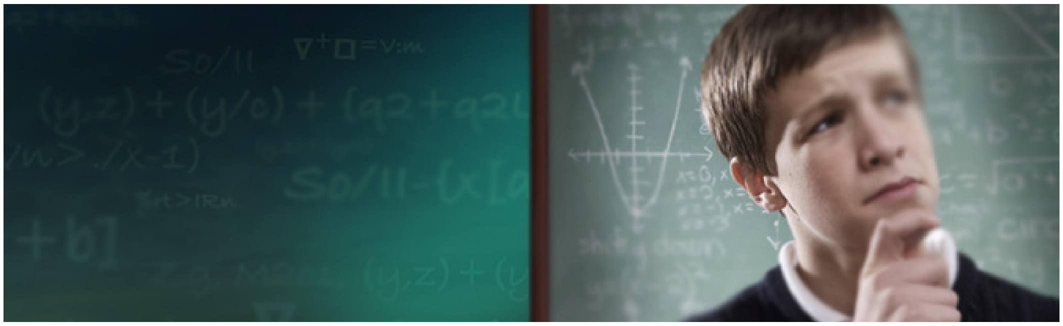
IDEAS from IBM

9 July 2007

Will I ever use this stuff?

Why math is more important than ever



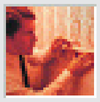
With industries and enterprises clamoring to apply mathematical models to innovate for all manner of problems, math has gone mainstream. As a result, the demand for skilled mathematicians is rising with career options burgeoning in fields from finance to medicine to entertainment.

You may have wondered whether all that trig and calculus would ever prove useful. But the old stereotypes of math and mathematicians no longer apply as the discipline has acquired major cachet in countless fields. Today's math whizzes are at the forefront of addressing some of the most pressing issues in business and society.

Math in the real world

As math steps out from the theoretical into the deeply practical, the world's awash with new math applications and commercial uses as a wide range of industries, some quite unexpected, are hiring mathematicians to create algorithms that optimize how they do things.

One reason math has hit this stride now is that data and technology have reached a level that enables mathematicians to crunch numbers in ways they never could before. "Now we have vast streams of data in most fields and access to that data in real time," said Baruch Schieber, senior manager of the Optimization Center at IBM's Thomas J. Watson Research Center. "We also have the computational power to solve larger problems than ever and networks that provide the required speed to execute on algorithms quickly."



Our math department

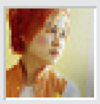
- **Mathematical Sciences**

Basic and applied research in algorithms, data mining, optimization and statistics

Math whiz quiz

- **Ponder This**

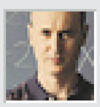
Try your hand at this monthly puzzle from IBM Research



Women in technology

Women have been making contributions to the advancement of information technology throughout IBM's history

- **Learn more**



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All this adds up to a period of great innovation in commercial math solutions in virtually every aspect of life. Here's just a sampling of math's impact on various industries.

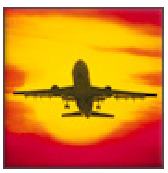
Supply chains

Algorithms work wonders in yielding greater operational efficiency across supply chains. This includes optimizing raw material acquisition, production scheduling, distribution and inventory levels. Math has proved invaluable for business optimization in other areas as well, including customer recognition, marketing, pricing and transportation.

Utilities

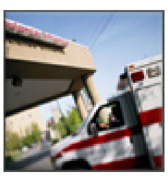
To help prevent power outages, electric companies can use math to create an "intelligent grid" that effectively monitors current and voltage throughout the system and can automatically detect where problems arise so they can be resolved quickly—maybe even before your lights go out. "This solution has the potential to lower downtime on the grid and, together with the optimized dispatch of repair crews, it may be a game-changer," Schieber said.

Airlines



Airlines use math extensively to manage their operations. Complex algorithms determine fleet assignment, crew scheduling, fuel acquisition and even predict the likely number of no-shows on a flight so the airline can strategically overbook while minimizing the risk of bumping passengers at the gate. "Given the current size of the airlines, they clearly could not survive without these types of tools to address key logistical matters," Schieber said.

Hospitals



The entire sequence of steps necessary to prepare for and conduct an operation can be modeled and processed mathematically to ensure optimal scheduling of surgeries and use of facilities. This includes acquiring prep rooms, doctors, nurses, necessary medical equipment, the O.R. itself and the recovery room. "We can vastly improve the flow of these steps using mathematical techniques, which can help cut costs and improve patient care," Schieber said.

Video games

Video games are becoming more realistic and challenging by the day?with stunning graphics and extraordinary environments?thanks to mathematical innovations. A complex algorithm sits beneath just about every precise droplet of water, strand of hair or realistic gesture by a character in today's hottest games.

Human capital

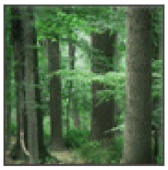
Mathematicians can model the skill sets and proficiencies of individual employees and then create algorithms to allocate the best qualified people to various jobs and projects?which includes teaming up employees with good chemistry and keeping apart those who don't work well together. "This sort of matching is almost impossible to do manually, but we can do it on a large scale using mathematical tools," Schieber said.

Algorithms can also be used to forecast long-term staffing requirements and then determine optimal hiring practices to meet predicted needs.

Finance

Mathematics is profoundly changing how financial markets operate, with complex algorithms increasingly used to analyze stocks, assess risk and value and automatically make trade decisions at lightning speed. Math has become crucial to all types of investing. In fact, one of the world's wealthiest hedge fund managers is a mathematician by training.

Forestry

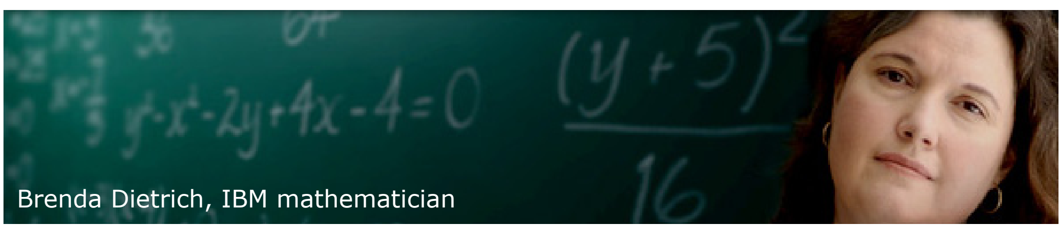


Algorithms can determine the highest risk areas for forest fires so agencies can allocate equipment and firefighters where they'll be needed most. Mathematical models take into account the type of vegetation in a given area, amount of rainfall, probability of a fire starting and various damage scenarios so agencies can respond to fires effectively and minimize acres burned.

Entrepreneurship

Math has become such a big deal, with mathematic solutions to all sorts of problems in such demand, that it's becoming an industry unto itself. Entire companies are being established to provide algorithms to specific industries. "As the world becomes increasingly math-driven, the market for sophisticated algorithms is only going to grow," Schieber said. "There's exciting, lucrative opportunity for new start-ups strictly built on math."

Mathematicians wanted



Brenda Dietrich, IBM mathematician

As the demand for math-based solutions grows worldwide, so will the need for top-notch mathematicians. Many experts express concerns, however, that the supply of math graduates and career mathematicians will fall short of global needs.

In the United States, poor math performance among primary and secondary school students has been an issue for years. Other countries, such as Australia, have raised red flags about math education and student achievement as well. By contrast, Singapore and China seem to excel in teaching math and turning out skilled graduates.

Ultimately, the state of innovation and progress across the global economy will be tied directly to the quality and quantity of mathematicians the world produces in coming years. Use the choices at right for a snapshot of math education around the world.

Kids and math

While assessments vary, international tests generally indicate a rise in math scores and competency by students in Asian countries and a decline in the United States. Singapore, widely regarded as a leader in math instruction, tops key tests while China and India, which have also demonstrated a strong commitment to math education, do not participate in most global comparisons.

"In the United States, the state of math education is certainly a cause for concern because with low interest and competency in math, we may be losing a generation of mathematicians," said Brenda Dietrich, IBM Fellow and director of mathematical sciences at the IBM Thomas J. Watson Research Center.

Average math scale scores of 4th-grade students, 2003

Country	Average score
Singapore	594
Hong Kong	575
Japan	565
Chinese Taipei	564
Belgium-Flemish	551
Netherlands	540
Latvia	536
Lithuania	534
Russian Federation	532
England	531
Hungary	529
United States	518
Cyprus	510
Moldova, Republic of	504
Italy	503
Australia	499
International Average	**495**
New Zealand	493
Scotland	490
Slovenia	479
Armenia	456
Norway	451
Iran, Islamic Republic of	389
Philippines	358
Morocco	347
Tunisia	339

Source: Trends in International Mathematics and Science Study

Average math scale scores of 8th-grade students, 2003

Country	Average score
Singapore	605
Korea, Republic of	589
Hong Kong	586
Chinese Taipei	585
Japan	570
Belgium- Flemish	537
Netherlands	536
Estonia	531
Hungary	529
Malaysia	508
Latvia	508
Russian Federation	508
Slovak Republic	508
Australia	505
United States	504
Lithuania	502
Sweden	499
Scotland	498
Israel	496
New Zealand	494
Slovenia	493
Italy	484
Armenia	478
Serbia	477
Bulgaria	476
Romania	475
International average	**466**
Norway	461
Moldova, Republic of	460
Cyprus	459
Macedonia, Republic of	435
Lebanon	433
Jordan	424
Iran, Islamic Republic of	411
Indonesia	411
Tunisia	410
Egypt	406
Bahrain	401
Palestinian National Authority	390
Chile	387
Morocco	387
Philippines	378
Botswana	366
Saudi Arabia	332
Ghana	276
South Africa	264

Source: Trends in International Mathematics and Science Study

College math

Which countries are producing mathematicians? It's difficult to pinpoint and compare the true number of degrees granted worldwide because countries use different criteria and definitions, and many (such as China and India) have not participated in most education comparison studies.

But for one kind of view, the **Organisation for Economic Co-operation and Development** reports on a variety of fields among its 30 member countries, including college or advanced degrees in mathematics and statistics.

Percent of mathematics degrees among all college/advanced degrees							
Country	1998	1999	2000	2001	2002	2003	2004
Australia	0.6%	0.5 %	0.5 %	0.4 %	0.5 %	0.4 %	0.5 %
Austria	-	0.7 %	0.8 %	0.7 %	0.7 %	0.8 %	0.7 %
Belgium	-	-	0.6 %	0.8 %	1.0 %	1.0 %	1.0 %
Canada	1.6 %	1.5 %	1.4 %	-	-	-	1.2 %
Czech Republic	0.4 %	0.8 %	1.0 %	0.8 %	1.0 %	0.8 %	0.8 %
Denmark	-	1.7 %	1.0 %	0.5 %	0.6 %	0.4 %	1.7 %
Finland	1.3 %	1.2 %	1.0 %	0.9 %	0.6 %	0.6 %	0.8 %
France	-	0.1 %	2.8 %	2.9 %	2.5 %	2.5 %	2.5 %
Germany	2.1 %	2.1 %	1.9 %	1.7 %	1.7 %	1.8 %	1.7 %
Greece	-	-	-	-	-	-	4.4 %
Hungary	0.6 %	0.1 %	0.1 %	0.1 %	0.2 %	0.1 %	0.1 %
Iceland	0.6 %	0.5 %	0.5 %	0.3 %	0.3 %	0.5 %	0.6 %
Ireland	0.7 %	1.4 %	1.1 %	0.9 %	0.9 %	0.7 %	0.9 %
Italy	2.3 %	2.9 %	2.8 %	2.1 %	2.0 %	2.0 %	1.5 %
Japan	-	-	-	-	-	-	-
Korea (Republic of)	2.4 %	2.3 %	2.1 %	2.3 %	1.9 %	2.0 %	1.8 %
Luxembourg	-	-	-	-	-	-	-
Mexico	-	0.3 %	0.4 %	0.3 %	0.4 %	0.3 %	0.5 %
Netherlands	1.0 %	1.0 %	0.3 %	0.2 %	0.3 %	0.3 %	0.4 %
New Zealand	0.1 %	0.1 %	0.1 %	0.1 %	1.0 %	1.0 %	1.1 %
Norway	0.3 %	0.2 %	0.3 %	0.2 %	-	0.2 %	0.3 %
Poland	1.5 %	0.9 %	0.8 %	0.6 %	0.6 %	0.6 %	0.5 %
Portugal	-	-	0.7 %	-	-	1.3 %	5.6 %
Slovak Republic	-	1.1 %	0.6 %	0.6 %	0.5 %	0.6 %	0.7 %
Spain	1.3 %	1.4 %	1.4 %	1.3 %	1.2 %	1.0 %	1.0 %
Sweden	4.1 %	0.7 %	0.6 %	0.6 %	0.5 %	0.6 %	0.7 %
Switzerland	1.0 %	1.1 %	1.1 %	1.0 %	-	0.7 %	0.9 %
Turkey	2.5 %	3.0 %	2.8 %	2.8 %	2.8 %	2.7 %	2.0 %
United Kingdom	1.5 %	1.5 %	1.3 %	1.4 %	-	1.5 %	-
United States	1.0 %	1.0 %	0.9 %	0.9 %	-	0.9 %	0.9 %
- data missing or categorized other than mathematics/statistics Source: OECD.Stat							

Women in math

Opportunity abounds for women with degrees in not just math but also math-dependent fields like engineering and computer science. In some countries (including the United States), however, women continue to lag behind men in choosing math as a field of study, particularly in pursuing advanced degrees and careers.

"Women have traditionally been unaware of the career options that math provides them," Brenda Dietrich, IBM Fellow and director of mathematical sciences at the IBM Thomas J. Watson Research Center, said. "It truly is a wonderful time to be doing the type of work that I do because we can have so much impact."

The percent of math degrees earned by women varies widely among countries, as the following information from the Organisation for Economic Co-operation and Development demonstrates. Other data shows that, at least in some countries, the more advanced the degree, the fewer women among the degree earners. For example, in the U.S., the National Science Foundation reports that in 2004, 45.9 percent of bachelor's degrees in mathematics were earned by women, but they earned only 28.4 percent of the field's doctoral degrees.

Percent of math degrees (college/advanced) earned by women

Country	1998	1999	2000	2001	2002	2003	2004
Australia	37.2%	41.1%	37.2%	37.7%	36.2%	38.1%	39.2%
Austria	-	23.9%	33.1%	40.8%	38.5%	36.7%	30.3%
Belgium	-	-	49.5%	45.5%	53.8%	45.2%	47.9%
Canada	41.0%	42.4%	41.6%	-	-	-	44.1%
Czech Republic	37.1%	35.5%	48.0%	45.9%	45.4%	50.3%	47.1%
Denmark	-	32.4%	40.5%	45.0%	37.2%	35.7%	24.2%
Finland	50.7%	36.8%	45.7%	39.1%	39.4%	43.2%	44.5%
France	-	20.0%	42.1%	43.3%	42.0%	42.2%	42.2%
Germany	41.3%	42.0%	42.1%	44.1%	45.2%	48.1%	53.1%
Greece	-	-	-	-	-	-	44.6%
Hungary	61.1%	30.0%	29.7%	22.2%	25.8%	25.3%	35.5%
Iceland	16.7%	16.7%	28.6%	20.0%	40.0%	27.3%	26.7%
Ireland	49.7%	42.1%	39.9%	48.6%	48.5%	34.7%	38.6%
Italy	67.1%	68.1%	62.7%	62.5%	62.0%	61.0%	59.6%
Japan	-	-	-	-	-	-	-
Korea (Republic of)	48.7%	54.2%	57.9%	55.6%	55.6%	56.3%	57.9%
Luxembourg	-	-	-	-	-	-	-
Mexico	-	-	45.8%	44.7%	45.2%	47.1%	41.0%
Netherlands	27.0%	26.4%	27.8%	26.9%	29.5%	30.2%	36.6%
New Zealand	20.0%	35.5%	55.6%	28.6%	43.4%	43.9%	44.9%
Norway	48.6%	18.9%	15.7%	32.7%	-	26.0%	27.4%
Poland	3.6%	26.9%	79.0%	75.4%	75.3%	72.5%	70.4%
Portugal	-	-	60.8%	-	-	69.2%	57.5%
Slovak Republic	-	51.6%	47.5%	38.7%	53.1%	47.8%	44.6%
Spain	49.9%	53.2%	55.9%	55.1%	54.6%	55.5%	57.6%
Sweden	24.0%	28.8%	29.9%	35.9%	28.8%	27.0%	40.3%
Switzerland	22.2%	19.6%	24.2%	22.0%	-	25.0%	28.9%
Turkey	44.1%	44.5%	46.4%	45.9%	46.2%	45.5%	47.6%
United Kingdom	27.3%	26.8%	38.1%	40.4%	-	39.8%	-
United States	43.5%	43.8%	45.2%	45.3%	-	44.0%	44.7%

- data missing or categorized other than mathematics/statistics Source: OECD.Stat

Podcast transcript:

Could algorithms ease frustrations for both airlines and passengers?

NARRATOR:
Welcome to the summer travel season. We're pretty sure you'll want to get to the airport early to check-in, just to make things easier.

But one thing you may not be able to control is whether you end up on your flight or not. That's because as airline revenue margins get tighter, airlines have to continue to overbook flights to make up for any of the "no-shows" with refundable tickets. It's a quandary for the airlines – business travelers, in particular, often demand refundable tickets, but if they don't show up, those empty seats can add up to billions of dollars in lost revenue for a major airline unless they overbook the seats to fill up the plane.

Yet if everyone does show up for a flight, bumping passengers can also be an expensive proposition – whether in vouchers for free flights or lost future revenue from annoyed customers.

It's a problem especially suited to mathematicians to solve. Dr. Rick Lawrence is a math scientist who manages the predictive modeling department at IBM's Watson Research Center.

RICK LAWRENCE:
"Airlines need to be able to predict quite accurately what the no-show rate will be on a specific flight. And the conventional approach to that problem is to build a historical, statistical based model, where they look at past instances of this flight and compute effectively what was the mean no-show behavior for this flight – perhaps a different no-show behavior if it was departing on a weekday as opposed to a weekend, and various other things – but the bottom line is, it was simply looking at aggregate historical behavior of similar flights. It does not... the conventional method does not take into account the composition of the passengers that are booked on that flight."

NARRATOR:
So in a test, Rick Lawrence and other IBM mathematicians worked with an actual airline to see if they could improve the predictions. To do that, they got more than a million anonymous passenger records over a 10-week period, with each record labeled as either a "show" or "no-show." And then they built a machine-learning model that started to make some connections for each of these nameless passengers, beyond just whether they'd bought a refundable or nonrefundable ticket.

RICK LAWRENCE:
"So we would not see the past history of this specific passenger; however we would know certain information about this passenger and this specific booking. For example, we would know what channel they booked this ticket through. Did they go through a travel agent? Did they go online? We even knew the specific identity of the online-booking channel. We found a significant amount of predictive information in that

feature alone. We would also look at other information. For example did they order a special meal? Were they flying with other people? How many connection flights were in their itinerary?"

NARRATOR:
They used the data from the ten-week period to "train" their model to predict which passengers were likely to show and which wouldn't.

To add to the accuracy, Dr. Lawrence's model also took into account the conventional, historical flight-based predictions the airline already used. So by combining the conventional flight prediction model with the passenger-level prediction and summing that up as a cabin-level prediction, the mathematicians could then compare how accurately the new model would perform against the conventional model alone.

RICK LAWRENCE:
"It's the statistical cross-validation that gives us a metric of how much better we're doing than the conventional, historical method. And we found in our analysis that we could identify no-shows with approximately two times (twice) the accuracy, that we were seeing in the conventional model."

NARRATOR:
Which, if applied, could cut down on both the lost revenue from no-show passengers and the frustrations experienced by the ones who now show up only to get bumped. However, Rick Lawrence sees even greater potential in an industry that's moving things other than people around, where the no-show rates can be as high as forty percent sometimes.

RICK LAWRENCE:
"One of the interesting problems that we see now is, instead of asking whether an airline passenger is going to show, is to ask in the shipping industry, is a container going to show up for a vessel for which it's been booked. Interestingly enough, it's a similar dynamic, but currently there are fewer penalties and fewer disincentives for customers of shipping lines to have their shipment show up for that vessel. The additional wrinkle which is quite interesting is the fact that here the containers in a vessel for example, of course, have many different dimensions, so the extension here is the fact that not only does that container have associated with it a probability of no-show, just like the airline passenger problem, it has associated with it dimensions and other characteristics – does it need to be refrigerated, for example? -- that impose an additional optimization component that is somewhat different than the scenario that we think about in the airline industry."

NARRATOR:
Solving that problem some day could help you a lot – since we all pay for shipping for most of the goods we buy, one way or another. But as far as your summer vacation goes? At the moment we can only say that you'd better hurry, or else you might miss your flight.

For Ideas from IBM and the ibm.com homepage, I'm Derek Baker.

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