NZIMAges

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Aircraft designer and hopeful astronaut

Auckland-born Karen Willcox is taking a sabbatical in her home town from her job as a professor of aeronautics and astronautics at the Massachusetts Institute of Technology on the USA's east coast. She spoke with Jenny Rankine.

Willcox's optimisation work has been one of the forces behind two revolutionary aircraft designs - the unmanned X-48B blended wing body (BWB), and the Silent Aircraft Initiative (SAI) conceptual design that may be flying commercially by 2030.

The Boeing BWB's integration of wings, fuselage, engines and tail makes it 30 percent more fuel efficient than a similar-sized conventional aircraft. The 1/12 scale prototype has a 21-foot wingspan, and is scheduled for remotely-piloted flight tests at the end of the year. The US Air Force says it could be in service within 15 years as a multi-role, long-range military aircraft. The 20-person design group for the Boeing BWB included specialists in aerodynamics, structures, engine, propulsion, weights and control systems as well as optimisation.

The SAI design is also triangular, with engines mounted above the wings to shield noise from the ground. Willcox led the SAI's design and acoustic integration research component.

She also leads an international research effort to cut fuel consumption and carbon emissions in 747-size aircraft, with Boeing, NASA, Purdue and Stanford Universities and MIT. While aircraft contribute about four percent of global human carbon emissions, "it is still important for aircraft to reduce that," she says. "Commercial aircraft operate for up to 30 years, so any reductions we make now will have an impact."

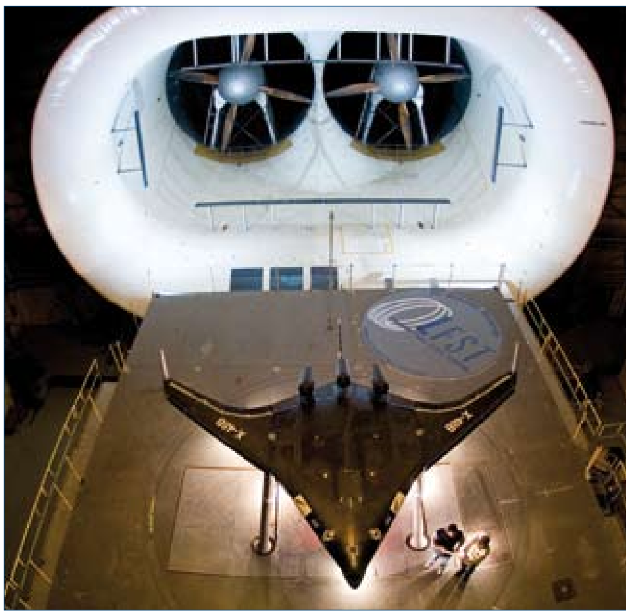
"We are looking at the whole design process and systems integration from aerodynamics to better controls and smart computers to change the way an aircraft uses fuel dramatically. There isn't a single technology to achieve the results we want."

"The kinds of maths students learn in high school is everywhere in this project. At the heart of optimisation are derivatives, which tell us how much change we will see in the aircraft's weight or load if we change some design parameter slightly."

These projects use multi-disciplinary design optimisation (MDO). "We write the design as an optimisation problem: minimise the weight of the aircraft subject to these constraints - for example, that the wings don't break, drag equals thrust, lift equals weight, noise doesn't exceed certain limits on take-off and landing - thousands of constraints."

"We'd set the computer running at night and come back in the morning and it would have a design. We'd take it back to the specialists and there might be something not quite right; we were constantly re- 2▶

Top: Willcox in the 'vomit comet', Nasa's zero-gravity aircraft. Below: The BWB prototype. Photo: Boeing/Bob Ferguson.



Welcome

Welcome to our seventh issue of NZIMAges, containing articles on the meeting point between maths and several natural phenomena including earthquakes, icebergs, waves, wood and weeds. There's also an interview with an aspiring NASA astronaut and a song about algorithms. We hope you enjoy it.

Marston Conder and Vaughan Jones
Co-Directors

INSIDE

New Zealand Institute of Mathematics & its Applications

taurangi

See also

Willcox's page - http://acdl.mit.edu/willcox.html

The Silent Aircraft site - http://silentaircraft.org/

The proposed silent aircraft design. Below: From computer modelling of astronaut collision constraints.

$$L = \prod_{K=1}^{15} (L_K)^{1/15}$$

fining the mathematical definition of the problem. The maths contribution allowed the team to evaluate thousands of designs overnight rather than manually change one element at a time."

"Mathematical methods are having a big impact on design. In aircraft design, safety considerations have meant that aircraft are heavier than they need to be. Statistical methods have the potential to come up with much more efficient systems and better designs. For example, an on-board computer alleviating wind gusts by wiggling the flaps in real time could save building extra structure into the wing to withstand them."

"Mathematics shows up everywhere, including computer models of how astronauts move in space - matrices, geometry, trigonometry, derivatives. All those things I learnt about in school that seemed abstract and not very practical turned out to be very meaningful."

Willcox isn't fascinated just with mathematics; she has applied for the next NASA astronaut intake after just missing out on the last one. After an eight-day immersion interview in March, she was in the shortlist of 40 out of 4,000 who applied, but budget cuts meant only nine were accepted. Applicants are selected for teamwork, ability under pressure, creativity and analytical skills.

Before she had her new baby, Willcox played on the MIT women's rugby team, competed in marathons and ultra-marathons, and climbed rock faces. "I really enjoy the challenge of going somewhere I haven't been before and putting myself far away from safety", she says.

Her sabbatical places her close to two grandmothers for her first child Pieter, and brings her back to the University of Auckland where she studied after Lincoln Heights primary school and St Cuthbert's College. "There's a lot of stochastic optimisation in Engineering Science at the University of Auckland, so it's a good community for the kinds of things I'm learning about."

> First appearances can be deceptive. While the ethos of every other science is that experimental evidence is all that you can truly rely on, mathematicians have learnt never to trust numerical data without proof.
>
> *Marcus de Sautoy,* Music of the Primes.

NOTABLE MATHS PROBLEMS

NAVIER-STOKES EXISTENCE AND SMOOTHNESS PROBLEMS

That solutions to the motion of fluids in three dimensions always exist (existence); and that if they do exist, then they do not contain any singularity, infinity or discontinuity (smoothness).

Also stated as: Show that the Navier–Stokes equations on Euclidean 3-space have a unique, smooth, finite energy solution for all time greater than or equal to zero, given smooth, divergence-free, initial conditions which decay rapidly at large distances. Or show that there is no such solution.

Discipline: Analysis.

Originators: French mathematician Claude-Louis Navier and English mathematician George Gabriel Stokes in 1822.

Incentive: US$1million, one of the seven Millennium Prize Problems - the most important open problems in mathematics, according to the USA-based Clay Mathematics Institute.

Usefulness: The Navier-Stokes equations are nonlinear partial differential equations in almost every real situation. They describe the physics of weather, ocean currents, water flow in a pipe, air flow around a wing, and the motion of stars in a galaxy as well as help with design for aircraft, cars and power stations, the study of blood flow, and pollution analysis.

Explorations: One approach - constructing a weak solution and showing that any weak solution is smooth - has had partial success. It is believed, though not known with certainty, that the Navier-Stokes equations describe turbulence properly. However, the equations are supercritical - energy can interact much more forcefully at fine scales than it can at coarse scales. There is no good large data global theory for any supercritical equation, without additional constraints.

Almost all the equations are written for Newtonian fluids, which continue to flow regardless of forces acting on them. Models for other kinds of fluid flows, such as blood, do not yet exist.

State of play: Since we don't even know whether solutions exist, our understanding is primitive. Some exact solutions of degenerate cases and non-linear equations do exist. Solutions may lie in related models, such as the Euler equations.

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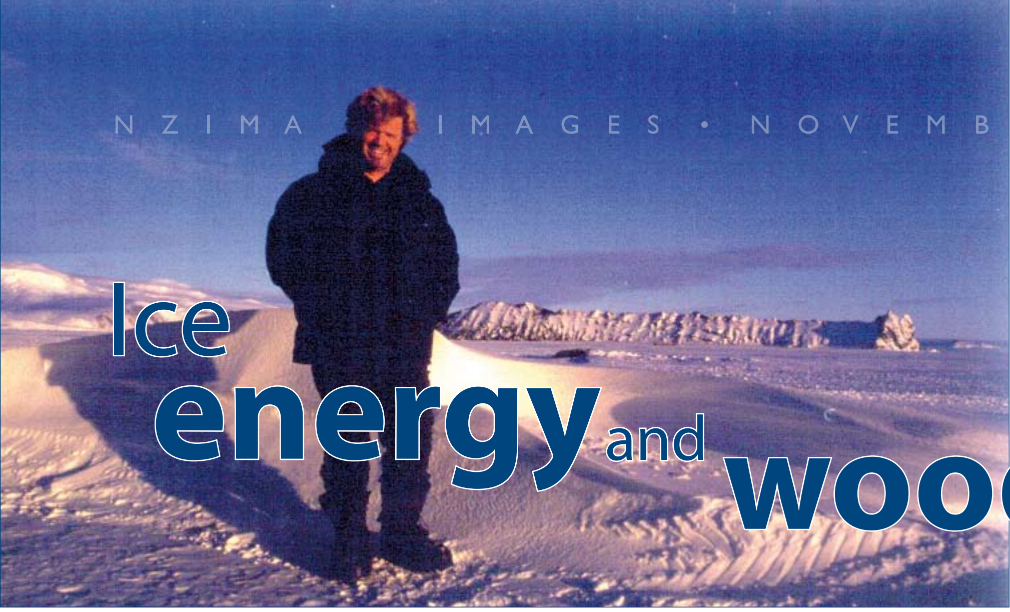


Ice energy and wood

"The magic of mathematics is that the same methods have applications in a whole range of fields," says Colin Fox. He described some to Jenny Rankine.

"Partial differential equations (PDEs) model energy propagating through a system that varies in space and time, like sound or seismic waves, or x-rays through human tissue," says Fox (above).

"For example, the gung-ho overuse of early geothermal fields is no longer acceptable," he says, "so those fields need to be modelled for environmental management and sustainable power generation." But underground measurement involves a lot of signal noise and uncertainty.

Fox was a co-director of the NZIMA programme on Analysis, Applications, and Inverse Problems in PDEs in 2007, and with co-director Professor Mike O'Sullivan, supervised NZIMA scholarship student Tiangang Cui to compute a Markov Chain Monte Carlo method.

"But if you use basic MCMC methods, the universe wouldn't last long enough for the computer programme to finish, so we developed some algorithms around that," says Fox. "The computations then became faster than standard engineering least squares optimisation methods; it's like a big camera for looking at the geological structures."

The solution is now used for resource consent hearings and long-range planning. Auckland was one of three centres in the world where the same combination of PDEs from engineering, inversion in graduate statistics and numerical and analytical maths was taught. The notes for Physics 707 - Inverse Problems, written in 1997 by Fox with colleagues Geoff Nicholls and Sze Tan, reached the 60 most-downloaded mathematical texts online. The area became a priority for the USA National Science Foundation this year, so Fox predicts that they'll catch up soon.

The largest seasonal process in the world, the southern ice freeze and thaw, is a very mathematical system, says Fox, and was another focus for his work with PDEs for more than 12 years. In the 1990s, he was part of the New Zealand science team K131, which studied sea ice far from Scott Base.

"The sea ice freeze was the biggest effect in southern hemisphere climate models, but modellers didn't know how to include it," he said. No one had made the measurements Fox needed to describe how ocean waves affect land-fast sea ice, so for years his team tried to gauge them with sensitive tilt meters at the edge of the sea ice, "hoping it didn't break that day and float off".

When they decided to make their own waves, the team built a hydraulic jack they called the Thumper. "In the first year, I left out some terms in the residue late one night, which cost the taxpayer about $50,000 because the Thumper was about ten times too small."

The second year he recalculated, and the 3m by 3m jack happily created waves by picking up two tonne lumps of ice and dropping them, safely away from the edge. The results led to better mathematical methods for solving those kinds of problems.

"To a mathematician, sea ice is a combination of fluids, thin elastic plates and waves. Lightweight timber construction in New Zealand is similar - plates and beams in a fluid." Fox had been interested in acoustics as a student, and directed the Acoustics Research Centre from 1998 to 2007.

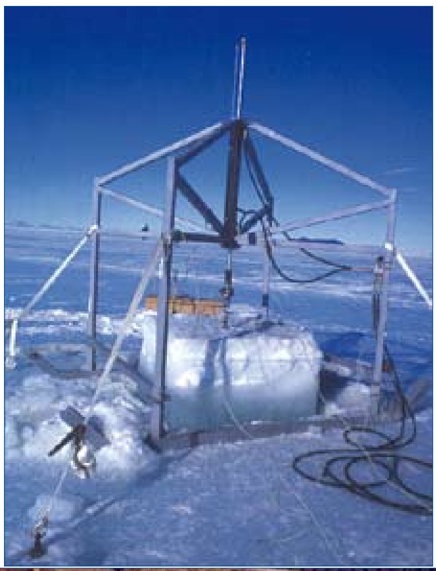
"Sound insulation in houses is a complicated problem - over the years we saw hundreds of entrepreneurs with the latest idea for quiet walls." Fox supervised post-doctoral student Hyuck Chung, who wrote the codes and did the modeling to design a timber floor with better sound isolation than concrete.

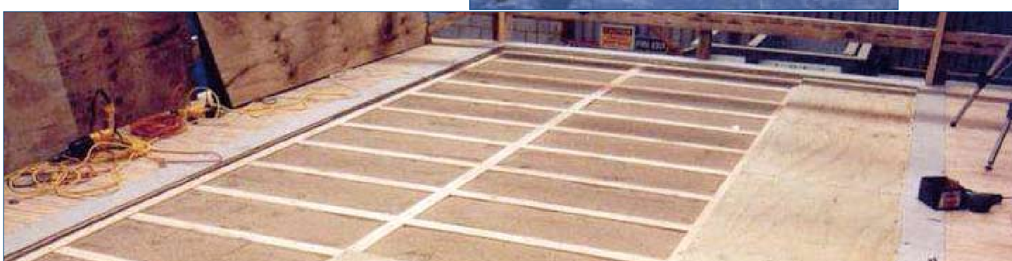
"We used a version of finite element methods, a standard engineering technique for solving PDEs. We wouldn't have come to these methods without the semi-analytic methods we'd developed for sea ice." They worked with acoustics and building specialists, building a simple floor and making sure the computer model exactly matched.

"Two designs both performed better than concrete floors. They included careful placement of joists, choice of material and layering - nothing exotic. One included a novel element - a layer of mixed sand and sawdust between ply and floorboards."

"Listener tests were part of final testing. We recorded the noise of walking over the floors and replayed them in a listening room. You would swear that someone was walking on the floor above you, and we asked them to rate the noise as better or worse. That's why I enjoy acoustics - at the end the human ear is the final arbiter."

Below: The thumper.
Bottom: The sand and sawdust sound isolating floor.





Sampling southern **weed** pests

Maths has enabled Environment Southland to obtain a statistically valid assessment of the amount of land in the region covered by introduced weeds. Jenny Rankine reports.

Environmental Science student Meghan Williams is developing simulations using geographic information systems (GIS) and the statistics software R for her PhD. The simulations will assess the effectiveness of spatially-balanced sample designs for mapping the spread of six different types of weeds, such as wilding pine and old man's beard, in different habitats over time.

She is using GRTS (generalized random tessellation stratified) sampling with Environment Southland's weed surveillance programme. "Historically, in environmental resource sampling, designs have been grid-based or spatially random," she says. "It's important to get a probability-based sample so that inferences are valid, but grids are inflexible and random can be clumpy. GRTS is a valuable alternative."

Statisticians Don Stevens at Oregon State University and Tony Olsen of the USA Environmental Protection Agency developed the GRTS design and an application using the New Zealand statistics software R in 2004, which is available free on the EPA website.

GRTS was initially designed for monitoring aquatic resources; the Southland project is its first use in New Zealand and its first for terrestrial weeds. Biosecurity Officer Randall Milne says Environment Southland had done random surveys in known weed habitats, and door-knocking surveys in urban areas, but "we needed some reliability about weed data".

They met Williams and her supervisor Dr Jennifer Brown at the University of Canterbury and agreed to field test the GRTS sampling design. They asked for 200 sampling points each year for five years, focussed along roads and rivers, and other accessible areas of Southland.

"While the GRTS input and output is GIS data, R does the processing," says Williams. "Using R requires familiarity with the programming language, and the GRTS library (spsurvey) has a relatively steep learning curve. So I made a user-friendly tool in ArcGIS. It generates a GIS shapefile to use with global positioning system (GPS) units, Google Earth, or other GIS software."

The shapefile included XY co-ordinates of the 200 points and tables for field workers to fill in. Williams also delivered a map of all 1,000 points and one of the first 200, and some oversample sites in case some points could not be sampled.

Meghan Williams with a new infestation of Old Man's Beard strangling some native Southland vegetation. Background: The GRTS algorithm converts area to line.

Says Milne: "We had a list of 94 weed pests from our regional pest management strategy and the Department of Conservation's weed surveillance list for Southland." Points were found using a GPS unit and weeds recorded on paper. "We look for weeds within a 100 metre-square area around the random point, noting the presence of any one within each one square metre sub-plot. We use a tape measure and a frame. We don't usually find more than half a dozen weeds in a subplot, but it can take from 40 minutes to two hours per site."

Using that information, Williams was able to supply an estimate of land area covered by each of the 94 weeds. "It was really exciting to plug in the season's site results and come up with statistically valid estimates of kilometres of roadside, riverside and regional weed occurrence. These results help managers identify the severity of weed infestation, changes in species and new occurrences. These numbers can document control efforts and help the case for funding. These sites can also be used to tailor sampling strategies to find specific species.

"It's been very useful," says Milne. "It's statistically valid evidence we haven't had before. The results to date back up what we largely know already - the most common weeds are the long-established species often found in the agricultural landscape. However, stonecrop was turning up a lot more than we expected. Over five years we also hope to get good data that can be used in predictive models of weed spread. This will help us focus on which weeds to keep a watch out for in the region."

Says Williams: "The field realities of sampling are much messier than on the computer. Fortunately, we can refine our methods as we learn and the stats are pretty straightforward with GRTS." Milne is hoping to change the model for the 2009/10 sample to exclude some of the highly-managed agricultural land. Williams says the flexibility of GRTS means "you don't bust the whole five-year plan by adapting the sampling design".

See also

The free GRTS software - http://epa.gov/nheerl/arm/analysispages/software.htm

Still too slow for me

Danzer Braganza won the NZIMA Programme in Algorithmics competition to produce a song about algorithms.

Still too slow for me

(To the tune of *It's Still Rock and Roll to Me*, by Billy Joel)
Lyrics © Danver Braganza. 2009

What's the matter with the sort I'm using?
Can't you tell that it takes too long?
Maybe Bubble Sort's the wrong way to go
Wanna finish by the end of this song...
Maybe I should not be trying to sort it in place?
Would it be better if it ran in ex-pon-en-ti-al space?!
All right, rewrite, one more try to get it right. It still runs too slow for me!

What's the matter with the code I'm writing?
Can't you tell that it's out of style?
Do you think that I should write in Java?
Only if you really like to compile!
Scripting languages are winning these days, newbie
Perhaps you should be programming in python, perl or ruby?
Boo hiss! Cache miss! Excuse me while I page to disk, it still runs
too slow for me!

Oooh,
You oughtta read the stuff they say in the textbook.
You just gotta optimise, Dividing and Conquering, but you fail at recurring.
So your stack goes off and silently cries I'm sorry for your code's demise...

How about I port the code to C and
See if that makes it fast enough.
What the hell, now I've corrupted the heap, man Writing C is
way too tough!
Don't waste your time, just use the language you like.
You're likely to do better if your algorithm is right!
New thought: Merge Sort, written just as it ought,
It still runs too slow for me.

Maybe I should go and talk to the smart kids,
Look at what they are handing in.
I've no clue what they are talking about,
And besides, plagiarism's a sin.
Now there's a message from the lecturer
on Cecil*
It turns out that the time requirements were
too excessive,
New run, what fun!

Looks like the assignment's** done -
It's now fast enough for me!

* Cecil - the University of Auckland course information system.
** Automatically-marked programming assignments for algorithms

The well-known parody of Billy Joel's *For the Longest Time* had reached 20 years old (http://valis.cs.uiuc.edu/~sariel/misc/funny/#longest-path), and programme directors were sure New Zealand could produce lyrics just as good.

Entry was open in late 2008 to anyone resident in New Zealand and advertised on the programme website (www.cs.otago.ac.nz/algorithmics/fun/), to the New Zealand Algorithmics Google Group and to students.

Mark Wilson presents the prize of $200 in book vouchers to Danver.

MATHEMATICAL EVENTS

23-26 November, Manawatu Marine Boating Club, Foxton Beach
2009 NZ Postgraduate Mathematics & Statistics Conference
http://nzmasp09.massey.ac.nz/

3-4 December, Christchurch
44th Annual ORSNZ Conference, hosted by the University of Canterbury
www.orsnz.org.nz/conf44/

8-10 December, North Shore City
Annual NZ Mathematics Colloquium, Massey University Albany Campus
http://nzmc2009.massey.ac.nz/

3-10 January 2010, Hanmer Springs
Annual NZMRI/NZIMA Summer Meeting, theme of Groups, Representations and Number Theory
www.math.auckland.ac.nz/wiki/2010_NZMRI_Summer_Workshop

12-18 January 2010, Hahei, Coromandel Peninsula
NZIMA workshop on Topological Quantum Field Theory & Knot Homology Theory
www.math.auckland.ac.nz/wiki/NZIMA_workshop_on_TQFTs_and_Knot_Homology_Theories

31 January - 4 February 2010, Queenstown
ANZIAM 2010 Annual Conference
www.math.canterbury.ac.nz/ANZIAM/

Changing the scientific paradigm

The era of the algorithm is upon us, says Bernard Chazelle, and it "promises to be the most disruptive scientific development since quantum mechanics". Chazelle is a Professor of Computer Science at the Ivy League Princeton University in New Jersey, USA, and made this claim in March during public lectures in Auckland, Wellington, Christchurch and Dunedin as part of the NZIMA Programme in Algorithmics. He talked with Jenny Rankine.

Bernard Chazelle advocates radical change. When asked how algorithmics can become not just a body but a *way* of thinking, he focuses first on maths and science. "Traditional maths focused on symmetries. You could write on one page math equations from physics that explain 99% of everything that happens around you in the physical world. The reason is that the natural world has so much symmetry."

"But the 21st century is looking very different; the problems are economic, technological, the behaviour of complex organisms, ecologies and social groups. The traditional tools of maths are not going to be as efficient to handle these new problems, because they don't hold the same symmetries."

An algorithmic way of thinking is pretty much the only candidate, he says. "If you squint hard enough, a network of autonomous agents interacting together will begin to look like a giant distributed algorithm in action." Algorithms may not be as successful as equations, but there is no plan B; "it's becoming the central scientific paradigm of the 21st century."

Then he focuses on education: "The way teaching is done in the USA and Europe, if I say the algorithmics toolkit is going to unleash a new world, it makes no sense. The curriculum will have to change."

University departments and curricula, and by implication those in secondary schools as well, are based on 19th century classifications, he says. "Algorithms and information science are becoming an integral part of how scientists think about their science. The biology part of the Human Genome Project was not the most important - the hard part was algorithmic, computer science."

He gives an integrated first-year biology course at Princeton as an example of how science and maths could be taught. He and another computer scientist taught the course with two biologists, a chemist and a physicist, aiming to show the relationships between the deepest concepts in these disciplines. "I talked about the algorithm behind Google, the chemist talked about the fundamental chemical process of diffusion; we taught together so students would understand that these are the same processes."

Chazelle's enthusiasm for integration may relate to his own abilities in multiple fields; he blogs regularly about politics and music, and draws cartoons.

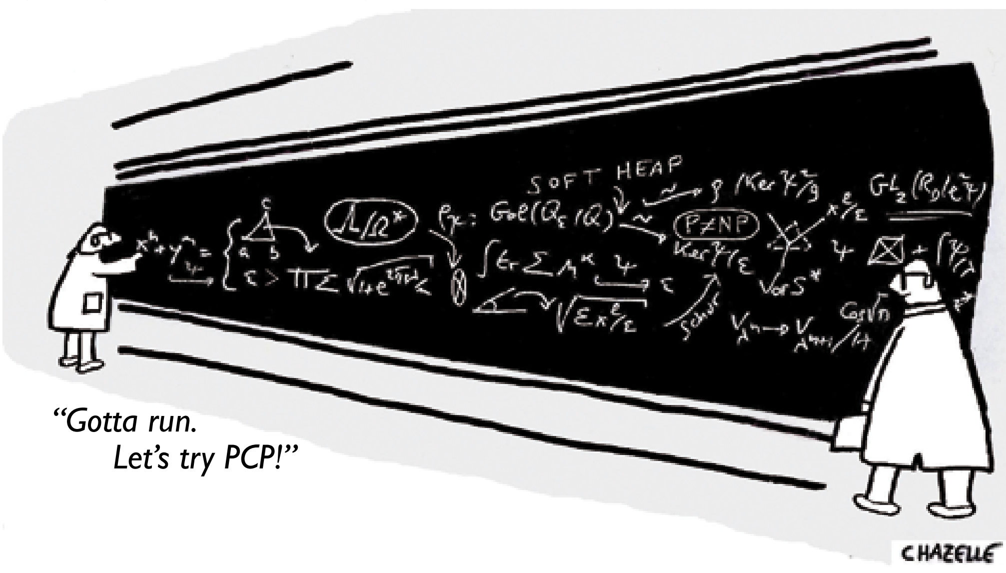
Chazelle argues that the field of algorithmics has been limited by its use only as a problem solver; publications systems have discouraged exploratory and theoretical work. He gets quite literary. "There are simple, zinger-like algorithms; local rules that produce complex systems." An illustration is an algorithm about bird behaviour that models migrating geese as well as undirected flocking networks.

Then there are algorithmic novels, which allow multiple levels of abstraction. Chazelle gives the example of war, which at its most basic "is a soldier valiantly following combat rules on the battlefield. At a higher level of abstraction, it is a clash of warfare strategies." These epics of the algorithmic world "devote most of their energies to servicing their constituent parts via swarms of intricate data structures."

Chazelle looks forward to the time when the ability of maths to modify, combine, harmonise and generalise equations is applied to algorithms, enabling us to knead them like dough to form new algorithmic shapes.

See also

Chazelle's home page: www.cs.princeton.edu/~chazelle/



*"Gotta run.
Let's try PCP!"*

Harnessing the waves and tides

New Zealand is rich in potential sources of wave and tidal energy according Margot Gerritsen, who spoke at the NZIMA Energy, Wind and Water programme workshop earlier this year. She discussed her work with Jenny Rankine.

Tory Strait and French Pass in the Marlborough Sounds and the Hokianga and Kaipara Harbours are all potential energy sites, says Gerritsen, a professor in the Department of Energy Resources Engineering at Stanford University in California.

A tidal power generation project has been proposed for the Kaipara, where currents move at up to three metres per second in a deep channel. Full tidal assessments involve radar observations, two-dimensional computer modelling to rank sites, three-dimensional modelling for design optimisation and risk analysis, as well as studies of possible effects on marine life and harbour floors. This has yet to be completed for the other sites.

Gerritsen has helped develop a computer model exploring the impact of tidal turbines, and hopes to extend it to their design. "They look just like a beefed-up wind turbine: the drag and friction forces are much larger in water and so they need to be a lot stronger." Cavitation, the formation and collapse of vapour bubbles in water with pressure changes, is also a problem for tidal turbines.

Gerritsen's computational mathematics has several other applications. She has developed a computer model of coastal erosion, for example the way in which sand in the Kaipara and Hokianga Harbours moves from the harbour to the ever-changing sandbar in the estuary. "I'm also interested in the transport of nutrients, which is very important for fishing. Nutrients may well up from the bottom to the top layers of the sea; this can show fishing boats when they should fish where, and when they should not, because they may be overfishing."

When she worked at the University of Auckland in New Zealand in the late 1990s, Gerritsen used computer modelling to help design spinnakers, mainsails and jibs for Team New Zealand's America's Cup yacht. "It requires a lot of mathematics; like turbine design you need to understand how air flows past a sail." She is now collaborating with international sail making company Doyle Sails and has worked on the unique no-rigging design of the 88m luxury clipper yacht, the *Maltese Falcon*.

Another application is the application of efficient numerical schemes to the recovery of oil from existing fields. "Pumping is not efficient for very long. You can inject carbon dioxide or other gases to increase the pressure in the reservoir, which helps get more oil out. A lot of the oil being produced now is very, very sticky, like peanut butter in the rock, and very hard to extract. One method is to burn some of the oil to heat and "soften" the oil. It's an optimisation problem working out where to inject the gas or where to burn. We build computer models to simulate the flow of gas and oil through the reservoir."

She and more than six other researchers have been working with multinational oilfield services corporation Schlumberger. "We use laboratory experimentation to validate the model. You can mimic a rock using very small glass beads, for example, and observe the flows." The team also uses CT scanners to look inside rock cores from the actual field.

In 2007 Gerritsen started Smart Energy, a podcast blog site that discusses energy issues and policies for the public and policy makers. "A lot of people don't like having new energy systems built close to where they live; NIMBY (not in my back yard) is very strong. It's hard to convince people that we always have to choose between the lesser of several evils, and that energy has to be paid for in different ways."

See also

Gerritsen's blog site - www.smartenergyshow.com

The no-rigging yacht - www.symaltesefalcon.com/about.asp

Top: Wave power buoy. Above: Gerritsen on her Triumph Bonneville with students in her department.

$$P=\left(\frac{15^2 20}{2}\right)=112.5MW$$

"There is an eternality about math questions, a feeling that you're really getting to the bottom of something." *John Conway*

Analysing earthquake signals

Ting Wang at the Forbidden City in Beijing.

Statistical analysis of a well in China by a PhD student in Palmerston North has developed diagnostics for seismic activity that are being used in Taupo and Southern California. Jenny Rankine reports.

The Tangshan Well (above) is about 100km north-east of Beijing, in an area which has had many small earthquakes since 1976, when a magnitude 7.8 earthquake directly under the city killed about 240,000 people and flattened most of the city's buildings.

Chinese seismologists have known for years that the water level in this well is very sensitive to earthquakes. The level has been recorded daily since 1974, hourly since 1981 and digitally every minute since 2001.

Chinese student Ting Wang has studied in Beijing and is now doing her PhD at the Institute of Fundamental Sciences at Massey University, supervised by Associate Professor Mark Bebbington, Dr David Harte of Statistics Research Associates and Victoria University Emeritus Professor David Vere-Jones. She has analysed well level records since 2002, supplied by the Tangshan Earthquake Administration (TEA).

"Most fluctuations in water level register for about a half an hour to an hour, so hourly data is not useful for extracting well signals," she says. Her data set is two million measurement points, one minute apart, over four years, and a catalogue of global earthquakes from the USA Geological Survey's National Earthquake Information Center.

From this she extracted the arrival times of different earthquake waves - the primary and secondary waves, which travel through the earth, and the Rayleigh and Love waves, which travel along the earth's surface.

The amplitude of well level fluctuations increases after earthquakes. "We extract signals from the well data using a moving average filter method over a 10-minute window, and move that window along one minute at a time." She has used skill score and Poisson process tests to choose well signal filter parameters and magnitude thresholds for earthquake series.

"From the well point of view, there is a lot of movement and you don't know the cause. We've identified what is an earthquake response and what isn't," says Wang. About 40 percent - 237 of the 600 earthquakes above magnitude 6 - appeared to trigger identifiable fluctuations in the Tangshan Well. "We also found a threshold in the relationship between the magnitude of the earthquake and the well's distance from the epicentre, above which earthquake-related changes in well level are most likely."

The existing theory is that changes in water level are caused by Rayleigh waves, but in Tangshan arrivals from earlier waves, particularly primary waves, are often noticeable, although the Rayleigh waves do amplify movement in the well level.

Wang then turned her attention to analysing New Zealand earthquake data. "GNS Science has over 100 GPS receivers, which measure east-west, north-south and up-down position in each site each day, but only about 12 were in place around Taupo before 2004." The standard wisdom was that GPS signals measure only deformation after earthquakes. Using a lot of the same techniques, Wang was trying to find if any pattern of GPS movements from around Taupo preceded earthquakes.

"We used a hidden Markov model to filter the data from the noise, then used mutual information to analyse which kind of movement is related to earthquakes. We found pre-seismic signals but they need more analysis; seismologists are very cautious."

While the Taupo analysis may provide some precursory information, there is not a risk to life or property. Wang moved her attention to GPS data and earthquakes in Southern California, which has more than 10 years of GPS data. "We needed a place with good GPS records and lots of earthquakes." There she found pre-seismic signals similar to what have been found at Taupo. With more testing and longer data sequences, Wang hopes that GPS measurements may be able to provide probability forecasts for large earthquakes.

$$V_t = \frac{1}{10}\sum_{s=t-9}^{t}\left(e^{-a(t-s)}d_s - \frac{1}{10}\sum_{s=t-9}^{t}e^{-a(t-s)}d_s\right)^2$$

Awards and honours

Professor **ROD DOWNEY** (Victoria University of Wellington) has been appointed to the Marsden Fund Council.

Professor **VAUGHAN JONES** was made a Knight Companion of the New Zealand Order of Merit (KNZM).

Professor **GAVEN MARTIN** (Massey University) and **DR ANDRE NIES** (University of Auckland) were invited to give lectures at the International Congress of Mathematicians in India in 2010

Emeritus Professor **DAVID VERE-JONES** (Victoria University of Wellington) was awarded the Campbell Award by the NZ Statistical Association.

VICKY WANG (NZIMA scholar, University of Auckland) won the best paper award at the MICCAI Society Conference (for medical image computing and computer-assisted technology), jointly with Hoileng Lam.