Departments of the Research School

Systems Engineering

The Department of Systems Engineering was formally established in December 1981 and, after twelve years of development and achievement and in company with the Department of Computer Science, left the School at the end of 1993 to form the Research School of Information Sciences and Engineering.

Brian Anderson, founding head of the Department of Systems Engineering.

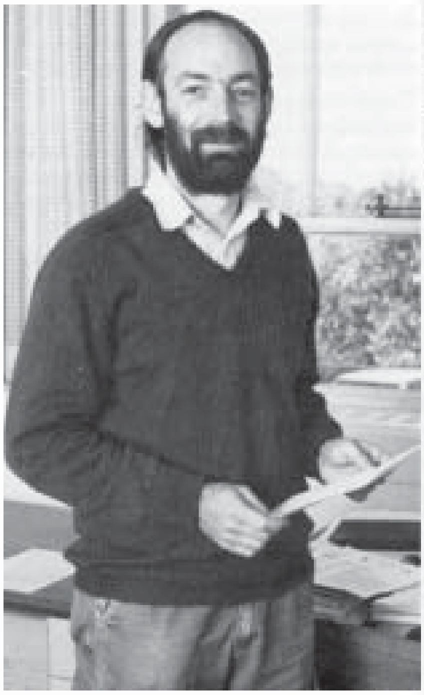
Some highlights from these years have appeared in the School's Advance magazine and are here appropriately summarised.

Putting the 'squeeze' on sugar (December 1990)
This project involved designing an advanced, feedback control system to maximise the crushing energy applied to sugar cane and hence to raise the extraction efficiency at Australia's largest sugar mill (the Victoria Mill near Ingham, in Queensland).

The new system was developed by Dr Bob Bitmead, in association with the son of a sugar cane farmer from Innisfail, Dr Philip Musumeci (formerly of the RSPhysS and now at the Australian Defence Force Academy).

Sugar cane is crushed in a cascade, through a series of four mills. One large mill might crush cane from several farms in one day. Cane quality varies (local jargon has it, from 'crushing broomsticks to crushing oatmeal'), and Victoria Mill's existing feedback control had difficulty coping with changes in crop variety. More responsive processing techniques were needed.

The original computer control system, based on a distributed multiprocessor architecture, could not adequately regulate feeding into the crusher by manipulating turbine speed and feed aperture width. The challenge the researchers faced was to provide process engineers with a higher performance controller with a limited number of design variables, and one which would provide better regulation of crushing. 'The intention was not to present the operators with a complicated controller with multiple design variables, or to leave them no choice at all. We aimed at developing a comprehensible system with a few pertinent variables, which they could then select from and tune to determine the impact on the 'liveliness' of the feedback process', Dr Bitmead said.



Bob Bitmead.

According to Dr Bitmead, many industries dealing with manufacturing processes which are subject to a range of variables had shown considerable interest in applying sophisticated software control techniques, because computers were now freely available and cheap. In the past, industry practitioners had tended 'to develop their processing methods on an *ad hoc* basis, via a collection of rules of thumb or 'incantations' for making the system work,' he said.
'We were able to demonstrate that those rules of thumb, together with

a solid theoretical understanding of the algorithms involved in the process, agreed entirely with modern control theory', as set out, for example, in *Adaptive Optimal Control: Thinking Man's GPC* (Generalised Predictive Control), a book reporting theory developed by Dr Bitmead in collaboration with two Belgium colleagues.

Dr Bitmead said feedback control applications of GPC which should benefit from the new theory are broad, and include bioreactors, cement kilns, industrial distillation and even pasta-drying. Ovens for drying pasta must be able to adapt to changes in temperature and humidity in the ovens, and vary the current into the oven as the pasta dries and oven loadings change.

'Noisy cells' put through the processor (December 1991)

The difficult job biologists face in unscrambling real data signals from background electronic garbage is being made easier, thanks to an elegant mathematical technique developed in Systems Engineering.

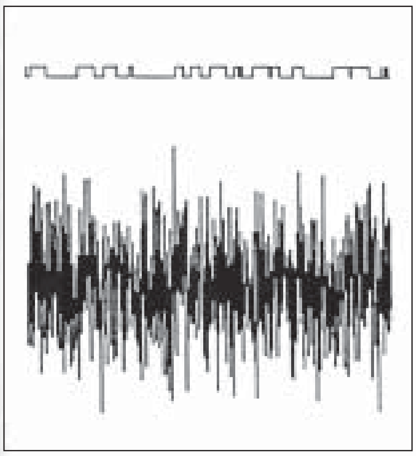
Unfortunately for researchers measuring highly sensitive cell processes, no cell, dead or alive, is ever completely 'quiet'. There is always white, or 'gaussian', background noise. This background 'hum' buries the true biological signals in the background, making them hard to extract and interpret. The ANU innovation applies principles of adaptive digital signal processing to remove the noise from biological signals. The method builds upon work carried out in Systems Engineering and overseas, which has applications to radar, telecommunications, speech processing and two-dimensional image processing. An interdisciplinary collaboration of systems engineers, biophysicists and medical researchers has applied the technique to biological data.

One member of the ANU collaboration is Peter Gage from the John Curtin School of Medical Research, who is studying message transmission in rat brain cells *in vitro*.

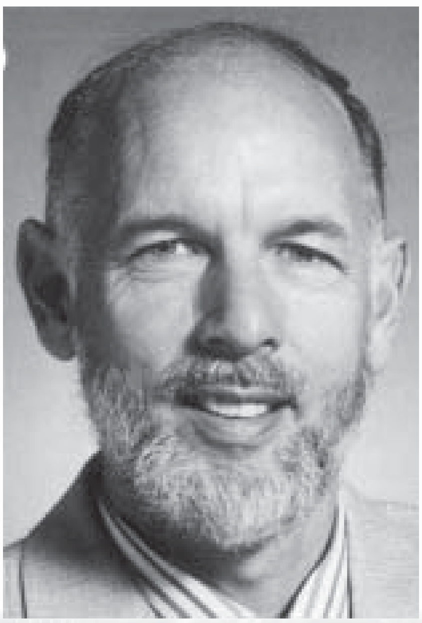
Messages in nervous systems are carried across each synapse, or physical junction between the cells, by a sequence of chemical and electrical events. 'Upstream' cells squirt a chemical neurotransmitter at a target cell, causing the opening of myriads of ion channels across its surface. The flow of ions across a single channel can be detected as a tiny electrical current. The nature of the current, its size and duration, tell researchers a lot about what the channel is like.

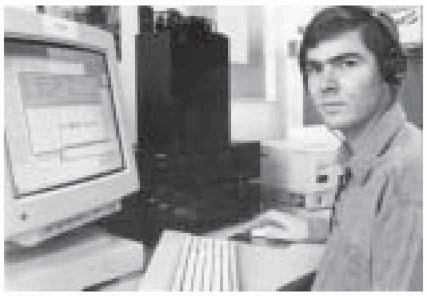
The John Curtin group is studying ion channels activated by the inhibitory neurotransmitter GABA. Drugs such as valium and barbiturates are thought to work by influencing the opening of these channels. Researchers hope such research will be used to design new drugs that act on the brain.

But initial results from the JCSMR experiment were messy because of noise. That's when Professor John Moore of the Department of Systems Engineering became involved. Professor Moore says that WYSIWYG (what you see is what you get) data analysis techniques can be applied to some data with very good results. (WYSIWYG is squinting at a jagged graph and picking the best line through it by eye alone!)



Signals before (below) and after (above) adaptive signal processing to remove noise.





Above right. Craig Watkings.

John Moore.

However, in biophysical experiments, large amounts of data are combined with high noise levels, so some form of signal processing is needed to extract the true signal, and this is where adaptive signal processing comes into its own. The researchers carried out up to 800 passes through Professor Gage's data using special algorithms and a computer to sift out signal from noise.

You can use the analogy of the Hubble Telescope to describe our technique, because it should 'see' ten times further than any land-based telescope. Our 'telescope' sees into the data twenty times better than the eye, for the cost of a desktop computer', Professor Moore said. Our next goal is on-line processing of signals, so researchers for example can watch changes in real time as drugs are administered to cells. That's a real challenge which we believe we can now meet.

Student award for speech coding researcher (May 1993)

Craig Watkins, then a PhD student in the Department of Systems Engineering, was awarded an OTC Australia Telecommunications Student Award and spent five months in the United States and Japan in 1993.

Craig's area of research was speech coding, and his award enabled him to work alongside researchers in some of the leading speech coding laboratories in the world. The prize consisted of $5000 in cash and $25,000 to fund his travel expenses.

Craig, who received his honours degree in computer science and electrical engineering from the University of Queensland, was half way through his PhD at Systems Engineering, under the supervision of Dr Bob Bitmead. His work formed part of the Department's program of research in the Co-operative Research Centre for Robust and Adaptive Systems (see below).

He saw the OTC award as an opportunity to 'add value' to his PhD studies, to ensure that upon graduation he was well placed to extend his involvement with the Australian telecommunications industry. He was engaged in basic research into low-bit-rate speech coding, in work that underpins development of the next generation of telephone networks based on Asynchronous Transfer Mode (ATM). This involves theoretical studies and computer simulations using a computer linked to a stereo tape player. On tape are spoken words, which are run through computer simulations of the speech coding algorithms being investigated. A simple sentence such as 'cats and dogs each hate the other' is sampled and quantised to form a digital representation. The focus was to determine how speech may be coded at eight kilobits a second without significant distortion. Then the three main telecommunications standards were 64, 32 and 16 kilobits/second.

This work should contribute to a new low-bit-rate standard, and the advent of more efficient and more compact mobile telephones and long-distance telecommunications. The advantage of producing a lower bit rate will be increased speech quality for the same given channel capacity. One scheme investigated provides practical elimination of overload distortion, consequent increase in stability and the logical accommodation of silence periods.

Generic research on signal coding, of which speech coding forms a major part, is important for the production of techniques that can be applied to the increasingly wide variety of data that users wish to transmit.

A goal for the future is the construction of a 'realistic' simulation that performs to the requirements of current telecommunications standards. This will form the basis of an assessment of the practical benefits of such a coding scheme. During the course of his PhD studies, Craig identified directions of the research that should lead to the development of speech coders in the future.

CRC

The Cooperative Research Centre for Robust and Adaptive Systems, based in the Department of Systems Engineering, incorporating participants from the Defence Science and Technology Organisation, CSIRO's Division of Radiophysics and BHP, and directed by Dr Robert Bitmead, has been in operation for several years and is producing outstanding results. Projects have included: furnace modelling, estimation and control, nonlinear image processing, communication methods over poor channels, several industrial consultancies, the publication of a number of research monographs, and the negotiation of several scientific exchange agreements.

John Moore