my judging during our Spring Break). So the time demands are not excessive and looking at skills demonstrated by high-school students is obviously rewarding.
Since the SIAM people make the administrative aspects wonderfully easy, being a judge is a fun exercise!

Are there secondary benefits? Absolutely! Several colleagues from my department are also judges, so we have some spirited lunch discussions as we compare notes and relate both good and bad ideas advanced by the students. Does it provide ideas for my own modeling classes? Again – absolutely! Is it easy to relate the problems to family and friends with minimal formal training in math – thus providing a little better idea of the scope of the duties of a university professor? Yet again – of course!

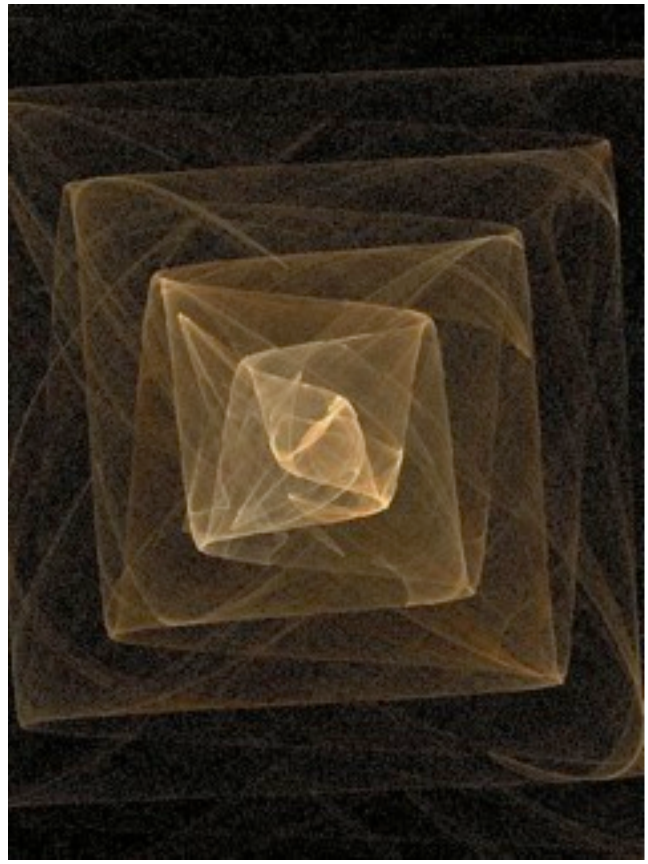
I should emphasize that being a judge is made very easy by the good people at SIAM. In addition to recruiting the judges, they distribute the problem statement, detailed instructions, and a scoring rubric. Because everything is done online, I can do my judging anyplace and any time (within a pre-agreed set of dates). So am I trying to recruit you? No, others will do this, but if interested, please contact SIAM at www.siam.org. If you want an opportunity to give back to our discipline by supporting a good program while having fun – then consider being an M3 judge!

Mathematics Major Options with Focus on Applications: The Bentley University Program
by Rick Cleary, Professor of Mathematical Sciences, Bentley University, Waltham, MA

Mathematics faculty at colleges everywhere are used to hearing the question, "What can I … or my son or daughter … do with a mathematics major?" Those of us in the field know that a mathematics major can be great training for a variety of fields. Many departments have put together excellent websites that refer students and parents to the various studies that have shown that students majoring in mathematics excel after graduation by a variety of measures. Whether the outcome of interest is strong testing in professional fields, salary, or job satisfaction, mathematics majors do well. One of the most informative websites in this area, and one that refers to a lot of the supporting literature, is maintained by Duke University Department of Mathematics, see http://www.math.duke.edu/major/whyMajor.html

Despite this mountain of evidence, it is often hard for undergraduates taking a 'pure math' course like abstract algebra, or complex analysis, to see how their studies make them valuable in business. Not every student with a talent for quantitative thinking enjoys learning about mathematics in a setting where the value of the subject is more subjective than immediate. Many options are available for the student who prefers to see mathematics as a toolkit to solve applied-problems. In addition to established programs in applied mathematics, operations research and statistics, students can now find mathematical sciences majors in which interdisciplinary think is stressed throughout the curriculum. We detail one example below.

At Bentley University, an institution with a business focus, we offer two majors in the mathematical sciences that prepare students to enter the business workplace with the skills they need for today's business-industry-government environment. One of our programs has a particular focus on actuarial science, and the other is an applied mathematics degree with an emphasis on business applications. Both programs begin like a traditional mathematics major, with three semesters of calculus and a course in linear algebra. However both are non-standard in that there are no further courses of a strictly theoretical nature.



Veiled Geometry, by Collin Carbno

We have no requirement (and in fact no courses!) in analysis, abstract algebra or topology. The details are at our department website, http://academics.bentley.edu/departments/mathematical-sciences.

So what courses do we have instead? Students in either the actuarial or applied math tracks require courses in probability theory (post-calculus), and two courses in statistics. The first statistics course is quite standard and part of our general business curriculum, while the second is a post-calculus look at linear models, variable selection and model interpretation. Each student needs at least four electives in the department. Actuarial students naturally tend toward two courses we have that prepare students for Society of Actuaries Exams P and FM; and to related electives in financial engineering and discrete options pricing. Applied mathematics majors often choose courses that are more commonly seen in other mathematics departments, such as Differential Equations, Discrete Mathematics and Logic; though we do tend to teach these courses with more emphasis on computing and applications than is typical. Finally, we have a large number of interdisciplinary electives (Mathematical Modeling of the Environment, Mathematics and Sports, Mathematics of Computer Graphics) that introduce sophisticated mathematical topics through applications.

Our students have done extremely well in the job market with this background. While the actuarial students, predictably, tend to wind up at the many insurance firms in New England and New York, our applied math majors have found niches in a wide range of industries. Small marketing companies have been particularly receptive. Perhaps more than any other field in business, marketing has moved rapidly from being seen as a 'soft' major that was a haven for our least quantitatively enabled students to a technical field eager to hire experienced problem solvers with good analytic skills. One important common thread through both programs is that students need to be good communicators, both orally and in writing, so that they can understand problems and convince people of the value of their solutions.

The number of majors in the Bentley Mathematical Science Department has grown from four or five per year a decade ago to over a dozen per year today, and is still growing. We have many curricular goals. While applied mathematics is our first love, we would like to develop a course with more theory on the basics of analysis and topology so our students are better prepared for graduate programs in quantitative fields. An undergraduate course in 'big data' is in the preliminary discussion phase. A "Mathematics and Public Policy" elective that reviews fairness, allocation of resources, and voting theory is another goal. At many fine liberal arts schools, Mathematics Departments teach a curriculum designed primarily for the small number of majors going on to graduate school in Mathematics. Coincidentally, these students have turned out to be very employable in many industries. We enjoy working with a slight twist on this model, training students to be good problem solvers with an eye on business applications throughout their careers.

Feel free to contact me at rcleary@bentley.edu with any questions about our program.

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