Proposed Talks for ASOR National Conference 2007

Keynote Talks

Solving Industry Problems with Integer Programming: Recent Experience and Challenges

Natashia Boland

Progress in linear programming and integer programming solvers and software tools over the last ten years or so has provided unprecedented power at the fingertips of practictioners tackling industry problems. However recent experience with industry problems highlights the challenges that remain: it does not take much for an industry problem to push the boundaries of what is solvable with current technology. This talk will discuss cases of real industry problems, highlight the challenges they present, and investigate the solution approaches used.

The Science of Better and Better Together

Mike Trick

Operations Research (OR) is the art and science of better decision making. By using mathematical models, organizations and individuals create value through these better decisions. Historically, OR has provided incremental improvement through better scheduling, resource allocation, and distribution planning but these improvements have been limited due to lack of data or limited computational power. With the recent trends towards massive data sets and significant computational power, combined with algorithmic advances in the field, OR is becoming much more relevant to practice. In contrast to these trends, OR as a field appears to be struggling. Professional society membership is decreasing, and there is a perception that academic course offerings are also on the decline. "OR groups" in industry are a vanishing breed. How can we reconcile this dichotomy, and what can we do about it? I'll bring some thoughts from my experiences in the US and New Zealand, along with consulting work I have done with Major League Baseball and the United States Postal Service and others.

My Personal View on Monte Carlo Simulation.

Reuven Rubinstein

In this talk I will present a survey on dramatic developments, which took place during the last 20 years in Monte-Carlo Simulation. The survey will be based on our book:
Reuven Rubinstein and Dirk Kroese " Simulation and the Monte Carlo Method", Second Edition, Wiley, 2007.

In particular, I will discuss the following topics:
1. Sensitivity Analysis and Monte Carlo Optimization
2. Probability of Rare Event Simulation
3. The Cross-entropy Method and its Application to Combinatorial Optimization
4. Counting via Monte Carlo (Hamiltonian cycles, Satisfiability, Self-Avoiding Walks, etc)
5. Randomized Algorithms
6. Open Problems

Invited Talks

Decision making under severe uncertainty: An Australian, Operational Research Perspective.

Moshe Sniedovich

For obvious reasons, models for decision-making under severe uncertainty are austere. Simply put, there is precious little to work with under these conditions. This fact highlights the great importance of utilizing in such cases the ingredients of the mathematical model to the fullest extent, which in turn brings under the spotlight the art of mathematical modeling.

In this presentation I examine some of the subtle considerations that are called for in the mathematical modeling of decision-making under severe uncertainty in general, and worst-case analysis in particular.

The presentation is based on my interaction over the past four years with non-OR Australian analysts involved with the modeling and solution of practical decision –making problems under severe uncertainty.

Symmetry and Search

Barbara Smith

Symmetry in a constraint satisfaction problem often causes serious difficulties if complete search methods are used to solve the problem. This is especially true if an optimal solution is required, since then we need to prove that there is no better solution, and the search may repeat essentially the same proof for many symmetrically equivalent subproblems. The talk will survey the methods that are used in constraint programming to deal with symmetry and discuss their relative merits. Examples of problems with symmetry that have been solved using both constraint programming and mathematical programming will be discussed.

ILOG Talks

New ILOG CPLEX

The new ILOG CPLEX delivers breakthrough performance gains for mixed integer programming (MIP) models along with enhanced parallel MIP optimization and innovative usability features. Learn how ILOG CPLEX's new search algorithms can solve your most challenging MIP problems. Come and learn about the new features

Using ILOG OPL-CPLEX and ILOG ODM to Develop Better Models

This presentation delivers an in-depth overview of how to build state-of-the-art decision support applications and models. You will learn how to harness the full power of the ILOG OPL-CPLEX-ODM Development System to develop optimization models and decision support applications that solve complex problems ranging from near real-time scheduling to long-term strategic planning. We will demonstrate how to use ILOG OPL to quickly model problems solved by ILOG CPLEX, and how to use ILOG ODM to gain further insight about the model. After this presentation, attendees will understand how to take advantage of the powerful combination of ILOG OPL to describe an optimization model and ILOG ODM to understand the relationships between data, decision variables and constraints.

Sports Theme

1 *Modelling Outcomes In Volleyball*

Tristan Barnett, Alan Brown and Karl Jackson[3]

A Markov Chain model is used to calculate outcomes in volleyball conditional on both the scoreboard and the server. Results from the model indicate that it is advantageous to be the receiver on the opening point of a set. The receiver has a similar, but reduced, advantage at the opening point of a match. An application of this model is given through sports betting.

2 *Applying Match Statistics To Increase Serving Performance*

Tristan Barnett , Denny Meyer and Graham Pollard

A large database of tennis statistics is used to calculate player match statistics for each court surface. Analysis is carried out to determine serving strategies to increase performance. The results of the analysis could be used by players and coaches to possibly increase serving performance.

3 *Success, By Quality Or Quantity?*

George Serrallach

Professional Football Clubs have tried to become factories of success. The majority of their effort has been concentrated on the purchasing of players of all possible nationalities from all areas of the world. There has been no scientific approach to produce players or to improve their own players to achieve success. All what they do is throw money at the problem without a proper cost benefit analysis.

To win a competition, in other words, to obtain success the clubs should have a more scientific approach to manage the output of their teams. Usually they do not use the most cost-effective methods in deciding which players to buy and how to look for players that would perform to the level required to be successful.

Coaches and analysts tend to concentrate in quantity of events, e.g. how many corners or how many times the ball penetrates the attacking third of the field, but at no stage they look at the quality of these events. The analysis systems in the majority of clubs only provide basic statistical data. Three successful crosses ending up in goals are more conducive to victory than 21 crosses that did not produce any goals. The basic statistical analysis would reveal 21 crosses and if this was their target figure for the game they will be satisfied.

So called good players are paid between £15,000 and £25,000 a week to play one or two games during this period of time. The clubs do not have a method or an analysis system that measures their performance. At the moment coaches measure

performance in a very subjective way, and it depends on who is assessing the performance.

There is a chain of events that lead to success. The first is Option Taking, which is defined as "the selection of the best option" for each event. In any event there are a few techniques that could be used but there is one that will maximize the expected result. The second link in the chain is Technique Execution. To execute the technique successfully requires not only a lot of practice, but the right practice paying attention to detail. Finally not all well executed techniques lead to success.

It is difficult to define success in a game of football unless a goal is scored, but there are other measurements or parameters that can be used as yardsticks for success as simple as metres gained, possession kept, free kicks milked out etc., but others could be more complicated requiring mathematical algorithms which take into account a variety of simple factors weighted in a specific way. These algorithms allow the modelling of the game, and they are called Key Performance Indicators (KPI).

The best possible and most cost-effective solution is to analyse each game and find out where success was not achieved and then ask the following questions:

- Was the best available technical option chosen?
- Was this technique executed correctly?
- Was the aim of the well-executed technique totally successful?

This paper will, with the help of a few examples, show how to break down unsuccessful events in a game and draw the necessary conclusions to use the cost effective and minimal resources to achieve a successful outcome.

4 *Analysis Of Spatial Data In Australian Rules Football*

Karl Jackson

Since 1998, Champion Data have collected comprehensive individual and team performance statistics for the AFL, such as the number and effectiveness of marks, kicks, handballs, etc. From 2002, these statistics have been coupled with the location of each possession. The main focus of my research is to use this data in establishing a continuous time, semi-Markov model for a match of Australian Rules football. Continuous time Markov chains and the spatio-temporal aspects of data have previously been used to model animal behaviour. Application of these models in the field of Sports Statistics has so far been limited to Ice Hockey, so this research is the first attempt to apply the concepts to Australian Rules football. Extensions to previous work in this area, such as the value of possession at a given location based on dynamic programming and regression analysis will also be considered. Applications include team and player rating systems, prediction of results for future games/tournaments, analysis of spatial strategies by teams, post-game analysis and the improvement of current television coverage of Australian Rules Football.

5 *Some Alternative Men's Doubles Scoring Systems*

Graham Pollard, Tristan Barnett[1], Alan Brown[2] and Geoff Pollard[3]

In 2006 the scoring system for men's doubles was changed. The purpose of the change was to have matches of shorter and more predictable duration. In this paper the statistical characteristics of the previous and the current scoring systems are quantified. Further, some alternative scoring systems making use of recent ideas are considered, and compared with the current system. The methods used in this paper to produce the results are new, and could be used for a wide range of other sports and other scoring systems.

6 *Using Dynamic Programming to Determine Strategy in a Contract Bridge Tournament*

Nicholas Beaumont

A contract bridge tournament often comprises several rounds of matches. Players compete as pairs for 'masterpoints'. Masterpoints are awarded for each match won or drawn and for being highly placed at the end of the tournament. In the second and subsequent rounds, pairs are matched against other pairs that have been approximately equally successful so far.

There has been vague discussion amongst bridge players of the possible advantages of 'throwing' i.e. deliberately losing a match in round /i/ so as to obtain a lower ranking and face an easier opponent in round /i+1./

This paper uses Dynamic Programming and the data from one tournament to identify optimal strategies as functions of a pair's ability, its placing after each round, the relative rewards for winning a match and finishing high, and the round. For example, we find that a very weak pair should 'throw' and 'play to win' in alternate rounds.

Scheduling

7 *The Two-Criterion Workforce Scheduling Problem: Lower Bounds And Heuristics*

Sorawit Yaoyuenyong, Suebsak Nanthavanij, Jian Yang

Everyday a number of workers have work-related injuries because of exposure to hazardous tasks. The U.S Department of Labor's Annual Survey of Occupational Injuries and Illnesses (ASOII) stated that the annual cost of occupational injuries is at least $10 billions. Workers regularly perform physical tasks with high level of energy expenditure. Thus, workers can have accidents and over-exhaustion. Moreover, the work environment usually has excessive noise. According to the National Institute for Occupational Safety and Health (NIOSH), 30 million workers are currently exposed to hazardous noise levels in their workplaces.

A new safety-based workforce scheduling problem is proposed. It aims to minimize the number of industrial workers to safely perform a set of physical tasks in each workday. The problem considers two safety criteria, namely, energy expenditure and noise exposure. For each worker, the amounts of energy expenditure and noise exposure each day must not exceed his or her daily limits. This workforce scheduling problem is related to the two-dimensional vector packing problem.

Two formulations for the problem are proposed. The first one is close to its natural presentation; and the second formulation applies the column generation technique. Aiming to solve this complex problem efficiently, we have developed lower bounding procedures and solution heuristics for the problem. Our computational study has confirmed the effectiveness and efficiency of some of the methods.

Key words: vector packing; algorithms; heuristic; manpower planning

8 *A Sequencing Approach For Train Timetabling*

Robert Burdett and Erhan Kozan

Train scheduling is a complex and time consuming task of vital importance in many countries. To schedule trains more accurately, efficiently and robustly than permitted by current techniques a novel job shop approach is proposed and implemented in this paper. Unique characteristics of train scheduling are firstly incorporated into the disjunctive graph representation of the solution. Constructive algorithms that utilise this representation are then developed. Two general meta-heuristic strategies namely simulated annealing and local search are then extended, and a new compound perturbation operator is proposed. Additionally, more complex return path scheduling situations involving re-entrancy and recirculation are also tackled. A large numerical investigation and case study is provided and demonstrates that high quality solutions may be obtained.

Keywords: Job shop, train scheduling, meta-heuristics

9 *Family Scheduling on a Single Machine With Uncertain Setup Times*

Simon Dunstall, Nectarios Kontoleon, Gaurav Singh and Andrew Wirth

We investigate properties and algorithms for the problem of scheduling jobs with family setups on a single machine where setup times are uncertain and characterized by an expected value and a variance. The objective in the problem is to minimize the weighted sum of completion times, where both expectation and variance are considered.

10 *Assigning Robust Due Dates to Jobs with Uncertain Arrival Times*

Gaurav Singh, Andreas Ernst and Geoff Robinson

Traditional scheduling problems have been deterministic in nature. This is highly unrealistic for many industrial problems. Online scheduling partially bridges this gap by providing scheduling policies. But, online scheduling does not consider the stochastic components of the problem. A common practice is to use simulation or scenario based stochastic optimisation to find a reasonable solution.

In this paper we concentrate on the following problem. A set of jobs is to be scheduled on two parallel processors/machines with precedence relations between jobs. The processing time for every job is the same and can be taken as a unit of time. Each job also has a lognormally distributed release date characterised by a mean and standard deviation. The goal is to set due dates for the jobs so that the sum of all these due dates plus weighted tardiness of the jobs is minimised.

We present a new method to evaluate a schedule and results on the comparison of this method with other known methods. We also compare the numbers of local minima for a problem with "noise" and its deterministic counterpart.

11 *An algorithm for scheduling on Parallel machines with Due Dates and Release Times*

Yakov Zinder, Gaurav Singh and Rene Weiskircher

The talk presents an exact algorithm for one of the classical scheduling problems which due to its considerable theoretical significance and practical importance remains a subject of research over three decades. The problem can be stated as follows. A finite set of tasks (operations) is to be processed on several parallel identical machines (processors, servers) subject to precedence constraints in the form of anti-reflexive, anti-symmetric and transitive relation on the set of tasks. If a task precedes another task in precedence constraints then the first task must be completed before the start of processing of the second task. Each task can be processed on any machine and, and each machine can process at most one task at a time. Once a machine begins a task, it continues until the task's completion (no pre-emptions are allowed). All the tasks have the same processing time which without loss of generality is taken as a unit of time. The processing of each task can commence only after its release time. Given the assumption that each task requires one unit of processing time, it is assumed that each release time is a non-negative integer. Each task is assigned a due date, and the goal is to construct a schedule with the smallest maximum lateness. If all due dates are zero, the maximum lateness problem becomes the so-called makespan problem with the goal of miminising the time needed to complete all tasks.

It is known that the considered scheduling problem is NP-hard in the strong sense even if all due dates are zero. (the makespan problem), all release dates are zero, and the precedence constraints are restricted to bipartite graphs. The considered maximum lateness problem is also NP hard in the strong sense if all release times are zero and the precedence constraints are restricted to out-trees. Given the NP-hardness of the problem, the main approach guaranteeing the construction of an optimal solution is the branch-and-bound method. Although the algorithm presented in this talk also uses branching and calculates bounds in order to reduce the corresponding

search tree, it significantly differs from the conventional branch and bound method. Unlike the conventional branch and bound method the presented algorithm does not partition the feasible region explicitly. Instead of constructing partial schedules, which is typical for the conventional branch and bound method, the presented algorithm changes priorities of tasks. For each assignment of priorities, the algorithm constructs a feasible schedule, using these priorities. The structure of this feasible schedule determines the changes in the corresponding assignment of priorities.

The analytical results including a proof of the convergence of this algorithmare complermented by a description of computational experiments. These computational experiments compare the approach presented in the talk with a conventional branch and bound algorithm and a genetic algorithm.

12 *Algorithms for scheduling variable multiprocessor tasks*

Yakov Zinder and Samuel Walker

The introduction of multiprocessor tasks relaxes the restriction of the classical scheduling models that each task can be processed on only one machine (processor/server) at a time. Although the models with multiprocessor tasks have attracted a considerable attention over the past decade, the majority of the results have been obtained only for the situation when the set of machines needed for processing a task is fixed. We relax this assumption and consider scheduling situations where the decision maker can choose the number of machines for processing a task. The corresponding scheduling models can be referred to as models with variable multiprocessor tasks.

The talk is concerned with several polynomial time algorithms for scheduling partially ordered variable multiprocessor tasks. The results, presented in this talk, pertain to the maximum lateness problem and to its particular case the so called makespan problem, which requires the minimisation of the maximum completion time. Both considered criteria are among the most frequently used in scheduling theory. The results, presented in this talk, fall into two categories: cases where an optimal solution can be obtained using a polynomial time algorithm, and the worst case analysis of the general case. It is shown that all presented performance guarantees for the general case are tight and therefore cannot be improved. Many known performance guarantees for the classical scheduling problems can be viewed as particular cases of the performance guarantees presented in this talk for the problems with variable multiprocessor tasks.

13 *Collaborative Planning and Scheduling Practice: A Case Study in the Beverage Industry*

Kaveh Nezamirad, Peter Higgins, and Simon Dunstall,

Field observations in the beverage industry show that in practice, longer-term plans and schedules are not followed precisely in shorter-term dispatching and execution.

Despite numerous efforts to make OR methods closer to practice, there is still a gap between the theory and practice of planning and scheduling.

From a hierarchical perspective, the gap between plans and actions indicates discrepancy in the system. Such discrepancies are perceived as flaws in the system's operation caused by management control systems developing plans that cannot be fully implemented in action. However, plans have other purposes that go beyond the sequencing of operations. Planning activity drives collaboration between all persons responsible for allocation of resources.

This paper demonstrates that the gap between plans and actions needs to be carefully analysed to reveal its meaning for the system of interest. In the case of grape intake for beverage making, this analysis shows that planning triggers subsequent collaboration over coordinated action across the supply chain. Indeed, the enquiry into the meaning of the planning-to-execution gap reveals a collaborative planning approach that proceeds through a number of action–recognition stages.

Environmental Issues

14 *Smart markets for water: answer to Australia's water crisis?*

John F. Raffensperger

Though water is one of the most important inputs to humanity's well-being, water is thinly traded everywhere, even when a country has no significant legal barriers to water trading. The only exceptions, and the exceptions are modest, occur when water is physically controlled. Why are water markets so difficult to operate? Why are water rights so thinly traded? The core difficulty in operating a water market is the transaction cost created from the need for societal vetting of every transaction. This societal vetting is necessary to protect third parties and the environment from externalities. Is the answer, then, to control water with expensive infrastructure? With analogies to Australia's electricity and gas markets, this paper proposes a promising alternative, which is a smart market. Smart markets have proven themselves for a wide range of complex commodities, such as electricity, gas, and radio spectrum. Yet they are not used anywhere for water.

A smart market for water would use hydrological optimisation to model the physical complexities of a catchment, including desired environmental flows. The desired environmental flows would be treated as constraints. Users' bids would be the objective function coefficients. Dual variables would provide the optimal market prices, which would depend on location and time period.

Such a smart market would reduce transaction costs in several ways. First, users would not need to find trading partners, because users need only use a web page for the smart market. Second, governmental review of the transaction would be encapsulated in the hydrological optimisation. Third, the smart market should work for any kind of hydrology, including uncontrolled ground water. That water need not be controlled allows water to be traded over much wider regions.

The smart market allows the benefits of a modern options exchange. Fulfilment of the contract is backed by the exchange; parties are generally anonymous; the market manager enforces regulation to ensure fairness and transparency; and markets are

orderly (especially during stressful conditions, i.e., drought). Smart markets are achievable due to an enabling confluence of technologies: hydrological simulation to inform a linear program, the internet to transmit users' bids and the resulting prices and quantities, increased computation power to run the simulation and linear program, and real time monitoring. We conclude the article with a discussion of the technical hurdles.

Keywords: water market, smart market, linear program, hydrological optimization

15 *Regional Sustainability Development under Climate Change: A Case of Agriculture Sector*

Omar Soliman and Ruhul A Sarker

The regional sustainability development (RSD) is an efficient use of regional scare resources. RSD comprises multiple, conflicting and often non-measurable goals such as economical, environmental and social goals. These goals are affected by the climate change. In this paper, we present a fuzzy goal programming (FGP) model to evaluate RSD under climate change in agriculture sector. It employs concepts of conflict among goals and fuzzy set theory for priorities setting. A solution methodology of the FGP model is presented. The proposed FGP model is more flexible than conventional goal programming and it is capable of evaluating RSD under different climate change scenarios. It also provides different alternative policies based on the degree of uncertainty. The introduction of fuzzy goals in the RSD model provides an assessment to uncertainty associated with various predictions of climate change.

16 *Optimising the Location of Tsunami Detection Buoys in the Indian Ocean*

Katerina Blazek and Layna Groen

In the 2004 Boxing Day tsunami waves as high as 10.5 metres crashed onto beaches at speeds of up to 8 metres per second. More than eight hours after this catastrophe was experienced in countries of South East Asia, the tsunami struck fishing communities in Kenya and Somalia. In total, more than 250,000 lives were lost in eleven nations surrounding the Indian Ocean. More recently, the July 17, 2006 tsunami, caused by a major earthquake off the coast of Java, killed approximately 550 people and displaced more than 50,000 others.

In the wake of the 2004 Boxing Day disaster, a global response to implement a tsunami warning system in the Indian Ocean became imperative, and there is little doubt that the impact of the disaster could have been mitigated if an alert system, similar to that operating in the Pacific for more than 30 years, had been in place. Steps in this direction were initiated in 2005, with plans for the deployment of up to 40 detection buoys in the Indian Ocean.

The purpose of this paper is to investigate the optimal placement of tsunami detection buoys in order to provide the greatest warning potential. We adopt a mathematical programming approach and show that the problem may be solved either by partitioning the Indian Ocean into a small number of regions or by solving for all

locations simultaneously. It is determined that at most 24 of the total 40 suggested locations are essential in ensuring the maximum number of people are warned of an impending tsunami. The proposed reduction in the number of buoys from 40 to 24 would save four million dollars in tsunami detector purchasing costs and two million dollars in annual maintenance costs. Alternatively, the 24 buoys can be viewed as the minimum required to maintain maximum warning potential for the purposes of ongoing maintenance.

17 *Mixed Integer Programming Models for Wind Farm Design*

Stuart Donovan, Hamish Waterer and Rosalind Archer

There is significant potential for optimizing the design of a wind farm in New Zealand. The complex nature of the wind resource and the larger size of the wind farms being built increase the complexity of the decisions that need to be made, while tight economic margins create a drive for greater efficiency. Current industry practice utilises commercial packages that are heuristic in nature and limited in the types of constraints that can be modelled.

A mixed integer programming model for optimizing the layout of a wind farm has been developed that is capable of determining the optimal locations of turbines subject to constraints on the number of turbines, turbine proximity, and turbine wake. Results have shown that this model produces layouts that are comparable to those from a commercial package. Moreover, this model can be extended to include capital budget constraints, noise and line of sight restrictions, constraints relating to wind quality such as maximum gusts, inflow angles and turbulence, as well as modelling reticulation and different mixes of turbines.

18 *Taming Wind Energy with Battery Storage*

Andreas Ernst and Gaurav Singh

19 *Controlling CHP Turbines as a Virtual Power Plant*

Nectarios Kontoleon, Rene Weiskircher and Simon Dunstall

Distributed generation with combined heat and power is one of the options for increasing the efficiency of the electricity network and thus reducing the emission of greenhouse gases.

In this paper, we investigate the use of micro-turbines for generating electricity as well as space and water heating. We present a control strategy based on integer linear programming for a set of micro turbines used in a combined heat and power role. The strategy guarantees a fixed heat service level while taking advantage of fluctuating prices in the wholesale electricity market by acting as a virtual power plant.

Our computational experiments show that following our control strategy , a company with a total electric generation capacity of 156 MWh per year would offer about 30% of the electrical capacity on the national market. Our results show the importance of being able to profit from periods of extreme prices in the NEM. This knowledge is useful in planning and scenario analysis of large scaled combined heat and power distributed deployment

Mining

20 *Models of Petroleum Geology for Improved Production and Reservoir Management*

Mark Horn and Leorey Marquez

WITHDRAWN

21 *Stockpile Blending with Uncertainty*

David Sier, Geoff Robinson and Andreas Ernst

We look at a model to deal with uncertainty in grade estimates when blending stockpiles to a target specification.

The aim is to prepare a shipment of coal by blending different stockpiles. The blend objective is to calculate the best possible blend for a target blend specification minimising the overall deviation from the target specification, given a set of source stockpiles of known quantity and quality.

If we assume fixed values for the different analyte grades in the source stockpiles then we can formulate the problem as a standard mixed integer linear program. However if we allow for uncertainty in the grade estimates then the objective contains quadratic terms associated with various sampling errors.

This paper describes a non linear programming model for incorporating grade variability when targeting a particular blend to make up a shipment of ore.

22 *Mine Grade Control Decisions taking Two Types of Uncertainty into Account.*

Geoff Robinson, Andreas Ernst and David Sier

Mine grade control decisions need to take both estimation variances and portion taking variances into account while targeting several aspects of grade and considering other mining priorities. This talk discusses model formulation with an emphasis on the reasons for being prepared to give up convexity of the objective function.

The algorithm for short-term grade control decisions can also be used for life-of-mine simulation. The planning for mining operations, ore blending and associated

metallurgical plants should ideally include prediction of the amount of grade variation that is likely to occur at various points in the material flow, so that process specialists can make informed decisions about whether planned processing options will be adequate.

Medical

23 *Modulation Of Intensity Beams In Cancer Radiotherapy Using Multileaf Collimators: Integer Programming Models For The Decomposition Cardinality Problem*

Giulia Wake[1], Natashia Boland[2], Les Jennings[3]

Cancer patients with certain types of tumours are best treated with intensity-modulated radiation therapy, delivered by machines known as multileaf collimators. A multileaf collimator administers a treatment plan by delivering a sequence of uniform intensity beams through a shaped field; these accumulate to create a modulated intensity profile. Whilst receiving treatment, patients must remain still, so minimizing the time needed for treatment can improve the outcome for the patient. We consider the problem of minimizing the number of machine set-up changes (Decomposition Cardinality) when the total beam-on time for the radiation is set to its minimum value. The Decomposition Cardinality problem is strongly NP hard. We present new exact integer programming models to solve the Decomposition Cardinality problem with minimal total beam-on time and numerical results comparing the different models.

24 *Optimisation of Patient Flow In An Emergency Department*

Mel Diefenbach, Erhan Kozan, James Collier and Michael Sinnott

This paper shows the analysis and optimisation of patient flow through a public hospital Emergency Department. An overview of the Emergency Department (ED) system, its complexities, processes, resources, demands, performance measures, inhibitors to the flow, and current contributions are explored. The complexity of the system is increased by the stochastic nature of demands, processing times, and resources as well as both the interactions within the system and its external interactions with the operating theatres, intensive care units, wards, other hospitals, and the community. The performance of the system can be measured by numerous factors, both quantitative and qualitative, and these are defined. The number of objectives by different parties (e.g. patients, doctors, and hospital administration) complicates the system as the objectives are often competing. Findings include results from the resource analysis, the positive influence on ED efficiency by balancing resources to meed demand, and optimisation of the system within the constraints of the scarce resources.

Key Words: Simulation, Emergency Department, Optimisation.

25 *A New Sequential Extraction Heuristic for Optimizing the Delivery of Cancer radiation Treatment using Multileaf Collimeters*

Davaasteren Baatar, Natashia Boland, Horst Hamacher and Robert Johnston

Finding a delivery plan for cancer radiation treatment using multileaf collimators operating in "step-and-shoot mode" can be formulated mathematically as a problem of decomposing an integer matrix into a weighted sum of binary matrices having the consecutive-ones property - and sometimes other properties related to the collimator technology. The efficiency of the delivery plan is measured by both the sum of the weights in the decomposition, known as the *total beam-on time*, and the number of different binary matrices appearing in it, referred to as the *cardinality*, the latter being closely related to the set-up time of the treatment. In practice, the total beam-on time is usually restricted to its minimum possible value, (which is easy to find), and a decomposition that minimiz es cardinality (subject to this restriction) is sought.

This decomposition problem is known to be NP-hard and the best available exact solution methods cannot solve, in reasonable time, problems with dimensions large enough to be of use in actual medical applications. In this paper we propose a new heuristic. To ensure that the heuristic is computationally efficient, we make use of exact bounds that apply to the decomposition, and prove that these bounds can be computed efficiently. We demonstrate that the heuristic performs very well numerically against the best previously published heuristic, (that of Kalinowski), reducing the gap between the cardinality of the solution found and the optimal value by up to 24% on average, for larger problems (for which optimal solutions can be found). Importantly, this new heuristic performs well on those instances that are problematical for Kalinowski's heuristic. A "best-of" algorithm, combining heuristics, produces a decomposition with cardinality within one of the optimal in about 98.7% of instances tested (for which an optimal solutions is available). It reduces the cardinality of solutions produced by about 5% on average. On instances for which optimal solutions can be found, it more than halves the optimality gap and finds an optimal solution in about 28% more cases than Kalinowski's heuristic.

26 *Determining Optimal Operational Hours Of A Surgical Care Unit*

Kari Stuart, Erhan Kozan, Michael Sinnott and James Collier

This paper describes the development of an integer-programming model for determining the optimal operational hours of a major public hospital's surgical care unit. Theatre utilisation, which is typically the major performance objective of hospital decision makers, is maximised. The model is solved by two methods; a branch and bound algorithm and simulation. Deterministic expected surgical durations based on historical data were implemented in the analytical model. Alternatively, the solution obtained via simulation takes into consideration the variability in surgical duration. The solutions obtained are compared and the effects on other performance objectives in the surgical care unit – number of cancellations, patient throughput and patient wait time - are demonstrated via simulation. The results may be used as decision support for hospital administrators wishing to predict the outcome of decisions before implementation.

Keywords: Optimisation, integer-programming, simulation, branch and bound

Defense

27 *Developing an Applied Model of Tactical Command and Control for Future Warfighting*

Andrew Coutts, Christina Stothard, and Daniel Goodburn,

Future warfighting concepts, such as the Australian Army's Future Land Operating Concept (FLOC), identify the requirement for smaller and more dispersed combat teams in order to more effectively operate in increasingly complex environments [1]. These concepts therefore impose an increased level of mission responsibility and task complexity at lower levels of tactical command when compared to their traditional tasks and responsibilities. Observations made during exercises and operations suggest that command, control and coordination effectiveness at the tactical level may be adversely affected by increases in task complexity unless there is a significant compensatory increase in command capability - not just communications capability. In order to assess the impact of future warfighting concepts on combat teams, we require a model of tactical command, control and coordination that will provide insights into the performance of tactical command within small combat teams operating in various structures and environments under stress. This paper builds on ongoing research into the fundamental characteristics of command in small teams and proposes a model that can inform experiments. The model is tested against available field data. A broader research project involving implementation of the model within an agent-based simulation is proposed.

28 *Exploring a concept for fly-in, fly-out (FIFO) operations in the "army of threes".*

Brandon Pincombe and Adrian Pincombe

The Australian Army deploys battlegroups made up of soldiers from multiple corps. Prior to deployment, personnel train together to become a cohesive unit. Battlegroups are deployed for six to nine months and are disbanded on return with the constituent parts sent back to their substantive (corps based) units.

The 'army of threes' aims to have only a third of the personnel eligible to be in battlegroups deployed. The other two thirds will be in their corps based units or undertaking pre- or post-deployment activities.

We consider an alternative concept using a larger battlegroup split into nine sub-units. Each sub-unit undertakes a three-week-on, six-week-off fly-in, fly-out (FIFO) schedule with their periods in theatre overlapping so that one sub-unit is rotated each week. The advantages and disadvantages of this concept relative to the status-quo are explored and the characteristics of operational situations where it would be more or less feasible are identified.

29 *Online Scheduling in Maritime Surveillance*

Philip Kilby and Patrick Tobin

The RAAF carry out surveillance operations daily in Australia's coastal waters. These operations present a difficult optimisation problem. The problem resembles a Travelling Salesman Problem, except that the targets are moving. Also the tasks to be performed are not known at the start of the operation - they only become known as the mission is flown. In this paper we look particularly at the on-line aspects of the problem. Can we make use of previous information to improve the performance of the heuristics used to solve this problem?

30 *Path Planning Through Maritime Minefields*

Ranga Muhandiramge

Sea mines are a significant problem to the planning and execution of naval missions, particularly amphibious landings. Mines are relatively cheap and easy to deploy but are able to cause huge damage and are disproportionately difficult to remove or neutralize. Thus mines pose an asymmetric threat that is potentially available to state and non-state aggressors with even limited military budget.

In this talk, we show how network optimization methods, particularly the weight constrained shortest path problem (WCSPP), can be applied to the minefield transit problem. First we briefly revise our solution method for the WCSPP. We then present several models for minefield problems such as mine clearance and minimum risk traversal. We consider both discrete and continuous models of mine threat.

Routing and Location

31 *Solving a Multi-Product, Multi-Shiptype Ship Routing Problem with Hold and Draft Constraints*

Natashia Boland, Heng-Soon Gan and Olivia Smith

We present a single time period ship routing problem where pre-specified amounts of one or more different products are to be loaded or discharged at specific load and discharge ports. This problem arose from a manufacturing company who require bulk import of raw materials from overseas source. We are given a set of ship types where each differs in hold (a "compartment" on a ship) configuration. More than one product can be loaded on a ship, but two products cannot share a hold. A ship is not allowed to dock at a port if its total mass exceeds the draft limit at that port. The problem is to determine a set of ship routes for each ship type that minimizes the total shipment cost, such that all products are loaded and discharged at their given ports, and ship hold and port draft constraints are obeyed. We have formulated the problem as a mixed integer program, and have developed heuristic solutions for the problem. Performances of these solution methodologies are tested and compared on data provided by the company.

32 *Improving The Method Of Seed Generation For A Route Optimization Software Package*

Liam Merlot and Peter Gipps

Quantm is a company that provides software for infrastructure planning, particularly medium length (10km -400km) road and rail infrastructure. One of the services provided by Quantm for road and rail planners is 'unseeded optimization', whereby 50 alignments (routes) are produced for the client without using any seed alignments for the route optimization software. To produce these alignments, the Quantm pathfinder software must generate 50 different seeds from a continuous space which satisfy the requirements of the client and are of a 'good' standard. The method for the generation of the seeds by constructing a 3 dimensional network over the land surface and using shortest path algorithms is presented, along with two different attempts to improve the quality of results produced by this method. The difference between the success and failure of these two attempts to improve the algorithm illustrates the unfortunate fact that when practical results are all that matter, good mathematical theory may not be the most important consideration.

33 *Aggregation in Hub Location Problems*

Elena Gavriliouk

Because of their usefulness and difficulty, hub location problems have been extensively studied in the past twenty years. Even though progress has been made some hub location problems still remain unmanageable when the number of nodes is greater than two hundred. We explore an alternative way of tackling this problem with aggregation. In this presentation, we consider a way to perform aggregation in hub location problems, explore the error resulting from such aggregation and present bounds on the objective function value when aggregation is applied. Furthermore we show how the developed error bounds lead to methods for conducting aggregation for different types of the hub location problem which then pave the way for heuristics for k-hub centre and median problems.

Agricultural

34 *Roving Stock In A Meat Processing Supply Chain Using A Game Theory Approach*

Maryam Esmaeili, Paul Moloney, and Prof. John Hearne

Interactions between pricing, ordering and offered quantities are very important in decision making in meat processing supply chains and are well documented for domestic livestock. However, this paper considers harvesting kangaroos, wildlife that is not contained by current fencing, in effect roving stock, as well as domestic stock, namely sheep. We consider decisions related to a meat processing supply chain between a farmer supplying sheep and kangaroo and a processing factory, using a

game theory approach. The optimal buying price and order quantity is determined for these substituted goods to minimise the factory's purchase cost while the order quantity is a function of buying price. The farmer's model determines the optimal quantities of sheep and kangaroo to offer so as to maximise their income based on buying price, considering factors like the farm's carrying capacity, animal fecundity and mortality and (in the case of kangaroos) migration. The interactions between the processing factory and the farmer will be modelled by both non-cooperative and cooperative games. We compare different scenarios by considering the relationship between the order size and the amount offered. Numerical examples will be presented in this paper to illustrate our model.

Key words: Game Theory, Kangaroo, Migration, Supply Chain

35 *Product Mix Optimisation of Dairy Bioactives*

David Sier and Rodolfo Garcia-Flores

Bio-actives (also called nutraceuticals or functional foods) are defined as foods that meet consumer needs for general health and well being and the prevention and management of compromised health conditions.

In the dairy industry, many high value protein based bioactives can be extracted from materials, such as whey, that were previously treated as waste products.

In this talk, we describe how different types of transfer functions can be used to formulate and solve LP mass balance problems representing dairy processes. Restrictions are placed on the relative composition of the ingredients in the final combination of products. We then discuss the commercial implications of optimising a dairy product mix when taking into account costs and opportunities for making bioactives.

36 *Models and Algorithms for RNAi Design*

Mark Horn

The DNA to RNA transcription mechanism uses messenger –RNA (mRNA) to translate an organism's genetic code into biochemical instructions. RNA interference (RNAi), also called gene silencing, is a process that manipulates this mechanism so as to suppress the expression of selected "target" genes. Several forms of this occur in nature where it aids in a an organism's defence against genetic abnormalities and harmful viruses. An effective artificial silencing process has been developed by a research team in CSIRO Plant Industry. Central to the process is the synthesis of a "silencing sequence" in double stranded RNA, directed at the taget genes. Dicer enzymes reduce the dsRNA to single strand base sequences of length 21 (silencer-mers). The silencer-mers produced in this way guide Argonaute proteins to biochemically matching locations (object-mers) on mRNA transcriptions of the target genes, leading to a degradation of the mRNA.

This paper is concerned with the development of analytical and design tools to facilitate the application of CSIRO's silencer technology, both of which have posed significant challenges. Analysis involves estimating a candidate silencer sequence's efficiency and non-lethality, where efficiency refers to the estimated impact on target genes , and non-lethality refers to cross-silencing impacts (i.e. impacts on parts of the genome other than the targets). For analytical purposes a procedure has been developed to search quickly for sites in the genome that are matched by a given silencer-mer, which can be seen as a special case of a problem arising in the implementation of "skyline" database queries. For the design task – to generate silencer sequences that are effective in terms of the criteria discussed above – some fairly elementary heuristic techniques have been found to serve present needs very effectively.

DEA and Comparison Modeling

37 *Identifying Bank Failures with Two Stage DEA Model in the Worst Case Scenario*

Fuh-Hwa Franklin Liu and Cheng-Li Chen

In the banking industry, the production process can be described as a two-stage process. There are a number of published data envelopment analysis (DEA) papers that study the bank performance with two-stage model. However, none of them is applied to identify bank failure. In fact, only one of them deals with negative profit data. In the real world, failed banks or firms often produced negative profit for several years before they went into bankruptcy. To fit this situation this paper introduces a two-stage worst-practice-frontier DEA (WPF-DEA) model that can deal with negative profit data and effectively identify failed bank(s) in the worse-case scenario. This model is applied in an empirical study. The result is then compared with the result from a best-practice-frontier DEA model to show the adequacy of WPF-DEA model for identifying failed bank(s) in the worst-case scenario.

38 *Multiplier Forms Of Fractional Programming DEA Models Of Variable Returns To Scale*

Lifen Wu

In 2005 at the 18th ASOR National Conference, I presented parametric solutions and dual formulations of linear fractional programming DEA models. These solutions lie between the two usual solutions from denominator or numerator normalisation. The consequent results provide alternative optimal solutions between those from input- and output-oriented CCR models for constant returns to scale DEA models and optimal scale efficiency in addition to technical efficient solutions from input- and output-oriented BCC models for variable returns to scale DEA models. In this 19th ASOR Conference, I would like to present non-convex linear fractional programming multiplier forms of the variable returns to scale DEA model.

Although in their envelopment form, the objective of variable returns to scale mixed-oriented DEA model is the same as that of constant returns to scale mixed-oriented DEA model and the latter has a unique optimal solution, the former has different local optimal solutions which can be evidenced by its multiplier forms.

ω_k in BCC fractional programming problems or BCC ratio forms can be expressed in u_r and v_i in $u-v$ coordinates. In a case of single input-output, it can be observed that $\frac{\mu_k}{v_k}$ and $\frac{-\omega_k}{v_k}$ in each iterate of parametric input-oriented variable returns to scale DEA model are slope and intercept of the level curve on u-axis while $\frac{v_k}{\mu_k}$ and $\frac{-\omega_k}{\mu_k}$ in each iterate of output-oriented variable returns to scale DEA model are slope and intercept of the level curve on v-axis. The level curve rotates around an efficient DMU. The efficient DMUin input-oriented model which is closer to the original point and that in output-oriented model are generally two different points which the level curves in the two orientation models radiate from respectively.

In the case of constant returns to scale, the level curve radiates from the original point in both the input- and output-oriented models; while in the case of variable returns to scale, the 0-level curve is not the v-axis (plane or super-plane) which is the case in constant returns to scale models or even not parallel to it.

The multiplier forms of parametric input- and output-oriented variable returns to scale DEA models are linear fractional programming models with non-convex feasible region and provide geometric interpretation for the BCC fractional programming problems.

39 *Systems Modelling Of Performance – Aspect Generation For Theory And Application To A Simple Repair Model*

Axel Bender and Gregory Sherman

Quantitative operations research often involves the measurement of system performance. This performance assessment is necessary to a) compare the performance of a real system or a system under development with the requirements set by operational constraints and b) make judgments about what is the “best” system in a given set of options. It can be cumbersome, in particular when systems are high-dimensional, contain a large number of components and need to perform several context-dependent mission profiles.

In this document we briefly outline an investigation into a *functional approach* for deriving consistent *systems measures of performance* (**SMOP**) even when they are strongly correlated. This approach provides a framework for the non-linear aggregation of performance measures. We discuss some of the requirements that need to be fulfilled in order to see such a functional approach realised. The realisation is based on the hypothetical – and in reality unachievable – assumption that there exists perfect knowledge of the state changes the system could potentially undergo; the mission profiles the system has to perform; and the effectiveness of any system state

in any given mission. While unrealistic, this assumption of perfect knowledge results in a powerful tool that, inter alia, allows for the exploration of some of the more abstract notions of SMOP. This then gives a foundation for defining more general behavioural aspects of performance from derivable mathematical/statistical actions on such performance measures and conditions under which such aspects are appropriately represented. These notions of aspects and the respective associated conditions can aid in the categorisation and classification of SMOP types to deliver a more consistent framework.

In our presentation we then describe a few aspects of the SMOP framework and illustrate its strengths by applying it to a *simple stochastic multi-component repair model* which behaves as a Markovian queuing system with performance measures having binomial and extended regularised beta distributions. We discuss the suitability of the performance measure distributions and the justification for obtaining particular aspects of this measure. The presentation as a whole gives an example of how a functional approach to SMOP can be used to derive results that are not overly complex but abstract in nature and easily identifiable for SMOP comparisons.
The aim of this research into repair models is to give insights into

- Conditions for building a *consistent framework* for SMOP;
- Model development that at the onset builds in a notion of consistency rather than ad-hocery in SMOP development;
- Aspect generation for performance measurement and conditions on model and behaviour for the justification of the association of such aspects;
- Exploration of repair processes, in particular when they involve large-scale Defence systems; and
- Applications for Defence OR, particularly for repair/refurbishment queuing models.

Transport

40 *Optimising Container Process At Multimodal Container Terminals*
Andy Wong and Erhan Kozan

Multimodal terminals are important facilities in the container transport network and due to the dynamic nature of the environment a large number of timely decisions have to be continuously reviewed in accordance with the changing conditions of the system. Numerous factors can affect throughput in such highly integrated systems. These include numbers and types of equipment, physical layout, storage capacity and operating strategies. This study aims to improve operating strategies by developing an analytical model to assist container transfers at multimodal terminals. The model is solved using meta-heuristic techniques in a reasonable time window. A numerical investigation is provided and shows that high quality solutions may be obtained.

Keywords: *Transportation, Scheduling, Optimisation*

41 *Analysis of Sydney Public-Private Partnership Road Tunnels*

Geoff Phillips

The Sydney Cross City Tunnel and the Lane Cove Tunnel have generated controversy both before and since their completion. Despite the amount of public discussion, there has been very little in the way of objective analysis of the costs and benefits of these projects. This paper investigates the relationship between the toll price level, usage level and public benefit. Because of experiments with toll-free periods and various toll levels, there is information about price elasticity of demand, which can be used to make predictions about the financial viability of these tunnels and about the costs and benefits to the public of the tunnel projects. Parliamentary inquiries into the two tunnel projects provide historical and financial information in a usable form to assist the analysis. The failure of the tunnel projects to meet the requirements of Pareto optimisation is described.

42 *Equilibrium and network optimization for airline market*

Amir Joshan (Auckland)

In this article we present a game where two airlines compete over a time horizon and try to optimize their revenue by setting their prices and releasing an appropriate quantity of seats in the market. We assume airlines have differentiated products and as a result each observes a unique demand function. We assume such demand functions can be affected by the competitor's prices for a similar product. We will discuss equilibrium issues for such a model and conditions under which it is strategically beneficial for an airline to expand its operating network.

Key words: Competitive pricing, Revenue management, Game theory, Perishable asset, Airline network structure.

General Operations Research

43 *Inventory Policy Optimisation in a Small Chemical Company*

Rodolfo Garcia-Flores

In this presentation, the development of a project intended to improve inventory handling in a small chemical company will be described. Issues like intermittency in demand , shelf life and seasonality were of concern to management. As part of the preliminary analysis, current practices were examined, and important information was extracted from the company's historical records.

Using this information, a scheme was proposed for classifying stock keeping units (SKUs) and tuning the parameters of a continuous review inventory policy in order to minimise costs while simultaneously keeping the service level. Actual savings obtained after implementing the suggested changes demonstrate the effectiveness of the new decision policy.

44 *Multi-Period Equipment Selection with a utilised Cost Objective*

Christina Burt and Louis Cacetta

When performing equipment selection, the cost of the equipment can be best accounted for by the utilised hours of the equipment. In a surface mine, equipment is often under-utilised and not accounting for this difference may lead to vastly different solutions. The co-dependency of the age of the equipment and the utilisation has provided a barrier to tractable models. We present a mixed integer linear programming model that achieves optimal equipment selection while accounting for equipment utilisation. In this model we also allow for pre-existing equipment and heterogenous fleets; and account for the subsequent compatibility issues that arise.

45 *Utility Functions Estimation and partial equilibrium modelling in economics*

Andrew Eberhard

In the household consumption formulations of CGE modelling a utility function is usually se-lected a priori without taking into consideration the detailed structure of preferences for goods and services. The most commonly used functional forms are the Cobb-Douglas and CES utility functions. Only relative few parameters of these functions are estimated using the real data on consumer preferences, raising questions as to their representativeness. This talk we out-lines a method via which a purpose built utility function is derived based on real consumer demand data. The method best fits utility from the class studied by (Afriat, 1967) and is based on revealed preference theory. Such methods can only work exactly if the Generalised Axiom of Revealed Preference (GARP) holds. Consequently a non-linear best fit optimisation algorithm is devised to find the minimum residuals that allow the GARP to hold and hence an Afriat like utility to be fitted.

As all CGE algorithms are based on a best estimate of the current state of the economy provided by the input-output table. These values maximise the underlying (real) utility subject to the budget constraint. Thus we impose additional constraints to ensure the equilibrium of the fitted utility exists and coincides with the entries in the input-output tables. Thus we arrive at a mathematical program with equilibrium constraints. We utilise a mathematical trick that allows us to formulate and solve our MPEC as a standard nonlinear programming problem for some test data sets.

46 *2-Period Convex Hull Closures For Big-Bucket Production Planning Problems*

Kerem Akartunali and Andrew J. Miller

Since the seminal paper of Wagner and Whitin [1958], various forms of production planning problems have been studied by researchers and practitioners. Although important results have been accomplished throughout years, results have been limited for the multi-level, multi-item problems with big bucket capacities. We present a new methodology to generate valid inequalities based on the convex hull closure of the 2-

period subproblems, which may be the simplest model that captures the basis of the difficulty of these problems. The proposed technique uses duality theory and does not need any predefined inequalities. However, one of the objectives of this study is to identify such inequalities. Computational results indicate that these two period closures improve lower bounds significantly.

47 *Optimizing Infrastructure under Uncertainty*

Kim Levy

We consider the problem of optimizing the rate (number of units/stage) and capacity of extraction for a finite stack of pure mineral. The extraction cost function is assumed to be linear. When the preferred number of units to be extracted exceeds the current capacity, the infrastructure must be modified which incurs extra costs. Because the stack is composed of pure mineral, the generated revenue is simply the asset price multiplied by the number of units extracted. As the price fluctuates, the optimal rate and capacity of extraction at any given stage also change. Solving a discrete version of the problem or using numerical approximations leads to large computational time and imprecisions. We introduce threshold policies and explain how they can improve problem solving for large state spaces with characteristic structures. The challenge is to show that the optimal policy is in fact a threshold policy and to use stochastic approximation (based on sample path estimations of the gradient) to optimize the price thresholds which determine when the optimal decision suddenly changes.

48 *Nature Inspired Computing in Supply-Chain Management*

Baikunth Nath

The supply chain of both manufacturing and commercial enterprises comprises a highly distributed environment, in which complex processes including materials procurement and storage, production, warehousing, sales and distribution; evolve in a network of companies. In this environment there are strong interactions of multiple entities, processes and data. Nature inspired computing offers effective tools for modeling and managing operations in the uncertain environment of supply chain, especially since the associated computational techniques are capable of handling complex interdependencies. These techniques therefore may be the basis for the development of optimal methods and systems that integrate effectively the various objectives of the supply chain. In this paper, we present applications of artificial neural networks, a major technique of nature inspired computing, in the supply chain management. Specifically we consider a real-time distribution management supply chain problem and using clustering achieve effective reduction in the complexity of the problem.

49 *Re-considering the route management of a large passenger vessel company (in Indonesia)*

Peter Serhalawan

Management of a large passenger shipping company in Indonesia felt that financial performance of the firm could be improved. The author's firm NFS was hired to develop a mathematical model to analyse whether efficiency improvements were possible.

Based on assessment, consultants formulated a number of decision problems to which appropriate answers were required. These questions include
a) What is the optimal fleet size and which vessel capacity needs to be employed on the various routes?
b) Which are the home base ports within Indonesia for the different vessels?
c) Which routes need to be included in the network to satisfy demand?
d) How much subsidy should be granted by the government in order to meet all passenger demand?

A mixed integer formulation was solved using branch and bound using a well known solver. The project took 6 weeks and resulted in recommendations on an alternative network. The recommendations have been acknowledged and inmplemented.

50 *An exact method for the minimum cardinality problem in the planning of IMRT*

Andreas T. Ernst, Vicky H. Mak, and Luke A. Mason

Inspired by constraint programming concepts, we introduce an exact method to solve the minimum cardinality problem (MCP) that arise from the treatment planning of intensity-modulated radiotherapy. We compare our method with, as far as we are aware, the only two existing exact methods. It turns out that our method is computationally much more efficient than these two methods.

51 *Optimal radio labellings of complete m-ary trees*

Xiangwen Li, Vicky Mak, Sanming Zhou

A radio labelling of a connected graph G is a mapping f: $V(G) \to \{0, 1, 2, \ldots\}$ such that $|f(u)-f(v)| \geq \mathrm{diam}(G)-d(u, v)+1$ for each pair of distinct vertices u, v in $V(G)$, where $\mathrm{diam}(G)$ is the diameter of G and $d(u, v)$ the distance between u and v. The span of f is defined as $\max_{u, v \in V(G)}|f(u)-f(v)|$, and the radio number of G is the minimum span of a radio labelling of G. A complete m-ary tree ($m \geq 2$) is a rooted tree such that each vertex of degree greater than one has exactly m children and all degree-one vertices are of equal distance (height) to the root. In this paper we determine the radio number of the complete m-ary tree for any $m \geq 2$ with any height and construct explicitly an optimal radio labelling.

Integer Programming

52 *Fifty years of pure integer programming: Review of solution methods and new directions*

Santosh Kumar, Elias Munapo and Brian C. Jones

This paper briefly reviews various approaches that have been developed during the past 50 years for solving the pure integer programs and moves on to discuss new directions in this fascinating field. Recent work is discussed with sufficient details to make it self-contained with regard to motivation for further research.

Key words: Pure integer programs, Cutting plane approaches, Corner Polyhedra, Branch and bound, Additive algorithms, Branch and cut, Branch and price, Interior point hybrids, Lagrange relaxation, Random search, Descending hyper-plane, Characteristic Equations and Characteristic Pure Integer Programs.

53 *Solving intractable MIP problems using Xpress-MP*

Richard Laundy

Over the past decade there has been a huge increase in the performance of commercial MIP codes. This increase in performance combined with the increased performance of computers has resulted in a dramatic increase in the size and complexity of MIPs that can be solved. In this talk we take a look at some of the hardest problems in the MIPLIB test set and show how some problems previously thought to be insoluble can be solved to optimality.

Constraint Programing

54 *Incremental Satisfiability and Implication for UTVPI Constraints*

Andreas Schutt and Peter Stuckey

Unit two-variable-per-inequality (UTVPI) constraints form one of the largest class of integer constraints which are polynomial time solvable (unless P + NP). There is considerable interest in their use for constraint solving, abstract interpretation, spatial databases, and theorem proving. In this paper we develop a new incremental algorithm for UTPVI constraint satisfaction and implication checking that requires $O(m + n \log n + p)$ time and $O(n + m + p)$ space to incrementally check satisfiablity where we have m UTVPI constraints on n variables and check implications of p UTVPI constraints.

55 *Propagation = Lazy Clause Generation*

Olga Ohrimenko , Peter J. Stuckey and Michael Codish

Finite domain propagation solvers effectively represent the possible values of variables by a set of choices which can be naturally modelled as Boolean variables. In this paper we describe how we can mimic a finite domain propagation engine, by mapping propagators into clauses in a SAT solver. This immediately results in strong nogoods for finite domain propagation. But a naive static translation is impractical except in limited cases. We show how we can convert propagators to lazy clause generators for a SAT solver. The resulting system can solve scheduling problems significantly faster than generating the clauses from scratch, or using Satisfiability Modulo Theories solvers with difference logic.

56 *A New Extension of the Support Vector Regression method to Division Algebraic Targets*

Alistair Shilton

Support vector regression (SVR) is a regression technique inspired by Vanik's support vector (SV) formulation for binary classification (SVC). Like Vanik's SVC method, SVRs achieve non-linearity using the so-called kernel trick - that is, they apply a linear regression method in a feature space implicitly defined by a Mercer kernel function. The advantages of the SVR approach over other methods include robustness, lack of non-global minima and sparsity of the result.

In this talk we present an extension of the SVR method to division algebraic (real, complex, quaternionic and octonionic) targets. The cost function of our extension differs from other similar extensions that have been proposed in-so-far as the empirical risk measure depends entirely on the norm of the training errors. We show that the dual formulation of our extension is an "almost" quadratic programming problem that is directly analagous to the standard SVR dual (and equivalent if we restrict ourselves to real targets) and inherits many of it's positive attributes, such as robustness, lack of non-global minima and sparsity of the result. We highlight some of the more interesting features of the dual that make it non-trivial to solve, and give a number of practical examples of the application of our technique.

57 *High-Level Implementation of Consistency Techniques*

Joachim Schimpf

Finding the right balance between strength of consistency and amount of search is often critical for the successful solving of constraint problems. We present some high-level programming techniques, available in the ECLiPSE system, which can be used to implement, or at least prototype, different forms of consistency in a constraint network.

58 *Rule Based Model Transformation : From MiniZinc to MIP*

Sebastian Brand, Gregory Duck and Jakob Puchinger

The last decade has seen a trend towards high-level modelling languages in constraint programming. Languages such as Zinc allow the modeller to state problems in a declarative human-comprehensible way and without having to make subordinate modelling decisions or even to commit to a particular solving approach.

In this paper we describe how we transform high-level models written in the modelling language miniZinc (a subset of Zinc) into mixed integer programming models. The transformations are written in our term-rewriting based model transformation language Cadmium. The rules and transformations are directly accessible to the modeller and thus can be freely adapted. A major strength of Cadmium is its tight integration with the Zinc modelling languages; the rules operate directly on Zinc expressions. As a result, transformations are often very compact and comprehensible.
Our computational experiments, where miniZinc models are transformed into CPLEX LP format, demonstrate the advantages of our system. It allows the user to experiment between different ways of liinearising logical constraints as well as some high-level constraints such as 'all-different'.

Statistical Issues

59 *Purely Sequential Fixed-Width Confidence Bands for Kernel Regression* Estimation

L Dharmesena, B de Silva and P Zeephongsekul

We consider a random design model based on i.i.d. pairs of observations (X_i,Y_i) where the regression function m(x) is given by $m(x) = E(Y_i \mid X_i = x)$ with one independent variable . In a nonparametric setting the aim is to produce a reasonable approximation to the unknown function m(x) when we have no precise information about the form and class of the true density f(x) of X. We describe an estimation procedure of nonparametric regression model at a given point by some appropriately constructed fixed-width (2d) confidence interval with the confidence coefficient of at least $1 - \alpha$. Here d (>0) and $\alpha \in (0,1)$ are two pre-assigned values. These bands are developed using both Nadaraya-Watson and local linear kernel estimators of nonparametric regression with data driven bandwidths. The sample size was optimised using a purely sequential procedure together with asymptotic properties of the Nadaraya-Watson and local linear kernel estimators. A large scale simulation study was performed to compare their coverage accuracy. The numerical results indicate that the confidence bands based on the local linear estimator have the better performance than that of the Nadaraya-Watson estimator. However both estimators are shown to have asymptotically correct coverage properties.

Keywords: Nonparametric regression, Nadaraya-Watson estimator, local linear estimator, fixed-width confidence interval, random design, purely sequential procedure.

60 *Using best root transformation technique to estimation the process capability index for non-normal processes*

S. Z Hosseinifard, M Abdollahian, B Abbas and S Ahmad

Estimating process capability index (PCI) for non-normal processes has been interested by many researches. There are two basic approaches to estimate PCI of non-normal processes: the first commonly used approach is to transform non-normal data to normal using one of the existing transformation techniques and then use the conventional normal method to estimate PCI for transformed data. This is straightforward approach and is easy to deploy. However there is no unique transformation technique that could be fitted to all type of skewed distributions and therefore would lead to PCI estimation that can not accurate. The alternative approach is to fit a appropriate distribution for the skewed data and use percentile methods. The later approach is not easily to implement, consequently is not popular amongst quality practitioners. In this paper we use best root transformation to transform to transform skewed data into normal data and then use the classical method to estimate PCI. Simulation study is presented to assess performance of the proposed method.

Key words: Process capability index, non-normal process, best root transformation, statistical quality control

61 *Non-Normal Process Capability Analysis Using Percentile And Proportion Of Non-Conforming Methods*

Shafiq Ahmad, Babak Abbasi, Mali Abdollahian, Panlop Zeephongsekul

Researchers across many disciplines have worked out several modifications of the traditional process capability measures (Cp, Cpk) to obtain better estimates of the products in the processes. However, these conventional capability measures heavily depend upon the theory of normality.

In this paper, we review some of the latest proposed PCI methods such as Burr percentile, Castagliola's (CDF) methods with commonly used Clements percentile method when the underlying distribution is non-normal. A simulation study using Gamma, Weibull and Beta distributions is conducted and the comparison of the results is presented. Finally, a case study is presented using the actual data from a manufacturing process.

Key words: Process Capability Index (PCI), Proportion of nonconforming in non-normal process, CDF method, Quantile based capability indices.

62 *An OR Modelling View of Six-Sigma*

Harry Gielewski

Operations Research (OR) lives in a parallel universe to Six Sigma. Practitioners from either world would quickly recognise very similar methodologies to the development of managerial solutions to decision-making problems. Whilst OR, as an

approach, has been used for over 60 years with many notable successes there is much that it can learn from Six Sigma's way of doing business.

Six Sigma has a team focus to problem solving, much as OR did in its early days, and a great deal of effort is invested in team tools and in creating an environment for teams to function effectively. In contrast, OR evolved into a consultant relationship with clients with a focus on the final report leading to possible implementation. The implementation phase has never been a strong point of OR projects since they often lacked a clear commitment toward implementation that the work team approach creates.

In contrast, OR makes modelling the centre point of its methodology. Judicious use of OR models can create the breakthrough in Six Sigma projects that have hit the brick walls of complexity or too much data. Properly constructed models also act as knowledge stores that allow the accumulation of knowledge properly weighted by relevance. 'What if' analyses can then be conducted to create even greater knowledge.

This presentation will be illustrated with case studies from Mental Health, the Supply Chain and Airline Travel.