Communications

A graduate modelling workshop: Canadian style

Nev Fowkes* **and Phil Broadbridge****

The Pacific Institute for the Mathematical Sciences (PIMS) held the 11th Graduate Industrial Mathematics Modelling Camp (GIMMC) and the 12th Industrial Problem Solving Workshop (IPSW) from 9 June to 20 June 2008 in Regina, Saskatchewan, Canada.

A total of 30 (mainly) postgraduate students from throughout the world attended the GIMMC, including four students from Australia (Thu Giang Nguyen (University of South Australia), Asef Nazari (University of Ballarat), Melanie Roberts (University of Western Australia) and Roslyn Hickson (Australian Defence Force Academy, a college of UNSW)). Almost all of the students remained on for the IPSW held during the second week and they were joined by a few local academics. In essence the GIMMC was the entrée, and IPSW the main course; a very effective arrangement. Support for attendance was provided by PIMS, and AMSI also provided support for the Australian representatives. This is the second consecutive year for which AMSI has sponsored Australian students to attend the PIMS Canadian GIMMC.

At the graduate workshop students were invited to address the problems presented by five appointed mentors and they presented the results they obtained at the end of GIMMC. Additionally students presented detailed reports. The IPSW format was similar with the problems being presented by industry representatives (similar to our MISG). The application areas ranged across combinatorics, financial mathematics, statistics and continuum modelling. A few of the problems will be described here.

Photo: Mike Esprit

The first example was a local one. Regina has a large casino (Casino Regina) run by the Saskatchewan Gaming Corporation which is a major tourist attraction and which reputedly offers a better deal for gamblers than Las Vegas. Over the long term the casino does very well (thank you) as you might expect, but there can be bad days (for the casino) and even bad weeks, and also particular tables can record a

*School of Mathematics and Statistics, University of Western Australia, Stirling Highway, Crawley, WA 6160. E-mail: fowkes@maths.uwa.edu.au
**Australian Mathematical Sciences Institute, The University of Melbourne, VIC 3010.
E-mail: phil@amsi.org.au

bad run (for example a $\$12,000$ loss over a day on a table). The total cash drop on a typical day is about $\$300,000$ and the actual daily gross result is quite volatile; it's a nervous business. Les Cloutier keeps an eye on the numbers and it is his job to detect any 'irregularities' (possibly due to cheating, theft, operator or equipment problems) in the recorded take from the various tables and if necessary call for management intervention. Over the years he has developed an eye for such irregularities but he was looking for an objective backup 'tool' for assistance. Whilst this superficially seems to be a standard statistical and/or probabilistic task, sifting through and analysing available data and presenting results in an immediately available form was challenging.

Photo: Gary Cowles

Snow clearance is, of course, an important and expensive task for towns in Canada. Ideally one would like to have snowplows traverse roads just once, clearing snow as they go, but dead runs can't be avoided. However, by a judicious choice of paths for the available snowplows one can minimise the number of dead runs or total cost, and perhaps even save the purchase of a new snowplow. This was the GIMMC problem posed by one of the mentors Ed Doolittle. Additional complications such as traffic lights, one- and two-way streets, primary and secondary roads, add to the challenge. A number of competing methods were examined and tested using real data.

A problem that is ideally suited for illustrating the power of scaling ideas in continuum modelling came from The Concrete Institute (Wits) and arose out of a South African MISG. During the construction of concrete dams, large slabs of concrete are poured and the hydration heat released as the concrete sets gives temperature rises typically in excess of 50°K. The conductivity of concrete is small so that very little of the heat generated within the concrete can be expelled through the surface during the construction period; the conductivity time scale for typical concrete slabs without cooling is about 20 years. The resulting temperature build up can lead to thermal stress induced cracking and resultant structural weakening and also can cause delays in construction. To reduce the effect, cooled water is piped through the concrete to extract as much of the hydration heat from within the slab as feasible without compromising its strength. Later the pipes are filled with concrete. The aim was to determine an optimal water pipe network to remove the heat.

Of course detailing possible winding paths of pipes through the slab is probably both impossible and pointless, so a simplified geometric model is essential. Additionally the time and length scales associated with heat transfer in the concrete and water are very different so that it is necessary to correctly assess the size of the various thermal interaction terms to arrive at a suitable approximate equation set. The students examined a simplified model consisting of a single pipe carrying water encased in an insulated hydrating concrete sleeve, and used scaling arguments to obtain estimates for the appropriate pipe spacing and length of, and flux through, pipes required to reduce temperature rise within the concrete to a prescribed level. It was an impressive effort.

The following oil exploration problem presented to GIMMC students came from BHP. The resistivity of a rock layer under the ocean is greatly increased by the presence of hydrocarbons and electromagnetic techniques have been used to detect the presence of such layers. To do this, a long wire carrying a high-voltage alternating current is trailed behind a ship close to the seabed and instruments previously placed on the sea bottom are used to record the electromagnetic field generated. The task was to use simple mathematical models to obtain explicit results for the dependence of the changed response on the depth and thickness of the (horizontal) oil layer. As many will appreciate, this is a demanding task more appropriate for a PhD project (there being six electrical and magnetic components to determine in an awkward geometry), so students were first asked to address a much simpler but analogous 1D thermal detection problem: There is a thin horizontal strip of material under the ground with conductivity different to that of the surroundings, is it possible to determine the location and thickness of the strip by observing differences in the thermal response of the ground due to an oscillatory heat source on the surface? Complete analytic solutions were obtained for the thermal detection problem and simple explicit results for the temperature change on the surface due to the thin strip, and using these results students described an oil exploration strategy. Surprisingly a small group of three students elected to directly attack the EMW problem. They obtained explicit results for the change in electromagnetic field components across a thin oil bearing layer and also they set out a plan for addressing the main problem; very impressive!

In the IPSW there were four problems presented including the following one posed by Professor Jack Tuszynski from the Division of Oncology Cross Cancer Institute in Edmonton, Canada. The current medical treatments for cancer include surgery, radiation therapy, gene therapy and chemotherapy, and much improved outcomes for patients have been achieved when these therapies have been used in combination. The general issue posed was how best to combine such therapies. It took us about a day to get to grips with the biology and medicine, after which we decided to restrict our attention to the general question: How can one evaluate and best improve the outcome for a patient by changing the application frequency of a particular drug or by using a combination of drugs? The drugs used generally fall into two categories: those that target particular stages of the cell cycle and those that interfere with the cell's environment. Antiangiogenesis drugs fall into the second category. These drugs inhibit the growth of blood vessels near the tumour, depleting the nutrient supply while enhancing the flow of other therapy drugs. Of course chemotherapy drugs are poisons which destroy both tumour and normal cells and effect the total physiology of the body, so balanced against the benefits are the side effects. This problem attracted a very large group of participants which broke into five groups examining various aspects using mechanistic, optimisation and probabilistic models. All the groups produced very worthy contributions of either fundamental or immediate practical interest. Most notably one of the groups developed a general dynamical system/probabilistic model that provides a practical framework for evaluating and modifying different treatment regimes. The Cancer Institute plans to set up a program based on this work.

This was a remarkably successful meeting, both technically and socially. The events were fully funded and represented a great opportunity for excellent students from throughout the world to learn from (and with) other students, and then immediately go on to apply their accumulated knowledge to real problems. The atmosphere during the second week was truly electric. Never before have I (Neville Fowkes) personally worked with such an enthusiastic group, and the outcome was outstanding; after the first week the students hit the ground running.

The four Australian students contributed well and thoroughly enjoyed the experience. Australia and Canada are realising the benefits of hosting international students to attend AMSI, MASCOS (Centre of Excellence for Mathematical and Statistics of Complex Systems), MITACS (the Mathematics of Information Technology and Complex Systems) and PIMS events. The attendance of Canadian students has enriched our AMSI-MASCOS industry workshops. PIMS encourages us to send students not only to the GIMMC but also to their annual summer school, which next year focuses on probability theory and stochastic modelling. We expect to send a couple of students to attend each of these events and will send details to university departments.

Neville Fowkes is a mathematical modeller and works mainly on continuum problems arising out of industrial, scientific and biological areas. He has participated in more than 30 maths-in-industry study groups (MISGs) held in many different countries. The companies he has worked with include Uncle Toby's, BHP, Hardie, CRA, ICI, duPont, British Steel, BrewTech, Mouldflow, Age Developments, Unilever, LNEC, Petronas and SAB. As an industrial modeller he has been asked to help initiate (and facilitate) MISGs in Indonesia and South Africa, and he has also helped set up industrial mathematics graduate and undergraduate programs in Portugal, China, Indonesia, Laos and Thailand. Neville has written a text on Mathematical Modelling based largely on problems arising out of his industrial mathematics experiences. This book has been used in Australia, UK and Europe (and possibly elsewhere) for industrial mathematics courses.