

MISG2010

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with some material from problem summaries written by moderators

MISG2010, the annual Mathematics and Statistics-in-Industry Study Group (MISG) workshop, was hosted by the School of Mathematical and Geospatial Sciences at RMIT University, Melbourne, between 7 and 11 February 2010. The MISG organising committee comprised Associate Professor John Shepherd (Director), Dr John Gear and Dr Lynne McArthur (Associate Directors) and Ms Petra Siskos (Administrator).

This was the first of a series of three workshops to be held at RMIT, following the exceptional job that the University of Wollongong performed moderating MISG2007, MISG2008 and MISG2009.

MISG2010 attracted four industry problems and 76 delegates, including 25 students. The workshop was opened by Professor Dennis Gibson, RMIT University Chancellor. Moderators at each session were assisted, as usual, by students who did a terrific job.

Invited speakers at the study group were Professor Phil Broadbridge of La Trobe University ('Some thoughts on MISG'), and Associate Professor John Boland of the University of South Australia ('Double counting — ensuring engagement includes academic output').

Dr Bob Anderssen also provided us with a very entertaining talk titled 'The impact of applications on mathematics'. In his concluding remarks, Bob Anderssen thanked all concerned for a very successful workshop and showed how MISGs illustrate the importance of the impact of applications on mathematics. He supported this with various quotations including 'My best pure mathematics was in applied mathematics, and my best applied mathematics was in pure mathematics' (V.I. Arnold, ICIAM, Hamburg, 1995).

The problems

Determining abnormal brain activity leading to seizures in patients with epilepsy by analysis of 'resting-state' functional magnetic resonance images. In patients with epilepsy, seizures occur episodically; there are periods of calm and then suddenly and apparently unpredictably a seizure will occur. The processes guiding the transition from seemingly normal brain behaviour to the changes of a seizure are poorly understood. Evidence now suggests functional changes occur in the

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brain many minutes prior to a seizure. The problem was submitted by The Brain Research Institute and presented by Dr David Abbott. The moderators were Dr Bob Anderssen and Dr Richard Masterton and the student moderator was Ms Jessica Dunn.

Taxonomic analysis of marine phytoplankton from pigment data. Phytoplankton are microscopic algae that comprise the base of marine food webs. Determining their distribution, abundance and composition is a major challenge in studies of marine ecology and global carbon flux. The problem was presented by Dr Simon Wright from the Australian Antarctic Division. The moderators were Professor Bill Whiten and Dr Barry McDonald and the student moderator was Mr Chris Drovandi.

Influence diagrams to support decision making. Conventional influence diagrams are based on cause and effect. However, many real-world problems have complex relationships between measures of effectiveness, and in these cases, causality may be difficult to determine. The objective of this project was to explore potential methods and metrics for exploitation of influence diagrams and other graph based diagramming methods. The problem was submitted by the Defence Science and Technology Organisation, and presented by Mr Samuel Sedgman and Dr Simon Goss. The moderators were Professor Graeme Wake and Dr Winston Sweatman and the student moderator was Mr Haydn Cooper.

Geothermal data analysis and optimisation. The objective was to assess the feasibility of extracting geothermal power from the deep sedimentary Perth Basin, based upon thermal data collected from boreholes and remotely sensed observations of surface temperatures. The problem was submitted by the WA Geothermal Centre for Excellence and presented by Dr Frank Horowitz. The moderators were Associate Professor Neville Fowkes and Professor Robert McKibbin, and the student moderator was Mr Brendan Florio.

Summary of The Brain Research Institute problem

The Brain Research Institute (BRI) uses various types of indirect measurements, including EEG and fMRI, to understand and assess brain activity and function. As well as the recovery of generic information about brain function, research also focuses on the utilisation of such data and understanding to study the initiation, dynamics, spread and suppression of epileptic seizures. To assist with future focussing, the BRI asked the MISG2010 participants to examine how the available EEG and fMRI data and current knowledge about epilepsy should be analysed and interpreted to yield an enhanced understanding about brain activity occurring before, at commencement of, during and after a seizure.

Though the deliberations of the study group were wide-ranging in terms of related matters, considerable progress was made with three aspects:

- The science behind brain activity investigations depends crucially on the quality of the analysis and interpretation of, as well as the recovery of information from, EEG and fMRI measurements. A number of specific methodologies

were discussed and formalised, including independent component analysis, principal component analysis, profile monitoring and change point analysis (hidden Markov modelling, time series analysis, discontinuity identification).

- Even though EEG measurements accurately and very sensitively record the onset of an epileptic event or seizure, they are, from the perspective of understanding the internal initiation and localisation, of limited utility. They only record neuronal activity in the cortical (surface layer) neurons of the brain, which is a direct reflection of the type of electrical activity they have been designed to record. Because fMRI records, through the monitoring of blood flow activity, the location of localised brain activity within the brain, the possibility of combining fMRI measurements with EEG, as a joint inversion activity, was discussed and examined in detail.
- For the Brain Research Institute, a major goal is to improve their understanding about *when* an epileptic seizure actually commences (relative to the EEG recording that it has commenced), *where* the source of this initiation is located in the brain, and *what* the initiator is. Because of the general agreement in the literature that, in one way or another, epileptic events and seizures represent abnormal synchronisations of localised and/or global brain activity, respectively, the modelling of synchronisations was examined in some detail.

Summary of the geothermal data analysis and optimisation problem

The aim of this project was to assess the economic feasibility of extracting geothermal energy from the deep sedimentary Perth Basin in Western Australia. The WA Geothermal Centre of Excellence (WAGCoE), based in the University of Western Australia, has been collecting temperature and pressure data from groundwater and oil boreholes in the area as well as examining remotely-sensed observational data of ground surface temperatures. The question was how to interpret the available data to gain information on the modes of thermally driven convective flows, if any, in the groundwater aquifers, thereby determining which parts of the system would be most economical to use for energy extraction.

The MISG2010 study group working on this topic concentrated on problems of advective transport of heat in stratified geological units appropriate for the conditions found in the Perth Basin. The main hypothesis examined, for several different sub-problems, was that advective transport of heat is an important contribution to the overall heat transport. Measured temperatures in the system indicate an approximate temperature increase through the main aquifers from about 40C to 80C. Clearly, conductive heat transport is present (as elsewhere over the Earth's surface), but the group wanted to find out whether the system is susceptible to unforced (or natural) convection.

The problem was tractable, but depended on suitable estimates of rock matrix properties from drill cores which were rather complex in structure. It also depended on good estimates of aquifer temperatures; the deeper values were elusive, and had to be deduced from extrapolations of shallow well measurements. However, by the end of the study week, there was a good increase of understanding

of the problem, the issues to be resolved, and possible mechanisms at work in the Perth Basin.

Geothermal systems are complicated entities comprising geological, geophysical and thermodynamical properties. Hence, a multi-disciplinary approach is necessary. However, the quantification of their attributes is well handled by mathematically able scientists and the MISG proved a suitable venue to tackle the WAGCoE problem.

Summary

The 2010 event ran very smoothly and was enjoyed by all attendees. The workshops provided a lively forum for mathematicians to work together on interesting problems and to socialise. Many delegates are regular MISG attendees, and their experience is invaluable in ensuring the continuing success of industrial problem-solving, and in providing guidance and inspiration to new attendees.

The MISG2010 dinner was held at the Melbourne Zoo, where the disco music provided by Petra compelled many delegates and students to dance. A few photos exist in evidence of some of the interesting dance moves demonstrated by unnamed professors!

Finally, a quote from Bob Anderssen ‘Thank you to the participants — we have all had fun, made new friends, renewed old friendships, learnt new things, reinvigorated our mathematical expertise’.

MISG2011 will be held again at RMIT between 6 and 11 February, and details can be found on the website (www.rmit.edu.au/math/misg) as they become available. We hope to see you all at MISG2011.