Department of
Mathematics and Computing

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Contents

Chapter 1

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Chapter 2

Research and development activity

The Department of Mathematics and Computing has an active research and development programme covering many different fields. The main activities can be conveniently classified under the following headings.

1. Fluid mechanics
2. Mathematical modelling
3. Applied Computer Science
4. Databases
5. Parallel Computing
6. Statistics
7. Educational development
8. Miscellaneous

Descriptions of the research and development being undertaken in the above categories may be found on the following pages.

In addition, a Simulation and Statistical Consulting Group has been established and is supporting the research needs of staff and postgraduate students.

2.1 Fluid mechanics

2.1.1 The free surface of water

(Roberts, Smith)

Although the flow of water involving a free surface (e.g. the sea's surface) is a difficult problem to analyse mathematically, there are important physical problems which need to be solved.

The aim of this project is to construct and use efficient numerical algorithms and dynamic models to calculate intricate nonlinear, steady and time-dependent flows of liquids with a free-surface. In particular, a major theme is the simulation of the highly nonlinear interaction between floating bodies and the free-surface of water; this is a very important class of problems in marine engineering. This continues research in two-dimensional flows where we have: developed efficient algorithms to calculate the breaking of water waves; investigated the generation of waves in front of a two-dimensional barge and by a submerged cylinder; studied the form and stability of two-dimensional standing waves and three-dimensional short-crested waves. However, problems of real engineering interest are necessarily three-dimensional; for example, the calculation of the wave drag of a ship, and the sloshing of liquid inside a moving and accelerating container.

To simulate the time-dependent dynamics of extreme water waves requires an enormous amount of computation. Supercomputers, both vector and parallel, are used as an integral part of the project.

2.1.2 Convection

(Roberts, Passmore)

Vertical heat transport in the ocean, atmosphere and mantle is dominated by the heat carried by the encompassing fluid. Simple convectional motion may be analysed mathematically. Variants of centre manifold theory are being used to develop accurate models of the complex, even chaotic, dynamics of convection between poorly conducting boundaries (representative of convection in the earth's mantle).

In particular, we are investigating the issue of how to specify boundary conditions for mathematical models of the complex dynamics. Such bound-

ary conditions will take account of realistic physical effects of the boundaries.

2.1.3 Turbulent flood flow

(Roberts)

We are developing a new model for the dynamics of turbulent flood water. Conventional models are based on the 150 year old St Venant equations. Using the techniques of centre manifold theory described in the next section, the new model is based on the k-ϵ model of turbulence but rigorously simplified for shallow-water (or long-wave) flow. The new model should be of wide utility.

2.1.4 Impact Delivery of Prebiotic Organics

(Brookshaw)

A significant fraction of the terrestrial planets' volatile inventory may have been acquired as a late-accreting veneer from impacts of carbonaceous asteroids and comets during the period of heavy bombardment 4.5×10^9 to 3.8×10^9 years ago. In addition to simple volatile molecules such as H_2O and short-chain hydrocarbons, carbonaceous asteroids and comets are also rich in complex organics. It has long been speculated that the earth accreted prebiotic organic molecules important for the origins of life from the impacts of carbonaceous asteroids and comets during the period of heavy bombardment. A comprehensive treatment of comet-asteroid interaction with the atmosphere, surface impact, and resulting organic pyrolysis is needed to quantify this source of prebiotic organic molecules.

This project (being done in conjunction with C.F. Chyba, Princeton and W. Davis, NASA Ames) is to extend early work that focused on the earth and quantify the sources of prebiotic organic molecules for Mars.

2.1.5 Impact Triggered Tsunamis

(Brookshaw)

A considerable amount of interest has been generated in the last few years on the problem of near earth object detection and interception. This interest has been fueled by so-called risk analyses of a catastrophic impact of an asteroid or comet on the surface of the earth. There is little doubt that an asteroid 10 kilometres in diameter (the size of the Cretacious-Tertiary impactor 65 million years ago) impacting the earth would cause global devastation, but the period of large impactors is approximately 25 million years. A far more likely scenario is the impact of an object tens of metres in diameter. The 20 Megaton explosion over Tunguska, Siberia in 1908 is thought to have been caused by a stony meteorite of this size.

Though smaller impactors are more frequent the devastation is localised when the impact occurs over land (the Tunguska explosion flattened 2,000 square kilometres of forest) The destructive potential of small impactors increases significantly if the projectile hits the ocean and can generate a tsunami. Little is known of small impactors ability to generate tsunamis, this project, using an hydrodynamic particle code to model the impact into water, and an incompressible finite difference code to model the subsequent wave motion, is making a study of the waves generated by a variety of *small* impactors. With these results a more informed risk analysis should be possible.

2.1.6 Hydrodynamics of Pulsar Driven Winds

(Brookshaw)

Eclipsing millisecond pulsars (*eg.* PSR 1957+20, PSR 1744-24A) are known to exist in binary systems. A stellar wind from the pulsar companion is induced by the high energy particles and radiation of the pulsar wind. The wind from the companion then interacts with the low energy radiation from the pulsar and a bow shock is formed. The bow shock geometry can explain many of the features of the observed eclipsing patterns.

Using a particle hydrodynamic numerical code we (this work is being done with M. Tavani, Columbia University) are modelling the expansion and bow shock geometry under different conditions relevant for vaporizing millisecond pulsars.

2.1.7 Hypervelocity Impacts

(Brookshaw)

Since 1994 a number of hypervelocity experiments testing scram-jet engines at the SHARP (Super High Altitude Research Project) facility at Lawrence Livermore National Laboratory, (LLNL) have been carried out. The SHARP gas gun is the

largest two-stage light gas gun in the world and is used as a hypersonic research facility. Projectiles 1-10 kg in mass are fired horizontally into air, past high-speed diagnostic equipment (roughly 20 m flight path), and into a projectile-retaining area, a concrete bunker filled with sand.

The recent experiments testing scram-jet engines provide an opportunity to conduct hypervelocity impact experiments at no cost with a total energy (20 MJ) more than 3 orders of magnitude larger than previous studies.

The project is to compare numerical models with the experimental results from diagnostic equipment placed in the sand in the target bunker and is being conducted with P. Fiske, LLNL.

2.1.8 The dynamics of thin films of fluid

(Roberts, Simpson)

Thin layers of fluids are of considerable importance in the world around us. They occur in many engineering situations including painting, coating and lubrication flows. The human body also uses such thin fluid layers to protect parts of the body and to transport or capture material. In this project, in collaboration with Dr Valery Roy of the University of Delaware, we are developing models for the flow of thin films viscous fluids and any material they transport. We look to model not only simple Newtonian fluid flows, but also the complex rheology of non-Newtonian fluids. Further, the models will properly account for curvature of the substrate as such curvature has a fundamental influence of the flow.

2.2 Mathematical modelling

2.2.1 Principles and applications of dynamical modelling

(Roberts, Passmore, Chao)

A significant achievement is the development of techniques, based on what is called centre manifold theory, for the rational and *complete* low-dimensional modelling of complicated dynamical systems. These techniques, which are born out of the recent explosion of interest in dynamical systems, have been applied to a variety of physical problems and lead to many new insights—some of which are relevant to chaos, while the vast majority enable us to understand classic approximations and their success and failure.

The range of applications for these ideas is enormous, as the making of tractable approximations is crucial in mathematical modelling. Just some of the physical problems to which they have been applied are as follows: the dispersion of material in rivers and pipes where we have been able to derive models for the dispersion in a varying channel; the dynamical evolution of forced convection where accurate models of pattern selection are shown to be inherently non-local; the deformation of an elastic rod where the four principle modes of deformation, that of torsion, longitudinal, horizontal and vertical displacement, are neatly captured in the one scheme; the nature of the quasi-geostrophic approximation which underlies much of meteorologists understanding of the dynamics of the lower atmosphere; the derivation of an appealing dynamical view of the concept of a quasi-stationary distribution in applied probability.

Currently we are extending the methodology to account for stochastic fluctuations in physical problems.

2.2.2 Gaussian models of queues in telecommunication networks

(Addie)

Queues have been used to model a wide range of telecommunications systems. Whenever traffic shares a valuable resource, some queueing is likely to be involved. Queueing performance is of critical significance in the Broadband-ISDN, in signalling networks, and in the intelligent network, for example.

Recent work by R.G. Addie and M. Zukerman has made available results for queues with Gaussian traffic models. The advantage of a Gaussian model over previous traffic models is that all the first and second order statistics of the input traffic can be accurately modelled (including the entire autocovariance). In this work, the application to telecommunication networks will be emphasised. The following specific areas will be tackled.

- Formulate call acceptance criteria for use in a B-ISDN which take into account the mean, variance, and autocovariance of the traffic already in the network, and the traffic which is being offered.

- Investigate the effect upon the autocovariance function of a traffic process of being passed through the typical elements in a network, ie. switches, queues, buffers, and smoothing devices.
- Investigate algorithms for estimating packet delay and loss in B-ISDN networks.

Substantial progress has already been made towards meeting the above objectives.

2.2.3 Finite difference models for derivatives

(Harman)

Methods have been devised for modelling derivatives by finite difference based on non-uniform grids. In collaboration with Dr Neville Robinson of C.S.I.R.O.(Adelaide) the methods have recently been generalised to allow approximations of all orders. The results are being applied to various applications which involve singular points or regions of singularity.

2.2.4 Automatic Differentiation Techniques for the Solution of Differential Equations

(Spunde)

High order Taylor Series approximations have been shown to be a viable alternative to classical approximations for the solution of systems of ordinary differential equations through the application of techniques of automatic differentiation. Multipoint techniques applied to stiff systems are being investigated; and also multi-variable techniques for partial differential equations.

2.2.5 Road traffic flow modelling

(Plank)

The performance of non-signalised traffic intersections is affected by variability in vehicle behaviour due to differences amongst vehicles/drivers and inconsistency in individual driver behaviour. Research so far has partly quantified the effects of these two factors on measures of intersection performance such as capacity and delay for stationary flow conditions and for simple traffic conflicts. Insight has been gained into the importance of including inconsistency and/or inhomogeneity parameters in formulae which traffic engineers use to measure and predict the degree of congestion at uncontrolled urban intersections under realistic flow conditions. Ongoing and planned research include the modelling of more complex traffic conflicts, the impact of severe inconsistency and inhomogeneity on performance measures, and the development of a useful model for non-stationary flow conditions.

2.2.6 Modelling of Driers used in Sugar Factories

(Pax (Eng. & Surv.), Plank, McFarlane, Cronin)

Sugar factories receive billeted cane and produce raw sugar by a number of complicated unit operations. The raw sugar has to conform to certain quality and physical characteristics to be able to be transported anywhere in the world in a variety of climatic conditions. It must also be able to be easily refined into white sugar.

To date, modelling of unit operations has, almost exclusively, assumed steady-state conditions. Unfortunately a variety of disturbances routinely occur in the cane supply, steam supply, mixing and chemical additives amongst others, some or all of which may impact on the raw sugar product.

This on-going project aims to examine the influence of variation in input variables on the raw sugar product using a stochastic process modelling approach. The ultimate intention is to model the entire sugar factory in order to better understand the nature of interactions amongst input variables and to devise control strategies to improve the output quality.

Work to date has concentrated on the final unit operation of the process - the drying stage. An existing steady-state model has been adapted to deal with variability in the input variables and a method developed of efficiently simulating the drying process in the presence of many input variables.

2.2.7 Dynamic Modelling in Decentralised Computing Systems

(Zhang & Wark)

In decentralised computing environments, data and applications are distributed. The same application may be issued from different sites, and may

access data at more than one site. The same data might be replicated in order to increase availability. Therefore, application processing, data placement and data transferring must be carefully scheduled in order to increase the systems throughput. However, most design methodology are static. It is assumed that the application patterns and data requirements are well known and fixed. As organisations develop, the processing procedures and data requirements will change. To cope with organisations' dynamic requirements, the traditional way is to redesign the systems as frequently as requirements change. This is a very expensive activity in maintaining the system. Therefore, heuristic and dynamic modelling is necessary in order to meet the organisation's dynamic requirements.

In this work, we will investigate the optimal or near optimal solutions for dynamic computing environments. It covers: data redistribution; dynamic scheduling of transactions; and formal analysis of system performance.

2.2.8 Dust Transport Modelling

(Butler)

In the last ten years most Australian capitals have been affected by major dust storms. The majority of this dust originated in the rich farming lands of rural Australia and carries a large amount of the nutrients/chemicals that were present in the soil. Current modelling work is aimed at producing a source based model that will accurately predict dust concentration downwind of the source. It is anticipated that this model will give us insight into where these nutrients/chemicals are being transported, and their effect on the various ecosystems in Australia.

2.3 Applied Computer Science

2.3.1 Object Oriented Techniques

(Fuller)

Developing a curriculum for introducing the fundamental OO ideas and concepts via an object oriented design method that involves specifying the design in the eventual programming language, thus obviating the need to learn any other (possible) complex specification notations or diagramming techniques. Self-teaching materials, using Eiffel as the teaching language, are currently being developed. The curriculum will be adapted for teaching C++ in the near future.

2.3.2 Programming language design

(House, Bowers)

A major problem in computing is designing computer languages that provide an effective medium for the design and implementation of large or complex systems. Some difficulties relate to specific language features, others to overall language design considerations.

This project addresses both of the above kinds of difficulties. The research focuses on methods of data and process encapsulation, and on methods of object declaration. A specific language feature success was the creation of a clean language feature for declaring scientific unit information that specifies allowable data combinations: for example, lengths and masses may be multiplied, but not added. An overall design issue tackled successfully was design of improved block-structuring rules for Algol-like languages.

Present work focuses on design of an inverse object-oriented paradigm which, in combination with existing object-oriented concepts, would permit unprecedented flexibility and clarity in a programming language.

A long-term goal is the design of a complete programming language that embodies these concepts.

2.3.3 Systems Simulation of Meat Processing

(McFarlane)

Systems simulation is a powerful strategy for modelling and analysing complex systems in which varying degrees of randomness impacts on the performance of tasks, the arrival and flow between processes, the availability of resources, and the interaction of subsystems competing for scarce resources.

The use of systems simulation as a decision support system is relevant to meatworks, enabling decision makers to explore the operational implications of adjustments to meat processing without the expense and associated risks of major alterations. In this way, managers can evaluate new/alternative technologies and examine the feasibility of implementation at minimal cost. Comparison of alternative technologies, plant design/layout can be made

in relation to bottle-necks, capacity, efficiency and resource utilisation as a function of plant layout. The ability to evaluate new technology at minimal cost will lead to more confidence in the expected performance of that technology, allow labour utilisation within new systems to be determined and planned as part of the development and will encourage quicker adoption of technology into industry.

These projects are concerned with the development of 'standard' systems simulation models for all meat processing activities, related to slaughter floor and boning room operations. The development of sophisticated user interfaces and animated graphical displays will allow the models to be used interactively by managers.

2.3.4 Systems Simulation of Food Distribution at the Toowoomba Base Hospital

(McFarlane & Parker)

Systems simulation is a powerful strategy for modelling and analysing complex systems in which varying degrees of randomness impacts on the performance of tasks, the arrival and flow between processes, the availability of resources, and the interaction of subsystems competing for scarce resources.

This project involves the use of systems simulation in the comparison of alternate technologies involved in the preparation and distribution of food throughout a large hospital.

2.3.5 Comparison of Alternative Slaughter Floor Configurations

(McFarlane)

Systems simulation is a powerful strategy for modelling and analysing complex systems in which varying degrees of randomness impacts on the performance of tasks, the arrival and flow between processes, the availability of resources, and the interaction of subsystems competing for scarce resources.

This project is concerned with analysing performance differences between these modifications proposed by a large meat processor.

2.3.6 User interface design in software development environments

(Toleman & Welch)

Computer-aided software engineering (CASE) tools have a vital role to play in software development and maintenance. In practice, however, the uptake of innovative CASE tools by software engineers is typically much slower than their designers expect, and the benefits are consequently limited. This slow uptake of CASE tools is often attributed to usability concerns, but use of systematic usability evaluation techniques to overcome such problems is certainly not common practice and has not been widely canvassed in the relevant literature.

The aim of this project is to apply usability evaluation techniques to a number of innovative CASE tool features, to determine the effectiveness of the evaluation techniques concerned in this context. If successful, the experiment will also provide valuable information on the potential of the innovative tool features evaluated.

The outcomes will be

- a documented case-study of the application of usability evaluation techniques to CASE tools, which will be of significant general value to tool developers, and
- a systematic evaluation of the specific innovative features concerned, which will help to determine their usefulness in future CASE tool developments.

The project is a collaborative one between researchers at the University of Queensland who have developed the tool features concerned, and researchers at the University of Southern Queensland, whose expertise in usability evaluation will ensure an independent, well-designed experiment.

2.3.7 Debugging Lazy Functional Languages

(Watson & Salzman)

Lazy functional languages offer significant advantages over other language paradigms for rapid development of reliable code. Unfortunately, functional languages can be difficult to debug, and no complete debugging environments have been developed.

This project aims to build on earlier work devoted to generating a trace of a lazy computation in order to build a usable debugging environment for the Haskell language. The work involves collaboration with researchers at the University of Queensland.

2.3.8 Operating Systems

(Vance)

Research focuses on the following areas:

- File systems and directory services for supporting cryptographic operations and wide area naming.
- Distributed operating systems.

2.4 Databases

2.4.1 Data Mining

(Plank)

Data mining has received increasing attention recently in computer science research because its potential applications in commerce, insurance, scientific discovery, health industry. Today's technology often generate huge amount of data, such as remote sensing via satellite. However, such raw data often cannot be used directly. Data mining tries to discover hidden patterns, trends, or correlations in data. The outcome of data mining can be indispensable to information management and decision support systems.

2.4.2 Linear Algebra Modelling in Database Query Processing

(Zhang, Roberts, and Lai)

Although distributed and parallel databases provide some performance improvement, further progress in decreasing the response time and reducing the processing cost is demanded by advanced database applications with large amount of data, such as spatial database and multimedia information systems. Based on our previous work in mathematical modelling, and database processing, this project aims to use new linear algebra techniques in the area of database query processing. We plan to develop a suite of algebra models:

- to support the graphic and logical representation of related database information, thus increasing the speed and accuracy of user's query formulation;
- to reduce the I/O cost of complex database query processing by reducing the number of input and output operations between external storage and main memory; and
- to improve the response time by better balancing the load and maximising the performance of parallel database processing.

Through this project, we will develop an integrated program on mathematical modelling, graphics, database and parallel processing.

2.4.3 Normalization in Object-Oriented Database Design

(Zhang, Xiao, and Fuller)

Normalization theory is an aid which provides a rigorous procedure for relational database design. Although the relational model has provided database practitioners with a modelling methodology independent of details of physical implementation, many designers believe that the relational model does not offer a sufficiently rich conceptual model for problems that do not map onto tables in a straight forward fashion. The past decade has seen the emergence of numerous data models with the aims of providing increased expressiveness to the modeller and incorporating a richer set of semantics into the database. This collection of data models can be loosely categorized as object-oriented or "semantic" data models since their one unifying characteristic is that they attempt to provide more semantic content than the relational model.

In this project, we will investigate the normalization process for object-oriented database design, including the object normal forms and the normalization procedure.

2.4.4 Design and Management of Distributed Databases

(Zhang)

The design methodology and transaction managements for centralised database have been well

studied and understood. Due to the development of network technology, mobile computing and the nature of decentralization of many nation-wide and world-wide organizations, the centralised database design and management do not meet the decentralised application requirements. To support distributed processing, one need to design distributed database systems, mobile distributed databases or integrate the existing database systems into a federated database system. In this project, we will develop algorithms or approaches for distributed database design and distributed transaction management, including concurrency control and recovery in federated databases and mobile distributed database systems.

2.4.5 Database Support for Cooperative Information System Design

(Zhang and Lu)

Although the traditional database transaction model is suitable for conventional database applications, it has limited applicability in many advanced applications such as software development environments. In those environments, transactions are usually very complex, have a need to access many complex data items, tend to be very long, and may need to cooperate with each other. For example, in cooperative environments, several designers might work on the same project. Each designer starts up a cooperative transaction. Those cooperative transactions jointly form a transaction group. Cooperative transactions in the same transaction group may read or update each other's uncommitted object versions. Therefore, cooperative transactions may be interdependent. However, the traditional transaction technique does not support cooperation among the transactions. Cooperative applications may require different correctness criteria rather than serialisability theory. Cooperative transactions might be long and able to interact with each other. Therefore, there is a special need for research in cooperative transaction management.

In this project, we consider cooperative environments of systems design. We treat the cooperative transactions as a transaction group, and relax the requirement for atomicity and serialisability. We start at a case study of a cooperative document editing system, investigate and implement practical operation transformation rules for an effective synchronisation of editing operations among the cooperative transactions, and then generalize it to more general cooperative design tasks.

2.5 Parallel Computing

2.5.1 Generating Efficient Parallel Code for SOR

(Tang)

This work has developed algorithms for parallelizing compilers to generate efficient parallel code for the sequential program based on Successive Over-Relaxation for solving partial differential equations. By incorporating existing loop transformation and tiling algorithms and using dynamic memory management for local data arrays, our scheme reduces the number of message passing per iteration per processor from 3^n-1 to 2^n-1, where n is the dimension of the problem.

2.5.2 Advanced Model for Parallel Programming

(Tang)

This project is to study the most suitable programming model (beyond OO model) for parallel programming which enables both parallel software productivity and efficiency. In particular, he wants to look at Aspect-Oriented Programming (AOP) model to see how it can help build a suitable model for the next generation parallel programming.

2.5.3 Parallel Programming Applications.

(Tang)

This project is to engage in a real-world distributed or parallel application to test the effectiveness of the new advanced programming model. Currently, we start from a distributed system for University of Distance Education based on the CORBA technology. In the future we will look at finite state machine-based protocol analysis and design for higher productivity of distributed applications development.

2.5.4 Web Parallel Programming.

(Tang)

As the largest distributed computing platform, the Internet provides a huge opportunity for parallel and distributed real applications. This project is to study parallel programming on the Internet. Java programming language, RMI and Servlet in particular, on the Internet is a starting point. This project is closely related to the project on Advanced Model for Parallel Programming above. The advanced model will guide us to find the most suitable parallel Web language of the next generation.

2.5.5 Statement-Level Control Flow Analysis

(Tang)

Work has been done on the statement-level control flow analysis for restructuring compilers. It is summarized in the technical report SC-MC-9606. The control flow analysis in source-to-source restructuring compilers has to be carried out in the statement level rather than in the intermediate code level. This work gives an algorithm to build control flow graph as well as basic blocks of a program in the statement level.

2.6 Statistics

2.6.1 Locum service

(McFarlane)

A report detailing data collection, storage, and analytical strategies and methodologies, to monitor and evaluate the Locum Service intended to support Continuing Education activities and relief for rural doctors, was presented to the Cunningham Centre at the Toowoomba General Base Hospital.

2.6.2 Predictive and Structural Inference

(Khan)

Predictive inference is based on the prediction distribution. Construction of prediction regions and different types of tolerance regions. Multivariate models involving dependent but uncorrelated, and correlated responses.

Inference for the parameters of different kinds of multivariate models with dependent and correlated errors. Simultaneous Equation Model with multivariate Normal and Student-t errors.

2.6.3 Improved Estimation for Multivariate Models

(Khan)

The usual estimators, both the least square and maximum likelihood, can be improved by incorporating *uncertain prior information* in the form of a null hypothesis. The unrestricted estimator and the restricted estimators can be improved by using all available information and recently developed statistical techniques. the method of preliminary test estimators (PTE) has been developed by Bancroft by using the 'Fisher's recipe' of testing out the uncertainty in the null hypothesis. The PTE depends on the levels of significance and is an extreme choice between the unrestricted and restricted estimators. Stein-type shrinkage estimator addresses those problems. however, the shrinkage estimator becomes unreliable when the value of the test statistic is close to zero. The positive rule shrinkage estimator provides further improvement in addition to solving the problem of the shrinkage estimator. Study of the above improved estimators are conducted for different multivariate normal and Student-t models. The later model based estimators are robust and include a family of elliptical models.

2.6.4 Variance Modelling in GLMs

(Dunn)

Generalised linear models (glm's) contain a very broad class of models that provide a uniform framework for regression modelling for many types of data. Glm's assume (among other things) that variance is proportional to some function of the mean. However, there are cases in which this mean-variance relationship fails or needs to be estimated. This research will examine the mean-variance relationship through the concept of double generalised linear models which assume link-linear predictors for both the mean and the dispersion. It will also examine statistical models whose responses are not members of the exponential family to extend the idea of generalized linear models.

2.7 Educational development

(Spunde)

The calculus/algebra reform program at USQ has been in effect since 1988. A computationally rich mathematics instruction program in first year mathematics was developed in a CAUT sponsored project providing an alternative approach to a first semester course in mathematics, and integrating work on both calculus and linear algebra. An Open Learning Quality Enhancement program builds on the work of the CAUT project to produce an alternative method of delivering the Foundation Mathematics course (MAT13) to open learning students equipped with a computer.

The USQ program is unique amongst calculus reform projects in that it concentrates attention on the direct numerical computation of functions, their derivative functions and indefinite integrals, and the application of the rules of calculus to the manipulation of numeric function tables rather that symbolic formulae (in the first instance). A workshop for teachers offered at APL95 by W. Spunde and R. Neidinger (Davidson, N.C.) demonstrated how these numerical ideas could be implemented in Mathematica, Maple, Matlab, APL, J and on the HP48G and the TI82 and TI85 calculators. Current development focuses on a hybrid language (J+TkTcl) for mathematics instruction.

The program aims to provide students with a strong background of computational experience on which to base an understanding of mathematical symbolism and symbolic manipulations.

2.8 Miscellaneous

2.8.1 Fractal geometry

(Roberts)

The distribution of plants and animals in their environment is frequently patchy. Recent research has shown that this patchiness occurs, at least sometimes, on all scales in the distribution of the species. This appearance of structure on all scales leads naturally to a description of the distribution as a fractal object. Indeed analysis of the settlement and subsequent evolution of fucoids ("seaweed") off the coast of South Australia is showing the distribution to be a multi-fractal.

A current project is to overcome present limitations in estimating fractal dimensions and determining the multi-fractal spectra. Current methods are based on straight line fits on log-log plots. By generating artificial multi-fractals and comparing the underlying structure of neighbour-distance information, we can determine which multi-fractals best match the physical data. With this fit, we then use the analytically known information about the artificial multi-fractal to estimate the fractal nature of the original.

2.8.2 Minimal surface nets

(Harman)

Simple methods have been investigated for numerically solving the Plateau problem for a net stretched on a frame. The resulting minimal surface configuration can be modelled by linear methods which leads to a form suitable for the third year mathematics classroom. More accurate non-linear methods are also being investigated as an extension.

2.8.3 Vehicle routing

(Wark)

Many industries transport their products to a large number of geographically scattered customers. The cost of transportation is a significant part of the cost of goods we buy, so it is important that deliveries are made in a cost-efficient way. Research in Vehicle Routing is concerned with finding ways to determine optimal or near-optimal routes for delivery vehicles.

A new heuristic, using repeated matching, has been developed which obtains results comparable to the best published for most of fourteen benchmark problems commonly used to evaluate VRP heuristics.

The use of parallel computing in association with the method has also been investigated. Good speed-up has been obtained by using the software package PVM to distribute the computation over a network of SUN workstations.

2.8.4 Airline Crew Scheduling

(Wark)

The application of repeated matching to determine cost-efficient tours of duty for airline crews was

investigated. This work was carried out in association with Dr. Mikael Ronnquist from the University of Auckland.

An extension of the basic scheduling problem was dealt with, in that in addition to so-called "regular crews" there was the option of scheduling a third pilot for parts of the tour of duty of a regular two pilot crew. The inclusion of a third pilot allows longer duty times, which may enable more cost-efficient tours. However, this is at the expense of higher salary costs, and the need to find schedules for the "third pilots". Thus there is the need to simultaneously find schedules for both the regular crews and the third pilots. A complicating factor is that the number of sectors requiring of third pilot is not known in advance.

Using data from an actual airline, we found tours of duty markedly superior to those used in terms of the overall costs. Our results were also better than those found by another investigator using a set partitioning approach.

2.8.5 Stochastic Vehicle Routing

(Wark)

In many real-world vehicle routing problems the demands of customers are not known in advance. Moreover, some customers may not need to be serviced in a particular service period, but that may not be known until after the vehicle servicing those customers has begun its travel. If vehicles are to be used efficiently, it is inevitable that on occasions a vehicle may not be able to service all customers on its intended route without an intermediate return to the depot. Thus vehicle routes need be determined to minimize the probability of *route failure*, or to minimize the total expected cost of routes. Investigations are being conducted to determine ways of finding good solutions for these stochastic vehicle routing problems.

2.8.6 Celestial mechanics and astronomical graphics on computers

(Forbes)

This is a well-established project which I have personally used to compare observations of satellite phenomena (eclipses, occultations, shadows, transits) of Jupiter and Saturn with computer program predictions.

A computer program shows images of the appearance of the planets and their satellites at any chosen time. Currently the rings of Saturn are invisible due to the plane of the rings being close to edge-on to the Earth and the Sun. The program is being used to predict the disappearance and reappearance of the rings. This means that the above satellite phenomena are now occurring for Saturn whereas they usually do not because of the large angle between the plane of Saturn's equator (and the ring plane) and the solar system's ecliptic plane. (This is as distinct from Jupiter, where such phenomena are always occurring frequently).

These events have caused me to recently refine the calculations for Saturn's rings and satellites and further refinement will no doubt be necessary after comparison with observations.

2.8.7 Two-dimensional spectral estimation using Pick Functions

(Forbes)

A very extensive chapter in my PhD dissertation was devoted to 1-dimensional spectral analysis using Pick functions. The method is new and appears to be successful.

Another chapter was on 2-D spectral analysis using Auto Regressive methods.

I am attempting to extend the Pick function method to 2 dimensions.

2.8.8 Data Analysis using Java

(Brookshaw)

Java, a language developed at SUN, is the first widely used language that is machine independent, and internet aware. The current generation of WWW browsers incorporate a Java virtual machine. This means that programs written in Java are currently runnable on all popular computers and can be incorporated into easily accessible WWW pages.

The current project is to design Java tools for the display, manipulation and analysis of data. The suite of tools can then be easily incorporated into larger Web documents.

2.8.9 Mathematics in Sport

(Chris Harman)

Satisfactory models have been developed by oth-

ers for the problem of running on a circular arc. This is of importance in sprint races such as the 200 and 400 metre events. The current study aims to extend these methods to optimising trajectories for running on more general curves. Applications include the baserunning problem in baseball.

Chapter 3

Grants and presentations

3.1 Research, consulting and teaching grants

Research, consulting and teaching development projects to be supported by competitive grants include the following.

- Y. Zhang and P. Tang: On High Performance Database Processing, supported by a USQ Incentive Research Grant for 1996 ($12,000).
- Y. Zhang: Cooperative Transaction Management in Distributed Databases ($12,000) supported by a USQ Incentive Research Grant for 1996 ($12,000).
- Y. Zhang, A.J. Roberts, & W. Lai. *Linear Algebra Modelling in Database Processing*, supported by USQ Project Team Research Program for 1996–1997 ($17,500).
- A.J. Roberts *et al.*: USQ Virtual Supercomputer Facility, supported by a USQ Research Infrastructure Programme grant for 1996 ($43,000).
- Zhang, Roberts and Lai: *Efficient Query Processing in Multimedia Databases*, USQ Project Team Research Grant, 1997-1988 ($51,247)
- C. Harman, O. Jegede and W. Tan: *Desktop Video Conferencing Technology to enhance teaching and learning in mathematics*, CUTSD(DEETYA Committee for University Teaching & Staff Development) Research Project, 1997 ($43945).

3.2 Seminars

The department has an active seminar programme. Seminars organised during the year by the department include the following.

- Valery Roy, University of Delaware, *Coating Flows: New Results & Research Needs*, July 19, 1996
- Peiyi Tang, Department Maths & Computing, USQ, *Wizard++: An Interprocedural Analysis System*, July 26, 1996
- Neil Cornish, Cambridge University, *Einsteins Butterfly: Chaos and fractals meet Black Holes and the Big Bang*, July 29, 1996
- Leigh Brookshaw, Department Maths & Computing, USQ, *Smooth Particle Hydrodynamics - What is it?*, Aug 8, 1996
- Desmond Fearnley-Sanders, University of Tasmania, *Using Mathematica as a Teaching Aid*, Aug 26, 1996
- Ishaq Bhatti, Griffith University, *A UMP Invariant Test for Testing Equicorrelation Coefficient: An Example*, Sep 20, 1996
- Soeren W. Perrey, Department of Mathematics, Massey University, *On Search Strategies in Game Trees*, Sep 30, 1996
- Gordon Smyth, Department of Mathematics, University of Queensland, *What is Overdispersion?*, Oct 3, 1996
- Yun Yang, School of Computing and Math, Deakin University, *The Java language environment – an overview*, Oct 4, 1996

- Francois Perron, Queensland University of Technology, University of Montreal, *Exponential bounds for the binomial cdf*, Oct 30, 1996
- Iain Clark, Department of Mathematics, University of Queensland, *Mathematical Models for Quantum Waveguides and Biological Microtubules*, Nov 6, 1996
- Leigh Brookshaw, Department of Mathematics & Computing, USQ, *Introduction to HTML*, Nov 12, 1996
- Mike Simpson, Department of Mathematics & Computing, USQ, *Thin Film Flows*, Nov 20, 1996
- Robert Anderssen, CSIRO Division of Mathematics and Statistics, *Mathematical Modelling in Food Technology*, Nov 27, 1996
- Patricia Cretchley, Department of Mathematics & Computing, USQ, *Report on the Sydney Conference: "Computers in Undergrad Maths Courses"*, Dec 5, 1996
- Bjorn Birnir, UC Santa Barbara, *Strange Attractors in Dynamical Systems of Nonlinear ODEs*, Jan 13, 1997
- Peiyi Tang, Department of Mathematics & Computing, USQ, *Generating Efficient Parallel Code for Successive Over-Relaxation*, Mar 26, 1997
- Jim W. Rottman, Applied Mathematics, UNSW, *Ship Tracks in the Sky*, May 9, 1997
- Nicolas Jourdan, Dept. Maths & Computing, USQ, *1997 Mathematics Modelling Competition*, May 23, 1997
- Alfio Parisi, Science Faculty, USQ, *Numerical Evaluation of the Biologically Effective UV from Dosimetric Measurements*, May 30, 1997
- Harry Butler, Dept. Maths & Computing, USQ, *Dust not just a problem in the home!*, Jun 20, 1997

3.3 Conferences and Presentation

Dr. P. Tang is a Program Committee Member (Software) of the 1997 International Conference on for Parallel Processing to be held in Illinois, USA.

Dr. P. Tang is a Program Committee member of the 1997 IEEE third International Conference Algorithms And Architectures for Parallel Processing to be held in Melbourne, Australia.

Conferences attended by members of the department, and their presentations, are listed below.

- Dr. P. Tang presented seminar "Generating Efficient Parallel Code for SOR", in December of 1996 at the following institutions:
  - School of Science and Engineering, Waseda University, Tokyo, Japan
  - Department of Information Sciences, Kyoto University, Kyoto, Japan
  - Fujutsu Limited, Kawasaki, Japan
  - Chinese Academy of Sciences, Beijing, China
  - Parallel Processing Research Center, Fudan University, Shanghai, China.
- A. Plank , P. Surman, C. McDonald, & R. Darnell, *The Australian Statistics Competition for Schools Initiative*, Sydney International Statistical Congress, Sydney, July, 1996.
- M. Toleman and J. Welch, *Can design choices for language-based editors be analysed with keystroke-level models?* HCI'96 at London, 20-23 August 1996.
- Y. Zhang and J. Lu, *Operation Synchronization in Cooperative Database Processing Environments*, XI International Symposium on Computer and Information Sciences (ISCIS-XI), Turkey, Nov. 1996.
- J. Lu and Y. Zhang, *On Conflicts of Cooperative Database Operations and Skip-Undo Approach*, The 2nd International Conference on Office Automation & Information Management, Tokyo, Nov. 1996
- R. Watson and E. Salzman. *A trace browser for a lazy functional language* 20th Australian Computer Science Conference, Sydney, February 1997.
- C.J.S. Vance, *PGP—Pretty Good Privacy*, CAUUG monthly meeting, Canberra, 1997.

- C.J.S. Vance, *Domain Name Service*, CAUUG Summer, Canberra, February, 1997 ($\frac{1}{2}$-day tutorial).
- C. Harman, *Mathematics curriculum, the past, the present, the ???*, Keynote address, MSC Mathematics Education Conference, Downlands College, Toowoomba, March 1997.
- Y. Zhang and J. Xiao, *A Boolean Algebra Approach for Class Hierarchy Normalization*, International Conference On Database Systems For Advanced Applications (DASFAA'97), Melbourne, Australia, April, 1997.
- P. Cretchley *Technology in Mathematics: Lively and Dynamic*, Joint Mathematics Conference: South African Mathematical Society, American Mathematical Society, Southern African Mathematical Science Foundation. 25 - 28 June 1997, University of Pretoria, South Africa.
- P. Cretchley *Secondary and Early Undergraduate Mathematics - the vital and dynamic way in which Australia addresses the challenges South Africa faces today, especially within Curriculum 2005*, Third National Congress of The Association for Mathematics Education of South Africa, 7 - 11 July 1997, Natal University, Durban, South Africa.
- D.H. Smith, *Stability and Branching Behaviour of Finite Depth Standing Wave*, Australian Applied Mathematics Conference, Lorne, Victoria, Feb. 1997.
- R.A. Pax, M. McFarlane, A.W. Plank and J. Penhaligon. *Stochastic modelling of a sugar drier*, Poster presentation, Australian Society of Sugar Cane Technologists, Cairns, April, 1997.
- C.J.S. Vance, *A Plan 9 File Server Supporting PGP Public Key Encryption*, AUUG'97, Brisbane, September 1997.

Chapter 4

Recent publications

This chapter lists the research papers written by members of the department for recognised journals and conferences since 1994.

R.G. Addie

- R. G. Addie and M. Roberts. A Bootstrap Evaluation of the Variation of Rainfall Sample Histograms Estimated from Finite Historical Records. In *Proceedings of the second Australian Conference on Meteorology in Agriculture*, Brisbane, October 1996.
- R. G. Addie. Traffic will be more Gaussian in Future. In *Proceedings of the Australian Telecommunication Networks and Applications Conference*. Melbourne, December 1996.
- R. G. Addie. Multiplexing Gain in Large Networks of the Future. Submitted to ITC 15, 1997.
- P. Dunn & R.G. Addie. Time Series Analysis of SOI and Rainfall in South-East Queensland, *Proceedings, 8th Australasian Climatology Forum, Toowoomba*, Feb 1994.
- R.G. Addie & M. Zukerman. Queues with Total Recall – Application to the BISDN, *Proceedings of the 14th International Teletraffic Congress, Antibes Juan-les-Pins, France*, June 1994.
- R.G. Addie. Tails of Stationary Distributions of Queued Work, *Proceedings of IEEE Infocom '94, Toronto, Canada*, June 1994.
- R.G. Addie & M. Zukerman. Queueing Performance of a Tree Type ATM Network, *Proceedings of IEEE Infocom '94, Toronto, Canada*, June 1994.
- R.G. Addie & M. Zukerman. Performance Evaluation of a Single Server Autoregressive Queue, *Australian Telecommunications Research 1994*.
- R.G. Addie & M. Zukerman. An Approximation for Performance Evaluation of Stationary Single Server Queues, *IEEE transactions on Communications*, December 1994.
- R.G. Addie, M. Zukerman & T.M. Neame. Dimensioning Networks for Fractal Traffic, *Proceedings, the Australian Telecommunication Networks and Applications Conference*, Melbourne, 1994.
- R.G. Addie & A.W. Plank. Transient Analysis of Queues, *Proceedings, the Australian Telecommunication Networks and Applications Conference*, Melbourne, 1994.
- R.G. Addie & M. Zukerman. Fractal Traffic: Measurements, Modelling and Performance Evaluation, *Proceedings of IEEE Infocom'95*, Boston, MA, USA, April 1995.
- R.G. Addie, M. Zukerman & T. M. Neame Performance of a single server queue with self-similar input, *International Conference on Communication*, Seattle, June 1995.
- R. G. Addie, Darren Platt & M. Zukerman. Performance of a P_i Persistent Protocol Subject to Correlated Gaussian Traffic *Proceedings, IEEE Infocom 1996*, San Francisco, USA.

4.1 L. Brookshaw

- Chyba C., Thomas P., Brookshaw L., Sagan C., "Cometary Delivery of Organic Molecules

to the Early Earth" in *Origins of Life: The Central Concepts* (eds. David W. Deamer and Gail R. Fleischaker) Boston: Jones and Bartlett, 1994, pp. 213-220

- Brookshaw L., "Solving the Heat Diffusion Equation in Smoothed Partical Hydrodynamics" *OAT-SISSA International Workshop on Smoothed Particle Hydrodynamics in Astrophysics* Mem. S.A.It., **65**, 1994.
- Tavani M., Brookshaw L. "Angular Momentum Loss and Accretion in Low-Mass Binaries" in *Millisecond Pulsars: A Decade of Surprise* (eds. A. Fruchter, M. Tavani, and D.C. Backer) Astron. Soc. of the Pacific, San Francisco, 1995.
- Brookshaw L., Tavani M., "Outflow Hydrodynamics of Eclipsing Pulsars" in *Millisecond Pulsars: A Decade of Surprise* (eds. A. Fruchter, M. Tavani, and D.C. Backer) Astron. Soc. of the Pacific, San Francisco, 1995.
- Thomas P., Brookshaw L., "Organic Survival in Cometary Impacts" Chapter 5 in *Comets and the Origin of Life*, (eds. P. Thomas, C. Chyba, and C. McKay) 1997, Springer-Verlag, New York.

4.2 L. Bull

- M. Nooriafshar, R. Temple-Smith and L. Bull. Forecasting Regional Housing Approvals using IV C System. In *Proceedings of the Second Australia-Japan Workshop on Stochastic Models in Engineering, technology and Management.* Gold Coast, July 1996.

4.3 H. Butler

- H.J. Butler, W.L. Hogarth and G.H. McTainsh. Towards a simple Gaussian model to describe multiple source areas during wind erosion. In *Proceedings of the International Congress on Modelling and Simulation.* Newcastle, November 1995.
- H.J. Butler, W.L. Hogarth and G.H. McTainsh. A source-based model for describing dust concentrations during wind erosion events: an initial study. *Environmental Software* 11(1-3): 45–52, 1996.

4.4 J. Cao

- J. Cao & M.W. Orlowski. On Partial Order Processing for Dynamic Concurrency Control in Database System. In *Proceedings of the International Conference for Young Computer Scientists 95*, Beijing, China 1995.
- J. Cao & M.W. Orlowski. On Dynamic Concurrency Control in a Multidatabase System. In *Proceedings of the International Conference on System Research, Infromatics*, Germany 1995.
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- J. Cao & M.W. Orlowski. Transactions classification and a concurrency control algorithm in a multidatabase system. *Proceedings of the 11th International Symposium on Computer and Information Systems (ISCIS-XI)* Antaly, Turkey, 1996.

4.5 P. Dunn

- P. Dunn & R.G. Addie. "Time Series Analysis of SOI and Rainfall in South-East Queensland", *Proceedings, 8th Australasian Climatology Forum*, Toowoomba, February 1994.
- P. Dunn & G.K. Smyth. "Randomized Quantile Residuals", *Proceedings of the Statistical Computing Section, American Statistical Association*, Alexandria, pp 81–84 (1995).

4.6 K. Forbes

- K. Forbes & V.V. Anh. "Condition of system matrices in image restoration", *Journal of the Optical Society of America*, vol.11, no.6, June 1994, pp 1727-1735.

4.7 A. Fuller

- A. Fuller. "The Importance of Design to the OO Novice", submitted to *APSEC 95*, to be held in Brisbane, Dec 1995.
- A. Fuller. "EIFFEL: Eiffel in Fifteen Fast Easy Lessons", submitted to *TOOLS Pacific 95*, to be held in Melbourne, Nov 1995.

4.8 C.J. Harman

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- C.J. Harman, & N.I. Robinson. Higher order diference operators. *International Journal of Computer Mathematics* Vol. 63, pp 265–274, 1997, Gordon & Breach.

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- R.T. House. *Beginning with C: An introduction to professional programming.* Thomas Nelson Australia, PWS Kent. (1994).

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- S. Khan& A.K.Md.E. Saleh. "Shrinkage preliminary test estimators of the mean for some Student-t populations", *Proceedings of the International Conference on Pure and Applied Mathematics*, Nov. 1995, University of Bahrain, Bahrain, to appear.

4.11 W. Lai

- W. Lai and M. Danaher. "A higher level tool than widget toolkit for specific applications". *Proceedings of OZCHI '94.* Pages 321-322 (1994).
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4.12 R.V.N. Melnik

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4.13 A.W. Plank

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4.14 A.J. Roberts

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