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## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Metaheuristics</td>
<td>2</td>
</tr>
<tr>
<td>Hyper-heuristics</td>
<td>3</td>
</tr>
<tr>
<td>Multiobjective Decision Making</td>
<td>4</td>
</tr>
<tr>
<td>Fuzzy Reasoning</td>
<td>5</td>
</tr>
<tr>
<td>Case-Based Reasoning</td>
<td>6</td>
</tr>
<tr>
<td>Adaptive Learning and Co-Evolution</td>
<td>7</td>
</tr>
<tr>
<td>Timetabling and eventMAP Ltd</td>
<td>8</td>
</tr>
<tr>
<td>Cutting and Packing</td>
<td>9</td>
</tr>
<tr>
<td>Personnel Rostering</td>
<td>10</td>
</tr>
<tr>
<td>Production Scheduling</td>
<td>11</td>
</tr>
<tr>
<td>Aircraft Scheduling</td>
<td>12</td>
</tr>
<tr>
<td>Inter-disciplinary Optimisation Laboratory</td>
<td>13</td>
</tr>
<tr>
<td>Medical Applications</td>
<td>14</td>
</tr>
<tr>
<td>Bioinformatics</td>
<td>15</td>
</tr>
<tr>
<td>Inter-disciplinary Scheduling Network</td>
<td>16</td>
</tr>
<tr>
<td>Publications</td>
<td>17</td>
</tr>
<tr>
<td>External Research Awards</td>
<td>22</td>
</tr>
<tr>
<td>Professional Activities</td>
<td>24</td>
</tr>
<tr>
<td>Contact Details</td>
<td>28</td>
</tr>
<tr>
<td>ASAP Personnel</td>
<td>29</td>
</tr>
<tr>
<td>How to Find Us</td>
<td>32</td>
</tr>
</tbody>
</table>

## Introduction

The Automated Scheduling, Optimisation and Planning (ASAP) Research Group is one of four main research groupings within the School of Computer Science and IT at the University of Nottingham. The School obtained a grade 5 in the 2001 Research Assessment Exercise. The ASAP group has expanded considerably since our last report (1999 – 2000). We have grown from four permanent members of academic staff at the end of 2000 to five members of staff and an Industrial Fellow at the end of 2002. In the same period, the number of research assistants within the group has doubled from four to eight and the number of PhD students has risen from 12 to 24.

One of the main themes of the ASAP group’s research strategy is to investigate and develop decision support technology that is capable of dealing with the ever increasing complexity of real world problems across a wide range of applications. Over the 2001 – 2002 period, we have expanded into new research areas, such as fuzzy expert systems and fuzzy / multiobjective scheduling approaches. We have also moved into important new application areas such as aircraft scheduling (page 12), neonatal assessment (page 14) and supermarket shelf space allocation (page 9).

These new application areas complement the wide range of applications that the ASAP group has been addressing for a number of years. Many of our recent advances in these applications are discussed in this report.

Another of our major research themes over the last few years has been raising the level of generality at which optimisation systems can operate. Since 2000, we have made significant advances in this area. This progress has been primarily in the areas of Hyper-heuristics (page 3) and Case-Based Reasoning (page 6).

The ASAP group currently holds 15 research council awards (from EPSRC, ESRC and BBSRC) in addition to a Teaching Company Directorate award. These 16 awards represent over £1.9M of external funding. The group also holds several PhD studentships funded by overseas governments and several internally awarded PhD studentships. Since 2000, ASAP has published (or is about to publish) 15 journal papers and 54 refereed conference papers. In addition, the group has played a major editorial role in leading international journals and conferences. This report outlines the group’s main research activity over the 2001 – 2002 period.
Hyper-heuristics

Since ASAP’s formation in 1996, the investigation of metaheuristic methods has played a major role in our research strategy. We continue to use and explore metaheuristics (and hybrids) to solve a wide range of complex real world problems. The main metaheuristic methods we employ are briefly described below.

Simulated Annealing: Hill Climbing is a very simple approach that always takes the best solution it can find until it finds no better solution in its neighbourhood. The major drawback with it is that it easily gets stuck in local optima. Simulated Annealing is, essentially, a hill climbing algorithm that can accept lower quality solutions in order to escape from local optima. It will accept worse solutions according to a given probability which gets lower as the processing time gets longer. The lowering of this probability can be thought of as cooling because the approach was originally motivated by thermodynamic principles.

Tabu Search: This approach is similar (in a certain sense) to Simulated Annealing. It is also based upon Hill Climbing and has a mechanism to escape from local optima. The basic approach employs a tabu list where certain moves are prohibited for a certain number of iterations.

Evolutionary Algorithms: The group is carrying out innovative research into a broad range of evolutionary methods such as Genetic Algorithms, Genetic Programming and Memetic Algorithms. Genetic Algorithms are motivated by the evolutionary process in the sense that a population of solutions is maintained and the population evolves according to ‘survival of the fittest’.

Genetic Programming draws on similar motivation but the population consists of programs rather than solutions. A Memetic Algorithm can be thought of as a hybridisation of a population based approach and a local search approach (such as Hill Climbing, Tabu Search or Simulated Annealing). The basic idea is that the local search algorithm is applied to each member of the population before the next generation is produced.

Swarm Optimisation Algorithms: These approaches mimic the way that animals, birds and insects collectively solve tasks. They are characterised by the emergence of group behaviour from simple individual actions. Perhaps the most often seen example of this type of behaviour is the way that birds flock together. Ant Algorithms are a well known example of this type of approach being employed as an optimisation technique. This method draws its inspiration from the way that ants forage for food.

Variable Neighbourhood Search: Local search methods tend to use the same neighbourhood structure throughout the search process. Variable Neighbourhood Search allows this structure to change as the search progresses.

ASAP’s work is concerned with solving real world problems and this often involves hybridisations of metaheuristics with other metaheuristics and with problem specific heuristics. The metaheuristics described here also play a major role in some of the methods that are presented elsewhere in this report (such as Hyper-heuristics, Case-Based Reasoning and Fuzzy Systems).

Hyper-heuristics

Hyper-heuristics can be defined to be heuristics (or other methods) to choose heuristics. One of the motivations behind the investigation of such approaches is to raise the level of generality at which optimisation systems can operate. The current state of the art in optimisation methodology tends to rely very heavily upon problem specific information and heuristics. The development of such problem specific approaches is expensive and resource intensive. There are, of course, many situations where it is critical to generate the best possible solution. However, in many real world situations, a company or institution does not require close-to-optimal solutions. Often, solutions that are “good enough – soon enough – cheap enough” are all that is required.

The overall strategy of hyper-heuristic research is far reaching and includes investigating the reduction of the number of parameters that optimisation systems require and the role of adaptive learning in such systems. We are also investigating Case-Based Reasoning within the context of heuristic selection.

Several of ASAP’s externally funded projects are concerned with hyper-heuristic development. One of our main EPSRC projects in this area is entitled, “An Investigation of Hyper-Heuristic Methods” (GR/N36837/01) and is held jointly with Prof Peter Ross of Napier University. The overall hyper-heuristic theme also runs through two more of our major EPSRC grants (GR/N36837/01, GR/M95516/01) and our ESRC/EPSRC grant (L328253012). More details about the area can be seen in our chapter entitled “Hyperheuristics: An Emerging Direction in Modern Search Technology” in The Handbook of Metaheuristics, published by Kluwer in 2003.

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**Multiobjective Decision Making**

The quality of solutions to scheduling, timetabling and other optimisation problems can be assessed from various points of view with respect to very different constraints and requirements that are imposed upon the problem. Multiobjective Decision Making methods enable constraints of a fundamentally different nature to be handled simultaneously and enable the system/user to make an appropriate compromise between them according to the regulations and requirements of the particular problem in hand.

ASAP has been investigating multiobjective approaches to university timetabling problems. A multiobjective method based on compromise programming has been developed. We have also investigated the integration of multicriteria approaches with metaheuristic methods for timetabling. The ASAP group has developed an examination timetabling algorithm which produces the best known results on most of the standard benchmark problems and out-performs the results of conventional multiobjective weighted sum methods.

**Fuzzy Reasoning**

The real world is characterised by uncertainty in many different forms: physical measurements may be inaccurate, human knowledge may be vague or incomplete, database records may be incorrect or missing, etc. When modelling the real world, therefore, we can either ignore such uncertainties or we can attempt to represent them and build them into our models. Many frameworks for handling uncertainty have been formulated, from long established techniques such as probability theory to relatively more recent developments built upon fuzzy logic.

Since its original inception, fuzzy logic has been expanded to a complete framework for handling all forms of uncertainty. Mechanisms have been created for inferencing or reasoning within this framework of uncertainty handling. The process of taking a specific application and creating the required data representations, inferencing rules and processing mechanisms is termed fuzzy modelling. Invariably there are many internal parameters in such a model which need to be optimised to ensure that the automated reasoning process best matches the real world. The ASAP group is investigating fuzzy reasoning methods in a variety of contexts.

Fuzzy reasoning is being explored for multiobjective production scheduling and rescheduling under uncertainty in a major EPSRC grant (GR/R95319/01) that is held jointly with the Control Theory and Applications Centre at Coventry. Two major problems are encountered when applying conventional scheduling theory to the real world. Firstly, parameters such as processing times and due times are often very uncertain. Secondly, in the real world, machines can fail or jobs can be cancelled. New jobs can arrive that have a high priority. Human schedulers have to handle such uncertainty to produce dynamic working schedules. In addition they often have to weigh up several conflicting objectives in deciding which schedules are ‘best’. The aim of this project is to establish more sophisticated scheduling algorithms and models required for uncertain multiobjective scheduling and rescheduling.

Another major EPSRC project (GR/R55085/02) is concerned with the development of automated decision making systems which are motivated by observations about the decisions that human experts make. Human decision making is not only characterised by reasoning under uncertainty, but also by the fact that different decisions may be reached by the same person at different times, even when faced with the same data. Such human inconsistency has previously been ignored and, indeed, positively avoided in automated reasoning. This project will undertake an adventurous ‘blue-sky’ investigation into the techniques required to incorporate such inconsistency into the automated decision making process and to assess whether this might in fact be beneficial in certain circumstances.
Case-Based Reasoning

Case-based reasoning is an artificial intelligence methodology based on the observation that human reasoning processes often employ specific experience rather than a set of general guidelines or first principles. In order to utilise past experience, the way that experts solve actual problems can be memorised as a collection of cases. The memorised cases are organised in a case base and utilised for solving new problems. The overall idea is that when the system is presented with a new problem, it searches the case base to find similar problems and their solutions. The retrieval of relevant previous cases is crucial to the success of a Case-Based Reasoning system. The usefulness of previous cases is determined by assessing the similarity of a new problem with the previous cases and the assessment of this similarity is a critical research issue.

ASAP has successfully developed Case-Based Reasoning approaches for educational timetabling and personnel rostering. We have employed case based reasoning in the following ways:

(a) Solution Re-use: The most similar timetabling problem is retrieved from the case base and its solution is adapted to meet the requirements of the new timetabling problem.

(b) Repair Re-use: Previously encountered constraint violations and their corresponding repairs are used to solve new personnel rostering problems. EPSRC (GR/N35205/01) has funded this research which is being carried out in collaboration with Queen’s Medical Centre and the School of Nursing within the University of Nottingham.

(c) Methodology/Heuristic Re-use: This work is motivated by the attempt to raise the level of generality of existing heuristic methods. The overall idea is that the case based reasoning system will choose heuristics that worked well on previous similar problems. We have a major EPSRC grant (GR/M95516/01) to investigate Case-Based Reasoning for methodology re-use for timetabling problems.

Adaptive Learning and Co-Evolution

Adaptive learning is a broad term which essentially refers to computational methods which can adapt to the particular circumstances of the particular problem that they are trying to solve. Co-evolution refers to techniques where different entities evolve in a co-operative or competitive environment.

The ASAP group has recently investigated and employed an adaptive learning approach to evolve a chess player that is able to beat the person who wrote the program. The main point about such methods is that domain specific knowledge is not hard coded into the program. Instead, the program learns how to play the game. We have also used co-evolutionary/adaptive approaches to develop other game playing programs (to play Awari, Poker and Cribbage).

We are also experimenting with computational methods for games of imperfect information and games where the environment changes as the game progresses. For example, we are exploring evolving agents which have to develop strategies in order to escape from a maze. However, the structure of the landscape is constantly changing and the agents have to update their strategies to cope with this change.

We are also investigating the evolution of trading agents to advise on stock market transactions. Each agent, using a neural network evolved via a genetic algorithm, decides whether to buy, sell or hold a given share. At regular intervals the best strategies are written to a central pool which can be used by the agents which are not performing very well, to replace their current strategy.

ASAP is investigating machine learning approaches for Go which is acknowledged to be a more challenging game than Chess. In 1997 a computer program (Deep Blue) beat the then world chess champion, Garry Kasparov. A similar computational achievement for Go does not seem likely in the foreseeable future. Current ASAP work is concentrating upon a reduced version of the board and future research directions are likely to concentrate on identifying the important board areas so that search techniques are more likely to find good solutions.

Kristian Spoerer (PhD Student)
Timetabling

The ASAP group has been working in timetabling research for many years and is internationally recognised for its work in the area. Since the 1999 – 2000 report, the group has achieved significant progress in developing adaptive systems to deal with timetabling. The group has also recently developed an examination timetabling system (based upon the Great Deluge Algorithm) which has produced results that are better than any of the currently published results on benchmark problems. We have also made significant progress in case based timetabling. See page 6 for more details about this work.

Since 2000, ASAP has continued to play a major role in the international timetabling community. We play a leading role in the organisation of the international series of conferences on the Practice and Theory of Automated Timetabling (PATAT). Previous PATAT conferences were held in Edinburgh (1995), Toronto (1997), Konstanz (2000) and Gent (2002). The next one will be held in Pittsburgh in 2004. Springer publishes a volume of selected papers for each conference. More details about PATAT can be seen at http://www.asap.cs.nott.ac.uk/patat/patat-index.shtml. The ASAP group has also continued to play a major role in the EURO (European Association of Operational Research Societies) Working group on Automated TimeTabling (WATT) which has over 300 members from over 60 countries [see http://www.asap.cs.nott.ac.uk/watt/index.html].

Two members of the group (Prof Burke and Dr Petrovic) have acted as guest editors of a feature issue of the European Journal of Operational Research on “Timetabling and Rostering” which will appear in July 2004 as issue 156/2.

eventMAP Ltd

During the last two years, the ASAP group has been instrumental in the formation of a spin off company (eventMAP Ltd) which deals in software for higher education (building on our research for intelligent timetabling systems). The company is currently marketing an examination timetabling system (called Optime) that was originated and developed within the ASAP group.

The Optime system has been commercially implemented in institutions in the UK, France, Australia, New Zealand and the USA, and a lecture scheduling system is currently being developed by eventMAP Ltd. Research results from ASAP are feeding into eventMAP’s commercial development and commercial expertise and experience from the company is feeding back into the research group. Two members of the ASAP group (Prof Burke and Dr Kendall) are playing a key role in this company and the University of Nottingham is a shareholder.

Cutting and Packing

Cutting and packing problems appear in many guises across many applications. A simple illustrative example is the task of cutting out a number of 2-dimensional shapes from a larger shape with the goal of minimising the waste. A variation is that the problem can be 1-dimensional (e.g. cutting lengths of steel rods) or 3-dimensional (e.g. loading pallets with a given number of boxes). The problem may also be expressed in terms of the requirements of a particular user in a particular situation.

An EPSRC funded project (“Applying meta-heuristics and hyper-heuristics to stock cutting”; CNA 00802329) is developing new heuristics to pack shapes. This project is supported by Esprit Automation Ltd and has resulted in the best reported results on a range of benchmark problems for packing rectangles and polygons. This award is being carried out in conjunction with a project funded by the Teaching Company Directorate (“New Approaches to Produce Efficient Nesting Patterns”: TCS 3047) which is incorporating the latest research techniques into existing commercial software and which is also supported by Esprit Automation Ltd.

One aim of the project is to improve the quality of the solutions produced when minimising the amount of waste. However, another key aim is to allow the user to have more control over the optimisation process. For example, while minimisation of waste is always important, in certain situations a cutting plan is required instantaneously (for example on a factory floor while other related production processes are taking place). In such situations, the search algorithm has to perform as well as possible in the time available to it. On the other hand, there are situations where the material is extremely expensive and where the situation allows the user to run the computer for a long time in order to find very high quality very low waste solutions (over the weekend, for example). These two examples are, of course, extremes and we are experimenting with allowing the user to use a simple slider to choose a trade off between computational time and quality of solution.

We are also experimenting with providing the user with the ability to stop the optimisation process and to interact with it (e.g. make some improvements, fix the position of certain shapes, etc.) before allowing the automated optimisation process to continue.

The Optime Examination Timetabling Software is Commercially Available through eventMAP Ltd. (http://www.eventmaponline.com)

We have been awarded an EPSRC grant (“An Investigation of Novel Methods for Optimising Shelf Space Allocation”; GR/R60577/01) to investigate automated approaches for supermarket shelf packing. This work is supported by Tesco (the UK’s largest supermarket) as well as a software development company (Space IT) and a retail consultancy company (Retail Vision).
Personnel Rostering

Recent years have seen an increased recognition of the importance of developing intelligent decision support systems for personnel scheduling, particularly in healthcare. The need to ensure adequate numbers of personnel with an adequate skill mix in order to maintain an appropriate standard of healthcare is a critical issue. For nurse scheduling, there is an absolute requirement to maintain 24 hour cover and high quality schedules should take into account resource utilisation, patient care and the preferences of personnel. The development of automated methods which can handle the wide variety of requirements that are generated by real world problems is a challenging research issue.

The ASAP group has been awarded two research grants (GR/N35205/01 and GR/S31150/01) in this area. The first of these grants is investigating Case-Based Reasoning for nurse rostering. The second of these grants has a wider application remit and is investigating novel metaheuristic approaches for the scheduling of doctors and nurses, and of clinics. These projects involve a number of UK and internationally leading research / commercial collaborators which include:

- The Queen’s Medical Centre, Nottingham
- The School of Nursing from the University of Nottingham
- The Intelligent Systems group from KaHo St.-Lieven (Belgium) who have carried out research into nurse rostering together with ASAP for several years
- ORTEC, a consultancy company from The Netherlands that has commercial interest in healthcare administration
- GOAL (UK), a software development company that produces optimisation/scheduling systems.

Our research work on hybrid tabu search with KaHo St.-Lieven has provided the basis of a commercial package Plane which has been deployed in more than 40 hospitals in Belgium.

Production Scheduling

Effective and efficient production scheduling is essential to modern production/manufacturing organisations. Scheduling processes are typically described by various temporal relations, resource requirements and capacity constraints, which involve a wide range of parameters such as job release dates, processing times, due dates, priorities of jobs and machine setup times. One area of production scheduling in which ASAP is involved is producing printed circuit board (PCB) assembly schedules. Given a number of components to mount on a PCB, how can we generate a schedule that does this as efficiently as possible?

Underlying almost all real production systems are activities that are fraught with uncertainties, and this often prevents the results of deterministic scheduling theory (which are rigid and assume ideal situations) from being applied to real world problems. A further challenging research issue is highlighted by noting that in most real-life modern environments, scheduling is an ongoing process where circumstances in both external business environments and in internal production environments may change dynamically. In order to ensure high customer service level and high profitability, there is a need to dynamically respond to disturbances such as machine breakdowns, delays in the arrival of materials, the arrival of rush orders, changes in orders, etc. Despite over 40 years of production scheduling research, there is still a gap between the theory and the practice.

The ASAP group aims to contribute towards bridging this gap by addressing three important themes:

1. Treating various types of uncertainty that exist in scheduling problems by investigating fuzzy based techniques.
2. Considering multiple criteria which describe various performance measures of schedules.
3. Investigating new fuzzy multicriteria rescheduling methods to respond to various disruptions that can occur in real manufacturing environments.

The ASAP group has a large inter-institutional EPSRC grant (GR/R95319/01) to explore these issues. The grant is held jointly with the Control Theory and Applications Centre (Coventry). The project is being supported by two industrial collaborators, Sherwood Press Ltd and Denby Pottery Company Ltd.
Aircraft Scheduling

The ASAP group has recently been awarded an EPSRC Case award to investigate metaheuristic approaches to airport runway scheduling. The project has been awarded through the Smith Institute for Industrial Mathematics & System Engineering and is being supported by National Air Traffic Services (NATS) Ltd.

Efficient runway scheduling is of significant importance for air traffic control. The project will look at airports across the UK, but will specifically concentrate upon data from Heathrow Airport. One of the major issues that has to be tackled is the dynamic and constantly changing nature of the aircraft traffic situation. This project is investigating hybrid metaheuristic reasoning in an attempt to handle the complexity that is inherent in the problem. In addition to easing the day to day bottleneck on airport runways, success in this project would also allow airports to have greater control over downstream trajectory planning and produce schedules more likely to meet the preferences of airlines.

In addition to our work on runway scheduling, the ASAP group is collaborating with KLM airlines to investigate their fleet scheduling problem. One of the main issues facing KLM is the problem of generating robust schedules that can absorb the effect of delays to single aircraft without leading to significant knock-on effects that could delay large sections of the fleet. It is easy to generate robust schedules by introducing large amounts of idle time between flights. Then, if a flight is delayed, it is the idle time that is used up rather than delaying the start of the next flight. The difficulty is that idle aircraft represent a significant expense to an airline. The goal is to generate schedules that provide an adequate and effective balance between robustness and cost. The ASAP group is working with KLM airlines to investigate novel approaches to solving the problem.

Runway Scheduling Commences when an Aircraft is ‘Pushed-Back’ from the Terminal

The Goal is Robust Schedules with no Delays

Inter-disciplinary Optimisation Laboratory

The Inter-disciplinary Optimisation Laboratory was established by the University of Nottingham in 2000. The lab involves researchers from 7 Schools who represent a variety of diverse scientific disciplines (Computer Science, Chemistry, Psychology, Clinical Sciences, Manufacturing, Mathematics and Nursing). The main aim of the lab is to provide an infrastructure and focus for a wide range of multi-disciplinary research themes that are being carried out by the ASAP group. It is currently funded to the value of over £850K from a variety of sources including BBSRC, ESRC, and 3 different programmes within EPSRC (Computer Science & IT, Engineering and Mathematics).

However, the laboratory’s remit is not limited to the University of Nottingham (or indeed to the UK). The lab supports the EPSRC funded Inter-disciplinary Scheduling Network (see page 16) which has over 70 members from over 40 institutions (both academic and commercial).

In addition, the laboratory was awarded a Visiting Fellowship from the EPSRC Mathematics programme to support research collaboration between ASAP and Professor Moshe Dror of the Department of Management Information Systems at the University of Arizona. The major externally funded projects that are being carried out within the laboratory are:

- The EPSRC Inter-disciplinary Scheduling Network - EPSRC grant GR/R12268/01 from the Computer Science & IT programme.
- Representational Design Principles to Humanise Automated Systems – ESRC/EPSRC grant L328503021 funded under the People at the Centre of Communication and Information Technologies (PACCT) programme.
- Case Based Reasoning in Personnel Rostering – EPSRC grant GR/N35205/01 from the Computer Science & IT programme (with the School of Nursing).
- Fuzzy Scheduling and Re-scheduling in Uncertain Environments – EPSRC grant GR/R95319/01 from the Engineering programme.
- An Investigation into Non-deterministic Fuzzy Reasoning – EPSRC grant GR/R5085/02 from the Computer Science & IT programme (with the School of Clinical Sciences).
- The Role of Duality in Scheduling – A Visiting Fellowship – EPSRC grant GR/S07124/01 from the Mathematics programme.

The laboratory has been successful in attracting a large inter-institutional grant (£420K in total) with Coventry University (awarded by the EPSRC Engineering programme).
Medical Applications

Clinicians often have to make difficult (and sometimes life-threatening) decisions in the light of uncertain data and knowledge. A major facet of modern medicine is the ever increasing quantity of data that is available to clinicians. In many ways, this makes the process of reaching the right decision more difficult and time consuming. Medical decision support systems aim to assist clinicians in reaching the best decision in light of the available evidence.

Many methodologies can be used to create decision support systems and fuzzy techniques have been shown to be particularly suitable for modelling the uncertainties present in the domain. However, the creation of fuzzy models of expertise is a difficult task and the process of attempting to optimise such models to give the best performance is even more difficult. The ASAP group has always been interested in optimisation in its most general sense and this particularly extends to the optimisation of models of automated data interpretation and decision making.

Bioinformatics

The ASAP group is exploiting an exciting multi-disciplinary synergy with the School of Chemistry (within the Inter-disciplinary Optimisation Laboratory). The group is working closely with Dr Jonathan Hirst and the Computational Chemistry Research Group to investigate novel meta-heuristic and hybrid approaches to solve representations of protein folding problems.

The ASAP group is also investigating the analysis of potentially cancerous cells for automated cervical cancer screening. The routine screening of women for the onset of cervical cancer has been carried out for several years in the UK and elsewhere. However, visual inspection of slides under a microscope is a difficult, time-consuming and tedious task that is prone to error. A technique known as Fourier transform infrared (FTIR) spectroscopy has the capacity to automate the process of detecting cancerous cells without the need for visual inspection, but models for accurate interpretation of the data have yet to be formulated. ASAP is working with members of the Interdisciplinary Optimisation Laboratory to develop and optimise fuzzy models of analysis to address this demanding research challenge.

Folding a protein sequence to its three-dimensional structure, from first principles, is one of the most difficult research challenges currently facing bioinformatics. We are carrying out a far reaching investigation into the modelling of this demanding problem and exploring how metaheuristics can be developed and employed to produce high quality solutions. We aim to develop methods to map real proteins onto the models and to apply and evaluate the developed strategies in the real world. This work is currently being funded by BBSRC and EPSRC under the Bioinformatics initiative (Ref: 42/BIO14458). A successful outcome to this project could bring significant pharmaceutical benefits. Protein structure prediction in the post-genome era is set to play a major role within the pharmaceutical industry and will have a major impact upon the development of new drugs.

One of our EPSRC projects (GR/55085/02) is concerned with the analysis and interpretation of umbilical cord acid-base balance for neonatal assessment. This analysis is carried out on blood drawn from the umbilical cord of newly born infants and can provide an objective indication of the health of the infant at the moment of birth, but such analysis is difficult and requires significant expertise. We are developing and investigating novel fuzzy models to capture the knowledge and experience of experts in carrying out this challenging task.

FTIR Spectra of Tumour and Non-Tumour Cells

A 19 Residue Lattice Protein

Yuri Bykov (Research Associate)

ASAP and the School of Chemistry are also exploring ways of exploiting recent advances in metaheuristic technology for parallel synthesis (the automated production of collections of chemical compounds). Metaheuristic and hybrid optimisation techniques could lead to more efficient approaches for the discovery of new catalysts.

We are also currently investigating applying our techniques to emerging bioinformatics fields such as analysis of complex post-genomic data sets.
Inter-disciplinary Scheduling Network

The Inter-disciplinary Scheduling Network (ISN) is supported by EPSRC grant GR/R12268/01. The ISN is a UK wide network which has over 70 members from over 40 institutions (both academic and commercial). Its main aim is to provide a national foundation and infrastructure to support major new inter-disciplinary and inter-institutional approaches for the modelling, optimisation, analysis, implementation and understanding of decision support systems for scheduling. The main objectives are to support:

- The cross-fertilisation of approaches to scheduling from other disciplines.
- The enhancement of the UK’s position as a world leader in scheduling research.
- The hosting of workshops which will help to train the next generation of scheduling researchers.
- Raising the awareness of industry, commerce and the public to the benefits of automated scheduling.
- The formation of an environment where researchers can respond quickly to new opportunities and developments.
- The development of a fundamentally more general approach to scheduling research.
- The integration of other aspects to scheduling such as planning, control distribution and marketing.
- The integration of emerging technologies with industrial and service sector scheduling.
- The creation of a framework in which high risk and high gain research can be carried out.

The network organises a series of multi-disciplinary workshops which have the overall aim of supporting and fostering inter-disciplinary and inter-institutional research in scheduling. Recent workshops have addressed inter-institutional scheduling research funding, transport scheduling and textile scheduling. A particular aim of the network is to support cross-disciplinary collaboration among PhD students working in scheduling and the network hosts a series of PhD student workshops (run by PhD students for PhD students).

Books

- G. Kendall : Co-Editor of Proceedings of the 2003 International Conference on Machine Learning and Applications (ICMLA’03), Los Angeles, USA, to appear, published by AMLA.

Publications

Journals (Editorships / Associate Editorships / Guest Editorships)

- E. Burke : Editor-in-Chief of the Journal of Scheduling (Kluwer).
- E. Burke : Area Editor (for Combinatorial Optimisation) of the Journal of Heuristics (Kluwer).
- E. Burke : Associate Editor of the IEEE Transactions on Evolutionary Computation.
- G. Kendall : Editorial Board Member of the International Journal of Systems Science (Taylor & Francis).
- G. Kendall : Co-Editor of Proceedings of the 2003 International Conference on Machine Learning and Applications (ICMLA’03), Los Angeles, USA, to appear, published by AMLA.
Book Chapters


Journal Papers

In press and to appear


2002


2001


Conference Paper Awards

- D. Ouelhadj, P. Cowling, S. Petrovic, “Utility and Stability Measures for Agent-Based Dynamic Scheduling of Steel Continuous Casting”, accepted for Proc. of IEEE Intl. Conf. on Robotics and Automation, Taipei, Taiwan, Sep 2003. This paper has been selected as one of the five finalists of the Best Student Paper Award.
- E. Burke, S. Gustafson, G. Kendall, “A Survey and Analysis of Diversity Measures in Genetic Programming”, Proc. of Genetic and Evolutionary Computation Conf. 2002 (GECCO 2002), New York, USA. Morgan Kaufmann, pp. 716–23, Jul 2002. This paper was among those nominated for a “Best at GECCO Prize”. Only 31 out of 160 full accepted papers were nominated for the prize.

Refereed Conference Papers

In press and to appear


2002


2001


External Research Awards

Novel Meta-heuristic Research Directions in Healthcare Personnel Rostering (£191,581 from EPSRC; £81,000 from ORTEC; £22,500 from Gower; £3,000 from KaHo)

Funding Body: EPSRC (GR/S31150/01)
Principal Investigator: E.K.Burke
Co-Investigators: S.Petrovic and G.Kendall
Collaborators: ORTEC Consultants BV, Gower Optimal Algorithms Ltd, KaHo St.-Lienie
Awarded: February 2003

Hybrid Meta-heuristic Approaches for Air Traffic Control Scheduling (£40,000 from EPSRC; £21,000 from NATS Ltd)

Funding Body: EPSRC
Principal Investigator: E.K.Burke
Collaborators: National Air Traffic Services (NATS) Ltd.
Awarded: February 2003
Notes: This project is a CASE studentship

Fuzzy Multicriteria Approaches to Scheduling and Rescheduling Problems in Uncertain Environments (£211,593 to Nottingham from EPSRC; £210,743 to Coventry from EPSRC; £70,000 from Denby; £60,000 from Sherwood Press)

Funding Body: EPSRC (GR/R53159/01)
Principal Investigator (Nottingham): S.Petrovic
Principal Investigator (Coventry): D.Petrovic
Collaborators: E.K.Burke, G.Kendall, K.Burnham and C.Reeves
Collaborators: Sherwood Press Ltd and Denby Pottery Company Ltd
Awarded: July 2002
Notes: This is a joint project between the University of Nottingham and Coventry University

An Investigation of Novel Methods for Optimising Shelf Space Allocation (£62,947 from EPSRC; £30,000 from Tesco; £8,800 from Space Software; £8,000 from Retail Vision)

Funding Body: EPSRC (GR/R05777/01)
Principal Investigator: G.Kendall
Co-Investigators: E.K.Burke, P.I.Cowling and S.Petrovic
Collaborators: Tesco Ltd, Space Software Solutions Ltd, Retail Vision
Awarded: July 2002
Notes: This is a CASE project in Science and Engineering for New Academics Award

A Hybrid Meta-heuristic Approach to Simplified Sequence-Structure-Function Problems (£134,844)

Funding Body: BBSRC/IEEPSRC Bios-informatics initiative (2J7014458)
Principal Investigator: J.Hirst (Chemistry)
Co-Investigators: E.K.Burke, P.I.Cowling, G.Kendall and S.Petrovic
Awarded: November 2000
Notes: This is a joint project between the School of Computer Science & IT and the School of Chemistry at the University of Nottingham

An Investigation of Hyperheuristic Methods (£196,343 to Nottingham; £256,547 to Napier)

Funding Body: EPSRC (GR/N68371/01)
Principal Investigator (Nottingham): E.K.Burke
Principal Investigator (Napier): P.Ross
Co-Investigators: P.I.Cowling, S.Petrovic, G.Kendall and E.Hart
Awarded: October 2000
Notes: This is a joint project between the University of Nottingham and Napier University

Case Based Reasoning in Personnel Rostering (£58,684 from EPSRC; £24,000 from QMC)

Funding Body: EPSRC (GR/N52050/01)
Principal Investigator: S.Petrovic
Co-Investigators: E.K.Burke and P.I.Cowling
Collaborators: Queen’s Medical Centre, Nottingham
Awarded: September 2000
Notes: This is a joint project between the School of Computer Science and IT, the Queen’s Medical Centre and the School of Nursing at the University of Nottingham

Applying Meta-heuristics and Hyper-heuristics to Stock Cutting (£28,920 from EPSRC: £13,200 from Esprit)

Funding Body: EPSRC (CNA/00802329)
Principal Investigator: G.Kendall
Collaborators: Esprit Automation Ltd
Awarded: September 2000
Notes: This is a CASE (Co-operative Awards in Science and Engineering) for New Academics Award

Representational Design Principles to Humanise Automated Systems (£264,650)

Funding Body: ESRC/EPSC People At the Centre of Communication and Information Technologies (PACIT) programme (L2/8523012)
Principal Investigator (Nottingham): P.Cheng (Psychology)
Co-Investigator (Nottingham): E.K.Burke (Computer Science and IT)
Co-Investigator (Bradford): P.I.Cowling
Co-Investigator (Queen's): B.McCollum
Awarded: June 2000
Notes: This is a joint project between the School of Computer Science and IT (Nottingham), the School of Psychology (Nottingham), Queen’s University of Belfast and the University of Bradford (following P.I.Cowling’s move to Bradford)

New Approaches to Produce Efficient Nesting Patterns (£62,268 from Teaching Company Directorate; £40,400 from Esprit)

Funding Body: Teaching Company Directorate and Esprit Automation Ltd (TCS 3047)

Lead Academic: E.K.Burke
Academic Supervisor: G.Kendall
Awarded: March 2000

Using Real Time Information for Effective Dynamic Scheduling (£45,939 from EPSRC; £43,500 from Dash)

Funding Body: EPSRC (GR/N04225/01-02)
Principal Investigator: P.I.Cowling
Universities: Bradford
Co-Investigators: S.Petrovic and E.K.Burke
Collaborators: Dash Optimisation
Awarded: December 1999
Notes: This is a joint project between the School of Computer Science and IT (Nottingham) and the University of Bradford (following P.I.Cowling’s move to Bradford)

A Case Based Approach to Heuristic Selection for Timetabling (£190,545)

Funding Body: EPSRC (GR/R55561/01)
Principal Investigator: E.K.Burke
Co-Investigators: S.Petrovic and P.I.Cowling
Awarded: October 1999

Tutorials in Optimisation and Search Methodology (£3,000 from EPSRC; £2,000 from LMS)

Funding Body: EPSRC and London Mathematical Society (LMS), under the MathIT initiative
Principal Investigator: E.K.Burke
Co-Investigators: S.Petrovic and G.Kendall
Co-Author: J.D.Landa Silva
Awarded: February 2003
Notes: This grant is supporting the INTROS workshop

An Inter-disciplinary Scheduling Network (£62,985)

Funding Body: EPSRC (GR/R12268/01)
Principal Investigator: E.K.Burke
Co-Investigators: P.I.Cowling, S.Petrovic and G.Kendall
Collaborators: Over 40 universities and companies across many disciplines
Awarded: January 2002
Notes: The ISN currently has over 70 partners from over 40 institutions across academia and industry

A Dual Examination of Scheduling Problems – A Visiting Fellowship (£7,800)

Funding Body: EPSRC (GR/R70124/01)
Principal Investigator: S.Petrovic
Co-Investigators: E.K.Burke and G.Kendall
Collaborators: Visiting fellowship for Prof. Moshe Dov
University of Arizona
Awarded: July 2002
Notes: This is a joint project between the University of Nottingham and Coventry University

An Investigation of Deterministic Fuzzy Reasoning (£62,451 from EPSRC; £5,000 from Neoventa)

Funding Body: EPSRC (GR/R55058/01-02)
Principal Investigator: J.M.Garibaldi
Collaborators: Neoventa Medical AB
Awarded: April 2002
Notes: This is a joint project between the School of Computer Science and IT (Nottingham) and the University of Bradford (following P.I.Cowling’s move to Bradford)
Professional Activities (2001 to Date)

Edmund Burke
- Member of the EPSRC Information and Communications Technologies (ICT) Strategic Advisory Team (2003 – 2004).
- Editor-in-Chief of the Journal of Scheduling (Kluwer).
- Area Editor (for Combinatorial Optimisation) of The Journal of Heuristics (Kluwer).
- Associate Editor of the IEEE Transactions on Evolutionary Computation.
- Chairman of the Steering Committee of the EPSRC Inter-disciplinary Scheduling Network (ISN).
- Chairman of the Advisory Committee and Co-ordinator of the EURO Workgroup on Automated TimeTabling (WATT).
- Chairman of the IEEE Neural Networks Society Task Force on Evolutionary Scheduling and Timetabling.
- Chairman of the Steering Committee of the international series of conferences on the Practice and Theory of Automated Timetabling (PATAT).
- Chairman of the Special Program Committee on Evolutionary Scheduling and Routing of the 2002 Genetic and Evolutionary Computation Conference (GECCO 2002), New York, USA, 9th – 13th July, 2002.
- Chairman of the Special Program Committee on Evolutionary Scheduling and Routing of the 2001 Genetic and Evolutionary Computation Conference (GECCO 2001), San Francisco, USA, 9th – 11th July, 2001.
- Member of the Programme Committee of the Congress of Evolutionary Computation 2003 (CEC03), Canberra, Australia, 8th – 12th December, 2003.
- Member of the International Advisory Board of the 2nd International Conference on Computational Intelligence, Robotics and Autonomous Systems (CIRAS), Singapore, 15th – 18th December, 2002.
- Member of Programme Committee of the 2003 UK Workshop on Computational Intelligence (UKCI-03) The University of Bristol, UK, 1st – 3rd September, 2003.
- Member of Programme Committee of the 5th Metaheuristics International Conference (MIC03), Kyoto, Japan, 25th – 28th August, 2003.
- Member of the Programme Committee of the 2003 Genetic and Evolutionary Computation Conference (GECCO 2003), Chicago, USA, 12th – 16th July, 2003.
- Member of the International Program Committee of the “Applied Mathematics, Operational Research and Optimization” Symposium, Lille, France, 9th – 11th July, 2003.
- Member of Programme Committee of the 6th International Conference on Industrial Engineering and Production Management (IEMP ’03), Porto, Portugal, 26th – 28th May, 2003.
- Member of Programme Committee of the IFAC International Conference on Intelligent Control and Signal Processing (ICONS 2003), Faro, Portugal, 8th – 11th April, 2003.
- Member of the Programme Committee of the 6th Workshop on Models and Algorithms for Planning and Scheduling Problems (MAPSP 03), Aixois, France, 30th March – 5th April, 2003.
- Member of the Programme Committee of the 3rd European Workshop on Evolutionary Computation in Combinatorial Optimisation, Essex, UK, 14th – 16th April, 2003.
- Member of Programme Committee of the 4th International Conference on Recent Advances in Soft Computing (RASC 2002), Nottingham, UK, 12th – 13th December, 2002.
- Member of Programme Committee of the 2002 UK Workshop on Computational Intelligence (UKCI-02), Birmingham, UK, 16th – 18th September, 2002.
- Member of Program Committee of the 7th Parallel Problem Solving from Nature (PPSN VII) Conference, Granada, Spain, September, 2002.
- Member of Program Committee of the 2002 Congress on Evolutionary Computation (CEC2002), Hilton Hawaiian Village, Honolulu, USA, 12th – 17th May, 2002.
- Member of Programme Committee of the 2nd European Workshop on Evolutionary Computation in Combinatorial Optimization (EvoCOP 2002), Kinsale, Ireland, 3rd – 4th April, 2002.
- Member of Programme Committee for the 20th UK Planning and Scheduling SIG Workshop (PLANSIG 2001), Edinburgh, UK, 13th – 14th December, 2001.
- Member of Program Committee of the 4th Metaheuristics International Conference (MIC 2001), Porto, Portugal, 16th – 20th July, 2001.
- Member of Programme Committee of the 1st European Workshop on Evolutionary Computation in Combinatorial Optimization (EvoCOP-2001), Milan, Italy, 18th – 20th April, 2001.

Graham Kendall
- Member of the EPSRC Peer Review College (2003 – 2005).
- Member of the Editorial Board of the International Journal of Systems Science.
- Chairman of the Special Program Committee on Evolutionary Scheduling and Routing of the 2002 Genetic and Evolutionary Computation Conference (GECCO 2002), New York, USA, 9th – 13th July, 2002.
- Chairman of the Special Program Committee on Evolutionary Scheduling and Routing of the 2001 Genetic and Evolutionary Computation Conference (GECCO 2001), San Francisco, USA, 9th – 11th July, 2001.
- Member of the Program Committee of the Congress of Evolutionary Computation 2003 (CEC03), Canberra, Australia, 8th – 12th December, 2003.
- Member of the International Advisory Board of the 2nd International Conference on Computational Intelligence, Robotics and Autonomous Systems (CIRAS), Singapore, 15th – 18th December, 2002.
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- Member of Programme Committee of the 2nd European Workshop on Evolutionary Computation in Combinatorial Optimization (EvoCOP 2002), Kinsale, Ireland, 3rd – 4th April, 2002.
- Member of Programme Committee for the 20th UK Planning and Scheduling SIG Workshop (PLANSIG 2001), Edinburgh, UK, 13th – 14th December, 2001.
- Member of Program Committee of the 4th Metaheuristics International Conference (MIC 2001), Porto, Portugal, 16th – 20th July, 2001.
- Member of Programme Committee of the 1st European Workshop on Evolutionary Computation in Combinatorial Optimization (EvoCOP-2001), Milan, Italy, 18th – 20th April, 2001.
• Co-chair of the Organising Committee of the 4th International Conference on Recent Advances in Soft Computing (RASC 2002), Nottingham, UK, 12th – 13th December, 2002.

Natália Krasnogor

• Member of the Organising Committee of the 4th Multidisciplinary International Conference on Scheduling and Timetabling (MISTA 2003), Nottingham, UK, 12th – 13th July, 2003.
• Member of the Programme Committee of the 4th International Workshop on Memetic Algorithms (WOMA IV), Chicago, USA, 12th July, 2003.
• Member of the Programme Committee for Congress Mexican of Computation Evolutionista 2003 (COMCEN’03), Guanajuato, Mexico, 28th – 30th May, 2003.
• Member of the Programme Committee of the 7th International Conference on Parallel Problem Solving from Nature (PPSN VII), Granada, Spain, 7th – 11th September 2002.
• Co-chair of the Program Committee of the 3rd International Workshop on Memetic Algorithms (WOMA III), Granada, Spain, 7th September, 2002.
• Co-chair of the Program Committee of the 2nd International Workshop on Memetic Algorithms (WOMA II), San Francisco, USA, 7th July, 2001.

Kathryn Dowsland

• Member of EPSRC Peer Review College (2000 – 2002 and 2003 – 2005)
• Member of the Professional Accreditation Panel of the Operational Research Society
• Member of the Steering Committee of the EPSRC Inter-disciplinary Scheduling Network
• Chair of the Special Program Committee on Evolitional Scheduling and Routing of the 2003 Genetic and Evolutionary Computation Conference (GECCO-2003), in Chicago, USA, 12th – 16th July, 2003.
• Member of the Programme Committee of the 5th International Conference on the Practice and Theory of Automated Timetabling (PATAT 2002), Gent, Belgium, 21st – 23rd August, 2002.
• Chair of the Special Program Committee on Evolitional Scheduling and Routing of the 2003 Genetic and Evolutionary Computation Conference (GECCO-2003), in Chicago, USA, 12th – 16th July, 2003.
• Member of the Programme Committee of the 4th International Conference on Recent Advances in Soft Computing (RASC 2002), Nottingham, UK, 12th – 13th December, 2002.

Sanja Petrovic

• Member of the Organising Committee of the 4th International Conference on Recent Advances in Soft Computing (RASC 2002), Nottingham, UK, 12th – 13th December, 2002.
• Member of the Organising Committee of the 1st Multidisciplinary International Conference on Scheduling: Theory and Applications (MISTA 2003), Nottingham, UK, 12th – 13th August, 2003.
• Member of the Programme Committee of the 2001 Genetic and Evolutionary Computation Conference (GECCO 2002), San Francisco, USA, 7th – 11th July, 2002.
• Co-chair of the Program Committee of the 4th International Workshop on Memetic Algorithms (WOMA IV), Chicago, USA, 12th July, 2003.
• Member of the Programme Committee for Congress Mexican of Computation Evolutionista 2003 (COMCEN’03), Guanajuato, Mexico, 28th – 30th May, 2003.
• Member of the Programme Committee of the 7th International Conference on Parallel Problem Solving from Nature (PPSN VII), Granada, Spain, 7th – 11th September 2002.
• Co-chair of the Program Committee of the 3rd International Workshop on Memetic Algorithms (WOMA III), Granada, Spain, 7th September, 2002.
• Co-chair of the Program Committee of the 2nd International Workshop on Memetic Algorithms (WOMA II), San Francisco, USA, 7th July, 2001.

Jon Garbaldi

• Member of the EPSRC Peer Review College (2003 – 2005).
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Associated Staff

Prof. Patrick De Causmaecker  
Visiting Professor  
from KU Leuven, Gent, Belgium  
Oct 2002 – Sep 2003

Prof. Moshe Dror  
EPSRC Visiting Fellow  
from University of Arizona, USA  
Jul 2002 – Aug 2003

Administrative Staff

Mrs Diana French  
Miss Alison Payne
How to Find Us

See http://www.nottingham.ac.uk/campuses/jubilee for full directions

Acknowledgements

Optime poster (pg. 8) courtesy of eventMAP Ltd.
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KLM aeroplane photographs (pg. 12) courtesy of KLM Royal Dutch Airlines
Protein lattice (pg. 15) courtesy of Dr Jonathan Hirst, School of Chemistry, University of Nottingham
External Research Awards

ASAP has secured external research funding of almost £2 million since January 2003.

Danger Theory: The Link between Intrusion Detection and Artificial Immune Systems (£657,407 from EPSRC; £15,000 from HP Labs; £18,000 from ECSC / Tedesco)
- Funding Body: EPSRC (GR/S47809/01)
- Principal Investigator: U. Ackelain
- Co-Investigators: J. McLeod, P. Tekelevan
- Collaborators: Hewlett Packard Labs, ECSC / Tedesco
- Awarded: October 2003
- Notes: Largest EPSRC Adventure Fund grant awarded (only 13 out of approx. 700 proposals were funded)

PLATFORM: Towards More General Optimisation/Search Systems (£422,908)
- Funding Body: EPSRC (GR/S70197/01)
- Principal Investigator: E.K. Burke
- Co-Investigators: S. Petrovic, G. Kendall, J.M. Garibaldi, N. Krasnogor
- Recognised Researcher: K.A. Dowland
- Awarded: August 2003

Prisoners Dilemma Competition: Celebrating the 20th Anniversary (£11,848 to Nottingham, £11,870 to Birmingham)
- Funding Body: EPSRC (GR/S63465/01)
- Principal Investigator (Nottingham): G. Kendall
- Principal Investigator (Birmingham): X. Yao
- Awarded: June 2003

DNA Mapping by Combinatorial Optimisation – A Visiting Fellowship (£10,224)
- Funding Body: EPSRC (GR/S64530/01)
- Amount Awarded: £10,224
- Principal Investigator: E.K. Burke
- Co-Investigators: J.D. Hirst, G. Kendall, N. Krasnogor
- Awarded: July 2003
- Notes: Supporting Prof. Jack Blazewicz

Hybrid Meta-heuristic Optimisation of Chiral Catalysts (£220,227)
- Funding Body: EPSRC (GR/S75765/01)
- Principal Investigator: J.D. Hirst
- Co-Investigators: E.K. Burke, B. Lyne
- Recognised Researcher: J.L. Melville
- Awarded: October 2003
- Notes: A joint project between the Schools of Computer Science and IT, and Chemistry

An Investigation of Cutting/Packing and Planning using Automated Algorithm Selection (£153,670 to Nottingham, £150,105 to Southampton)
- Funding Body: EPSRC (GR/S52414/01)
- Principal Investigator (Nottingham): G. Kendall
- Co-Investigator: E.K. Burke
- Principal Investigator (Southampton): J. Bennell
- Awarded: August 2003

The Supervisor: Towards A Human Scheduling Algorithm (£69,282)
- Funding Body: EPSRC (GR/R92898/02)
- Principal Investigator: U. Ackelain
- Awarded: January 2003
- Notes: Fast Stream Grant

Scheduling Agents for Distributed Timetabling and Rostering – A Visiting Fellowship (£10,350)
- Funding Body: EPSRC (GR/S34590/01)
- Principal Investigator: G. Kendall
- Co-Investigators: E.K. Burke, S. Petrovic
- Awarded: June 2003
- Notes: Supporting Prof. Amnon Mendels

Service Level Agreement Based Scheduling Heuristics (£141,492 to Nottingham, £202,916 to Manchester)
- Funding Body: EPSRC (GR/S67661/01)
- Principal Investigator (Nottingham): J.M. Garibaldi
- Co-Investigators: E.K. Burke, S. Petrovic, T.A. Rodden
- Principal Investigator (Manchester): R. Sakellariou
- Awarded: August 2003
- Notes: Funded under the Research in the Fundamental Computer Science for e-Science call

BIOPATTERN FP6 Network of Excellence (Approx. £220,000 to Nottingham)
- Funding Body: EU (FP6 IST 508803)
- Lead Researcher (Nottingham): J.M. Garibaldi
- Awarded: December 2003
- Notes: The Network of Excellence was awarded €64 million to a consortium of 31 members
Publications

Journals (Editorships / Associate Editorships / Guest Editorships)

- E. Burke : Associate Editor of the INFORMS Journal on Computing.
- G. Kendall : Member of the Editorial Board of the International Journal of Systems Science, Taylor & Francis.
- G. Kendall : Member of the editorial board of Interfaces in Accounting Finance and Management, Wiley.
- G. Kendall : Associate editor of INFOR, the journal of the Canadian Operational Research Society, University of Toronto Press.

Books


Book Chapters


Journal Papers

In press and to appear

- P. Innocent, R. John and J. Garibaldi, “Fuzzy Methods and Medical Diagnosis”, accepted for publication in Applied Artificial Intelligence, 2004.

Refereed Conference Papers

The group published in a wide range of refereed international conferences during 2003, with many more accepted or submitted to conferences due to be held in 2004. Full details will be included in the next research group report.

New Group Members

- Dr Uwe Aickelin Lecturer
- Jingpeng Li Research Associate
- Jamie Twyecross Research Associate
- Jason Akin PhD Student
- Camille Beyrouthi PhD Student
- Qi Chen PhD Student
- Tim Curtois PhD Student
- Aniza Mohamed Din PhD Student
- Julie Greensmith PhD Student
- Lin Li PhD Student
- Cyril Schoreels PhD Student
- Prof. Jacek Blazewicz EPSRC Visiting Fellow August 2003 – July 2006
- Prof. Amnon Meisels EPSRC Visiting Fellow August 2003 – April 2004

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