ECCO-XI

European Chapter on Combinatorial Optimization
University of Copenhagen, May 27-29, 1998

Conference Program and Abstracts*

Contents

*CR Subject Classification: G.1.6, Integer Programming, Linear Programming, G.2.1, Combinatorial Algorithms, G.2.2, Graph Theory, G.4, Algorithm Analysis, Efficiency

Welcome

ECCO is the annual meeting of the EURO Working Group on Combinatorial Optimization. ECCO provides an excellent opportunity to discuss recent and important issues in Combinatorial Optimisation and its applications.

ECCO-XI has brought together scientists and industrialists working in the area of combinatorial optimization, computer science, operations research and management science. The meeting features plenary tutorials by invited speakers and contributed papers organized in two parallel streams. Following the tradition of ECCO, contributions from young researchers and industrial engineers have been strongly encouraged.

The conference is hosted by Dept. of Computer Science and Dept. of Operations Research at University of Copenhagen. The organizers are grateful for the economical and practical support of the departments, and we would like to bring a special thank to Karin Outzen for her great help.

We hope that ECCO-XI will live up to the very high standard of previous ECCO conferences — both with respect to the scientific program and the social activities. On behalf of the organizing committee I wish you a rewarding and enjoyable stay in Copenhagen.

David Pisinger
(chairman of the organizing committee)

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Sponsors

The ECCO-XI conference has been sponsored by EURO (*The Association of European Operational Research Societies*), DORS (*The Danish Operations Research Society*) and SNF (*The Danish Natural Science Research Council*).

Map of the Conference Site

Places to eat Lunch

The Campus of Natural Sciences has several good canteens for lunch.

- **HCØ Canteen**:
  Located in the hall of the HCØ building.
  The canteen has a warm dish of the day, the Danish "smørrebrød" (rye bread sandwich), salad.

- **August Krogh Building**:
  Canteen located first floor. August Krogh is located west of HCØ.
  The canteen has sandwiches, salad, sometimes a complete meal.

- **School of Physiotherapy and Ergotherapy**:
  Canteen located in the basement of Universitetsparken 4, north of HCØ.
  The canteen has a warm dish of the day and some sandwiches, salad. Reasonable prices.

- **School of Pharmacy**:
  Canteen located in the basement of Universitetsparken 2, north of HCØ.
  The canteen has a warm dish of the day and some sandwiches.

- **DIKU Canteen**:
  Located at 2nd floor of DIKU.
  A very modest and cheap self-service canteen. There is white bread and meat/cheese available. You pay in the red box according to the price list. The users are expected to wash their own dish afterwards.

Moreover there is a restaurant **Fælledpavillonen** in the *Fælledpark*, 10 minutes of walk from Universitetsparken. Please ask the organizers whether it is open. Other Restaurants and Cafés can be found around *Sankt Hans Torv*, 15 minutes of walk down *Nørre Alle* in southern direction.

Program

Tuesday, May 26 1998

- *Registration, Reception*

Wednesday, May 27 1998

- Tutorial: Dominique de Werra
- I. Graphs I
- II. Scheduling I
- Tutorial: Fred Glover, Arne Løkketangen and David Woodruff
- III. Graphs II
- IV. Applications
- *Evening:* Canals Tour

Thursday, May 28 1998

- Tutorial: Jürg Nievergelt
- V. Parallel aspects
- VI. Heuristics
- VII. Scheduling II
- VIII. CHIC2 I
- IX. Graphs III
- X. CHIC2 II
- *Evening:* Conference Dinner in Tivoli

Friday, May 29 1998

- Tutorial: John Beasley
- XI. Scheduling III
- XII. Networks
- Tutorial: Gabor Galambos
- XIII. Combinatorial optimization

Tuesday, May 26

17:00-19:00 Registration

- DIKU, University of Copenhagen, Universitetsparken 1.

17:30-19:00 Reception

- Reception with a light meal and drinks

Wednesday, May 27

8:45-9:15 Registration

- HCØ building, Universitetsparken 5.

9:15-9:30 [Aud2] Opening

9:30-10:30 [Aud2]

- *Dominique de Werra* Locally and Globally constrained coloring problems (*chairman*: Jakob Krarup)

10:30-11:00 Coffee

11:00-12:30

- **I. Graphs I** [Aud2] (*chairman*: Dietmar Cieslik)
  - *Daniel Kobler* On some properties of DNA graphs
  - *Michael Gerber* Partitioning a graph to satisfy all vertices
  - *Jørgen Bang-Jensen* Increasing the edge-connectivity of a graph without adding forbidden edges
- **II. Scheduling I** [Aud3] (*chairman*: Maciej Drozdowski)
  - *Małgorzata Sterna* The Machine Representation of the Disjunctive Graph
  - *Per Willenius* Aspects of structural Analysis in Shop Scheduling Problems with Makespan Objective
  - *Vitaly Strusevich* Batching policies for shop scheduling problems

12:30-13:30 Lunch

13:30-14:30 [Aud2]

- *Fred Glover* Commercial and Research Implementations of Tailored Metaheuristics for Integer Programming (*chairman*: Jacek Błażewicz)

14:30-15:00 Coffee

15:00-17:00

- **III. Graphs II** [Aud2] (*chairman*: Michael Gerber)
  - *Dietmar Cieslik* The Vertex Degrees of Minimum Spanning Trees
  - *Martin Zachariasen* Exact Algorithms for Plane Steiner Tree Problems
  - *Jakob Krarup* A linear algorithm for the pos/neg-weighted 1-median problem on a cactus
  - *Federico Della Croce* An improved general procedure for lexicografic bottleneck problems
- **IV. Applications** [Aud3] (*chairman*: Van-Dat Cung)
  - *Yves Niquil* Using a Gallois Lattice for Constructing a Minimal Set of Capacity Constraints in Stock Management
  - *Patrick Healy* An Optimal Algorithm for Rectangle Placement
  - *Marat Arslanov* Continued fractions in optimal cutting of rectangular sheet on equal small rectangles

18:00- Canal Tour in Central Copenhagen

- Meeting point: Gammel Strand, located next to *Christiansborg*. (Share a taxi or take bus 1 directly, bus 42/43 with a walk through the city).
  We take a boat through the canals of Copenhagen, visiting the little Mermaid, the former Danish naval station "Holmen", and the fortress "Trekroner".

Thursday, May 28

9:00-10:00 [Aud2]

- *Jürg Nievergelt* Exhaustive search and combinatorial optimization: Exploring the potential of raw computing power (*chairman*: Jens Clausen)

10:00-10:30 Coffee

10:30-12:30

- **V. Parallel aspects** [Aud2] (*chairman*: Jürg Nievergelt)
  - *Adrian Moret-Salvador* Parallel tabu search for two-dimensional cutting
  - *Jens Clausen* Iterative Bounds in Branch-and-Bound — Quality vs. Time.
  - *Piotr Formanowicz* A Parallel Branch and Bound Algorithm for the Flow Shop Problem with Limited Machine Availability
  - *Harald Gropp* Configurations in Steven Vajda's books on combinatorics
- **VI. Heuristics** [Aud3] (*chairman*: Ramon Alvarez-Valdes)
  - *Jerzy Nawrocki* Periodic Loading Problem: Exact And Heuristic Algorithms
  - *Olivier Hudry* Lamarckian genetic algorithms applied to the linear ordering problem
  - *António Anjo* On the Adequacy of Simulated Annealing: a Statistical Analysis
  - *Yves Niquil* Using a Genetic Algorithm for Optimizing the Location of Phase Shifters in the French Electric Network

12:30-13:30 Coffee

13:30-15:00

- **VII. Scheduling II** [Aud2] (*chairman*: Per Willenius)
  - *Ramon Alvarez-Valdes* Design and implementation of a course scheduling system using Tabu search
  - *Thomas Bartsch* Scheduling the German Soccer League
  - *Adam Czajka* Static Scheduling of Real-time Tasks With Binary Periods
- **VIII. CHIC2 I** [Aud3] (*chairman*: Fred Glover)
  - *Eric Jacquet-Lagreze, Philippe Wolff* The Chic-2 Methodology: An efficient and effective methodology for combinatorial optimisation in practice
  - *Claude Le Pape* Creating and Evaluating Hybrid Algorithms for Inventory Management Problems

15:00-15:30 Coffee

15:30-17:00

- **IX. Graphs III** [Aud2] (*chairman*: Daniel Kobler)
  - *Vadim Lozin* Transformations of graphs for the stable set problem
  - *Dragoš Cvetković* Combinatorial optimization, graph spectra and the graph isomorphism problem
  - *Igor Ushakov* An Object Oriented Approach To Generalized Generating Sequences
- **X. CHIC2 II** [Aud3] (*chairman*: Eric Jacquet-Lagreze)
  - *Philippe Wolff* The Extended Car Sequencing Problem: initial results from the Chic-2 Project
  - *Joachim Schimpf, Mark Wallace* The ECLiPSe Approach to Solver Integration and Cooperation

18:00- Conference dinner in Tivoli

- Meeting point in Tivoli: We enjoy a banquet in Restaurant “Glassalen”. Afterwards you have the opportunity to enjoy the exciting atmosphere of the world-famous amusement park.

Friday, May 29

9:00-10:00 [Aud2]

- *John Beasley* Population heuristics (*chairman*: Jørgen Tind)

10:00-10:30 Coffee

10:30-12:30

- **XI. Scheduling III** [Aud2] (*chairman*: Thomas Bartsch)
  - *Maciej Drozdowski* Scheduling multiprocessor tasks on two parallel processors
  - *Joanna Józefowska* Minimizing maximum lateness for discrete-continuous scheduling problems
  - *Inna Drobouchevitch* A 5/4 heuristic algorithm for the two-stage multi-machine open shop with a bottleneck machine
  - *Grzegorz Pawlak* Scheduling tasks and vehicles in Flexible Manufacturing Systems
- **XII. Networks** [Aud3] (*chairman*: Oli Madsen)
  - *Nina K. Detlefsen* Basis characterization in multicommodity network
  - *Kaj Holmberg* A ring network design problem
  - *Franz Salzborn* An overflow model for network design problems
  - *Marcos Colebrook* An Efficient Procedure for Locating a Center on a Multi-Objective Network

12:30-13:30 Lunch

13:30-14:30 [Aud2]

- *Gabor Galambos* Lower Bounds for On-Line Bin-Packing Algorithms (*chairman*: Silvano Martello)

15:00-15:30 Coffee

15:30-17:00

- **XIII. Combinatorial optimization** [Aud2] (*chairman*: Inna Drobouchevitch)
  - *Thomas Tautenhahn* A Comparison of Heuristic Algorithms for Flow Shop Scheduling Problems with Setup Times and Limited Batch Size

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Design and implementation of a course scheduling system using Tabu search

THU-VII Scheduling II, 13:30-14:00

RAMON ALVAREZ-VALDES
University of Valencia
authors: Ramon Alvarez-Valdes, Enric Crespo, Jose Manuel Tamarit
keywords: timetabling, course scheduling, heuristics, tabu search

This paper reports on the development of an automatic course timetabler for the University of Valencia, Spain. As Carter & Laporte pointed out, course timetabling problems may be divided in two categories, Master Timetables or Demand Driven Systems, depending on the moment in which the students make their course choices, after or before the assignment of times to courses. In our case, the problem is, basically, to build a Master Timetable, according to the specifications of courses, sections and programs defined by academic authorities. Nevertheless, students choices are taken indirectly into account by collecting pre-registration information or by using the data of the previous academic year. The problem includes many other requirements, concerning the availability of teachers, the assignment of suitable classrooms to lessons, according to their type, size and location, and sometimes special requirements for courses.

The solution process is divided in two phases. For a given timetable, the problem is assigning students to course sections to minimize conflicts. When we fix the student assignment, the problem is to build the best course schedule. We have solved the assignment phase with a tabu search procedure with strategic oscillation that combines the objective of producing good timetables for students with the relaxed capacity constraints of course sections.

For the timetabling phase we are developing another tabu algorithm. The objectives and relaxed soft constraints are combined in a complex cost function. The relative weight of its different components is controlled by a strategic oscillation procedure in the search of acceptable compromise solutions. The algorithms are imbedded in a system currently being developed by our colleagues of the Computer Science Department.

On the Adequacy of Simulated Annealing: a Statistical Analysis

THU-VI Heuristics, 11:30-12:00

ANTÓNIO ANJO
Departamento de Matemática - Universidade de Aveiro
authors: António Anjo, Maria Rodrigues
keywords: combinatorial optimization, simulated annealing, statistical analysis

It has consistently been observed that different combinatorial problems of the NP-hard class (and even instances of the same problem) seem to react in very different ways to the Simulated Annealing approach (and to different cooling schedules).

We believe that the adequacy of a given problem instance to a particular Simulated Annealing algorithm can be estimated in advance, by means of simple and fast statistical evaluations.

In this talk we present a framework for the statistical analysis of combinatorial problem instances, as well as the results of a comparative study relating the values of a chosen set of statistical parameters with Simulated Annealing performance measures.

Continued fractions in optimal cutting of rectangular sheet on equal small rectangles

WED-IV Applications, 16:00-16:30

Marat Arslanov

Institute of problems of informatics and control, Almaty, Kazakhstan

author: Marat Arslanov

keywords: continued fractions, rectangular cutting

Cutting problems are difficult problems of discrete programming even in a simple case of cutting of a rectangular sheet on smaller rectangles. We consider so-called guillotine cutting, at which cutting lines will be spent through the whole sheet parallel to sides. Even in the case of cutting of a rectangle on smaller equal rectangles known algorithms for optimum cutting has nonlinear complexity.

In the present work for the decision of a practical problem of optimum cutting of a rectangle on equal rectangles such classical number-theoretic results as a method of continued fractions, Chinese remainder theorem, the integer decision of linear equations from two variable, Farey fractions are used. Using of these results has allowed to construct a linear time complexity algorithm for the decision of this problem.

Main results obtained in this paper are next:

1. It's shown that common problem of cutting of a rectangle on equal smaller rectangles can be reduced to the case when the sides of larger rectangles are integer combination of sides of smaller rectanle (analoguesly to such well-known property of Pallet Loading Problem);

2. The main theorem is proved:

$$\frac{rc + sd, tc + ud}{c, d} = ru + st + \frac{rc, tc}{c, d} + \frac{sd, ud}{c, d},$$

where big rectangle has sides $rc+sd, tc+ud$, small rectanle has sides c, d, symbol $\frac{A,B}{c,d}$ equal to maximal number of rectangles (c, d) cutting from (A, B) and r, s, t, u are nonnegative integers.

3. A theoretic foundation of index method of Kantorowitch by the method of continued fractions is made;

Based on this results designed algorithm allows to solve practical cutting problems with the help of the vest-pocket calculator. Thus, this algorithm has not only theoretical character.

Increasing the edge-connectivity of a graph without adding forbidden edges

WED-I Graphs I, 12:00-12:30

JØRGEN BANG-JENSEN
Department of Math. and CS, Odense University
author: Jørgen Bang-Jensen
keywords: edge-connectivity, connectivity augmentation, flows, legal ordering, splitting, simple graph, partition constrained augmentation

The edge-connectivity of a graph $G = (V, E)$ is the minimum number of edges one has to remove to obtain a new graph $G' = (V, E')$ which is not connected. The problem of finding the edge-connectivity of a given graph has an efficient solution, either using techniques from network flows, or the recent edge-connectivity algorithm by Nagamochi and Ibaraki which calculates the edge-connectivity of a given graph without using any max-flow calculations.

In many applications one starts with a graph G of a certain edge-connectivity ℓ and wishes to increase the edge-connectivity of G to a certain number $k > \ell$ by adding new edges to the graph. The goal is to use as few new edges as possible (the weighted version is NP-complete, even for weights 0 and 1). This is called the **edge-connectivity augmentation problem**. There are several polynomial algorithms for this problem and these either use the so-called splitting techniques by Lovász and Mader, or the successive augmentation approach which uses the so-called cactus. Both of these approaches have the drawback that the optimal set of new edges cannot be easily controlled, for example the new set of edges may contain many parallel edges. In this talk we will first discuss the solution of the edge-connectivity augmentation problem when one uses the splitting technique and then we shall consider two variations of the edge-connectivity augmentation problem, one in which we require that both the starting graph G and the final graph $G = (V, E + F)$ is simple (i.e. it contains no parallel edges) and one in which we are given a partition $\mathcal{P}$ of V and we are not allowed to add any edges inside a partition class (i.e. each new edge goes between two distinct partition classes). It turns out that the second problem can be solved in polynomial time and that the first problem is NP-complete if k is part of the input, but for fixed k there exists a polynomial algorithm to find the minimum number of new edges to be added. The solutions of both problems are based on extensions of the splitting-technique. We illustrate the ideas to the extend that time allows. This is joint work with Jordán respectively, Gabow, Jordán and Szigeti.

Scheduling the German Soccer League

THU-VII Scheduling II, 14:00-14:30

THOMAS BARTSCH
Inst. für Betriebswirtsch., University of Kiel
authors: Thomas Bartsch, Andreas Drexl
keywords: sports scheduling, decision support system

The purpose of our talk is to present an approach to sports league scheduling, which is suitable for generating schedules for the premier German soccer league. Based upon an interview with the German soccer association (DFB), three categories of demands for sports league schedules - organisational feasibility, attractiveness and fairness - could be determined. These categories were integrated into a binary optimisation model. Thus for the first time economic interests of clubs, sponsors and broadcasting stations can be taken into account simultaneously. For solving the problem, heuristic and exact schemes specifically tailored to the problem structure are described. Their suitability is demonstrated in an extensive computational experiment, which also includes the generation of a solution for the real scheduling problems in Germany and Austria of the season 1997/98.

Population heuristics

FRI-Plenary, 9:00-10:00

JOHN BEASLEY
Imperial College, London
author: John Beasley
keywords: population heuristics, genetic algorithm, bionomic algorithm, heuristics

Standard heuristics for combinatorial optimisation problems (such as greedy, tabu search and simulated annealing) work on improving a single current solution. Population heuristics use a number of current solutions and combine them together to generate new solutions.

In this tutorial we discuss the basic features of population heuristics, focusing on genetic algorithms and the bionomic algorithm of Christofides.

The Vertex Degrees of Minimum Spanning Trees

WED-III Graphs II, 15:00-15.30

DIETMAR CIESLIK
University of Greifswald
author: Dietmar Cieslik
keywords: graphs, minimum spanning tree

Motivated by practical applications, we study the Minimum Spanning Trees (MST). Solutions of many other problems hinge on the construction of an MST as an intermediary step. Several efficient algorithms to compute an MST are known. Applications often would benefit from MST's with low maximum degree of the vertices. In this sense, we consider methods to solve

The Bounded Degree Minimum Spanning Tree (BDMST) Problem: Given a finite set N of points in a metric space and an integer $\beta > 1$; Find a tree connecting the points of N in which each vertex has degree at most β and with minimal total length.

Shortly, a BDMST of maximum degree β is called a β-MST. In general, this problem is NP-hard for any fixed number $\beta > 1$.
It will be shown that in finite-dimensional Banach spaces there is a number z, depending only on the space, such that a β-MST can be computed as efficiently as an ordinary minimum spanning tree if $\beta \geq z$. Consequently, we can find a β-MST in polynomially bounded time. The numbers z will be estimated and for many spaces exactly computed.
Additionally, we reduce the numbers z applying some derivations of known algorithms for minimum spanning trees.

Iterative Bounds in Branch-and-Bound - Quality vs. Time.

THU-V Parallel aspects, 11:00-11:30

JENS CLAUSEN
IMM, Technical University of Denmark
authors: Jens Clausen, Stefan Karisch, Torben Espersen, Eranda Cela
keywords: branch and bound, bounding functions, iterative bounds, quadratic assignment problem

Branch and Bound is one of the major algorithmic paradigms used to solve NP-hard combinatorial optimization problems. A key component in a Branch and Bound algorithm is the bounding function, which for a given problem produces a bound on the optimal value of this.

In general, bounding functions providing bounds close to the optimum value are regarded to be preferable and are called strong bounding functions.

Some bounding functions are, however, iterative: The bound is the result of a sequence of iterations, where each iteration results in a bound at least as good as the one obtained in previous iteration. For this type of bounding function, a trade-off between quality and time occurs: Is it worthwhile to spend a large amount of iterations in one node before branching ? Alternatively, for a given number N of iterations, should one spend all iterations bounding the current problem, or should one branch (subdividing the current problem into n subproblems), use N/n iterations on each of these, and take the minimum value obtained as the new bound ?

Computational experiments with Quadratic Assignment Problems are reported, which illustrates the trade-off.

An Efficient Procedure for Locating a Center on a Multi-Objective Network

FRI-XII Networks, 12:00-12:30

MARCOS COLEBROOK
Dep. de Estadística, I.O. y Computación, Universidad de La Laguna
authors: Marcos Colebrook, Rosa Ramos, Joaquín Sicilia, Teresa Ramos
keywords: network optimization, multi-objective network location, center problem

In this paper we study the location of a facility on a network which has multiple weights on its vertices and multiple costs on its edges. Such a location is made using the mini-max criterion, that is, considering the center problem. We show an algorithm that calculates all the non-dominated location points where the facility can be located. Computational results obtained from random generated networks are presented.

Combinatorial optimization, graph spectra, graph isomorphism problem

THU-IX Graphs III, 16:00-16:30

DRAGOŠ CVETKOVIĆ
University of Belgrade, Faculty of Electrical Engineering
author: Dragoš Cvetković
keywords: graph spectra, graph isomorphism, cliques, matchings, cuts

For a graph on n vertices we consider a special basis of R^n (n-dimensional real vector space) consisting of eigenvectors of the adjacency matrix of G. This basis is defined independently of the labelling of vertices of G and is called the canonical star basis of G. Two graphs are isomorphic if and only if they have the same eigenvalues and the same canonical star bases. The canonical star basis can be defined in several ways starting from the spectral decomposition of the adjacency matrix. Determination of the canonical star basis of a graph is reduced to some well-known problems of combinatorial optimization, e.g. problems of finding a maximal clique, a minimal matching or a minimal cut in a weighted graph. The type of the combinatorial optimization problem depends on the class of graphs under consideration. This approach enables us to prove the existence of polynomial algorithms for the graph isomorphism problem for certain restricted classes of graphs, e.g. for graphs with bounded multiplicities of eigenvalues (a result obtained earlier in another way).

This approach to the graph isomorphism problem is described in Chapter 8 of the book by the author, P.Rowlinson and S.Simić : Eigenspaces of Graphs, Cambridge University Press, Cambridge, 1997. In our talk we discuss further variants in defining a canonical star basis for various classes of graphs and provide some interesting examples.

Static Scheduling of Real-time Tasks With Binary Periods

THU-VII Scheduling II, 14:30-15:00

Adam Czajka
Poznan University of Technology
author: Adam Czajka
keywords: scheduling, real-time systems, dynamic programming, heuristics

In real–time systems, e.g. in an air craft controller, there are many tasks which are executed in parallel. Most demanding are so called hard real–time tasks. Each hard real–time task is assigned a *deadline* and its execution *must* complete before the deadline. Usually hard real–time tasks are vital to the system and missing the deadline can lead even to a disaster. Many of hard real–time tasks are cyclic (there are also sporadic tasks but they can be transformed into cyclic ones). A cyclic task is assigned a period p and it must be repeated every p units of time, i.e. it must be executed within each interval of time $[kp..(k+1)p)$, $k = 0, 1, 2, ...$ and $(k+1)p$ is the deadline for the k^{th} instance of the task. Now the problem arises, how to schedule hard real–time cyclic tasks to meet all the deadlines. One of the possible approaches is static scheduling: at compile time a timetable is computed and it is used by a dispatcher at run–time. The timetable shows which task should be executed at the moment. The table's size is the least common multiple of all the periods.

To make such scheduling, testing and debugging simpler, a class of cyclic tasks with binary periods has been introduced and studied in the literature. For these tasks periods are no longer random values but they have to form a geometrical progression with the quotient equal to 2 (there can be 0, 1 or more tasks having a given period). Thus, there is a so-called basic period p_0, and for task T_i its period p_i equals to $2^j p_0$ for some $j = 0, 1, 2, ...$ The MAFT distributed system and implementations of MIL–STD–1553 communications protocol are examples of systems in which the idea of restricting periods to binary progression has been applied in practice.

In the paper the static scheduling of the hard real–time tasks with binary periods is discussed. Computational complexity of the problem is analysed, a heuristic is proposed and it is shown how to find the binary approximation of a given set of task periods.

Locally and Globally constrained coloring problems

WED-Plenary, 9:30-10:30

Dominique de Werra
Chaire de Recherche Opérationnelle, EPFL
author: Dominique de Werra
keywords: graph coloring

Coloring models have been used in various ways for scheduling purposes. The many constraints arising in practical scheduling problems have motivated the introduction of a huge collection of additional requirements in the coloring models; a collection of variations and extensions of colorings has been generated by many authors. We shall mention a few of these applicable models.

A main difficulty is due to the simultaneous presence of so called local and global requirements; we shall give a few examples and some indications on possible approaches for handling these constraints. A special type of such a situation arises in the register allocation problem which occurs in the optimization process of a compiler.

In particular when compiling loops in a computer programme one often tries to reduce the number of registers needed while keeping the amount of code to be compiled for an iteration below a given volume.

We shall describe the graph-theoretical models used in this situation and derive some coloring properties related to the various problems appearing in the optimization of the process of compiling.

An improved general procedure for lexicografic bottleneck problems

WED-III Graphs II, 16:30-17:00

FEDERICO DELLA CROCE
D.A.I., Politecnico di Torino
authors: Federico Della Croce, Vangelis Paschos, Tsoukias Alexis
keywords: lexicographic problems, combinatorial optimization

In combinatorial optimization, the bottleneck (or minmax) problems are those problems where the objective is to find a feasible solution such that its largest cost coefficient elements have minimum cost. Here we consider a generalization of these problems, where under a lexicografic rule we want to minimize the cost also of the second largest cost coefficient elements, then of the third largest cost coefficients and so on. We propose a general rule which leads, given the considered problem, to a vectorial version of the solution procedure for the underlying sum optimization (minsum) problem. This vectorial procedure increases by a factor of m (where m is the number of different cost coefficients) the complexity of the corresponding sum optimization problem solution procedure.

Basis characterization in multicommodity network

FRI-XII Networks, 10:30-11:00

NINA K. DETLEFSEN
Department of Industrial Economics and Technology Management
authors: Nina K. Detlefsen, Stein W. Wallace
keywords: multicommodity network, linear programming, graph theory

We think of a multicommodity network problem as a directed capacitated network for each commodity and then we let side constraints take care of bounds on total flow. This formulation allows capacity intervals on individual flows in the arcs. We also expand the directed networks with an extra node and arcs from this extra node to each of the original nodes. Then the flow in these new arcs can be interpreted as external flow. This way we are able to allow the external flow to vary within intervals. Almost all standard fomulations are special cases of our formulation.

For the multicommodity problem we describe the structure of a basis combinatorially. That is, given a selection of columns from the constraint matrix we can say if it is a basis by looking at the structure in the graph of the columns. In order for a selection of columns to be a basis, the network graph of the columns can not contain cycles for the commodities which creates certain structures. We will show why and give a more detailed and accurate description of the structures.

In this paper we choose to prove constructively what the bases are by having an algorithms generating all square submatrices which does not contain the structures and then prove that a matrix generated by the algorithm has full rank.

A 5/4 heuristic algorithm for the two-stage multi-machine open shop with a bottleneck machine

FRI-XI Scheduling III, 11:30-12:00

INNA DROBOUCHEVITCH
School of Computing and Mathematical Sciences, University of Greenwich
authors: Inna Drobouchevitch, Vitaly Strusevich
keywords: open shop scheduling, approximation algorithm, worst-case analysis

We study the $m-$machine open shop problem in which each of n jobs consists of two operations only; moreover, we assume that for each job one of its operations is processed on the same (bottleneck) machine. The objective is to minimize the makespan. This problem is proved to be $NP-$hard for $m \geq 4$ by Gonzalez and Sahni.

As proved by Williamson et al., for the open shop scheduling problem to minimize the makespan there exists no polynomial-time heuristic algorithm that guarantees a worst-case performance ratio better than 5/4, unless $P \neq NP$. However, the proof technique used implies that this result holds only if the instance of the problem contains jobs consisting of at least three operations. For the two-stage $m-$machine open shop with the bottleneck machine, we develop a heuristic algorithm that runs in $O(nm)$ time and finds a schedule with the makespan at most 5/4 times the optimal value, and this ratio bound is tight.

Scheduling multiprocessor tasks on two parallel processors

FRI-XI Scheduling III, 10:30-11:00

MACIEJ DROZDOWSKI
Institute of Computing Science, Poznan University of Technology
authors: Jacek Błażewicz, Paolo Dell'Olmo, Maciej Drozdowski
keywords: scheduling, multiprocessor tasks, parallel algorithms

Scheduling multiprocessor tasks on two parallel processors is considered. Multiprocessor tasks can be executed by more than one processor at the same moment of time. Ready times, due-dates and precedence constraints are included in the analysis. We give polynomial time algorithms for scheduling unit execution time and preemptable tasks to minimize schedule length and maximum lateness.

A Parallel Branch and Bound Algorithm for the Flow Shop Problem with Limited Machine Availability

THU-V Parallel aspects, 11:00-11:30

PIOTR FORMANOWICZ
Institute of Computing Science, Poznań University of Technology
authors: Jacek Błażewicz, Piotr Formanowicz, Wiesław Kubiak, Günter Schmidt
keywords: flow shop scheduling, non-availability machine periods, branch and bound, parallel computing

This talk is concerned with a problem of scheduling jobs in the two-machine flow shop where machines have some periods of limited availability. A problem of minimizing makespan in such a flow shop is NP-hard in the strong sense. Moreover, no polynomial time heuristic with finite relative error exists for the problem unless $P = NP$. One of the standard approaches for solving intractable problems is a branch and bound method. In the talk two parallel algorithms will be considered. Both have a master-slave structure and have been implemented on IBM SP2 machine.

A comparison of the efficiency of different variants of the algorithms depending on a search strategy and a number of processors has been made. Possible generalitations are pointed out.

Lower Bounds for On-Line Bin-Packing Algorithms

FRI-Plenary, 13:30-14:30

GABOR GALAMBOS
Comp. Science Dept, Teacher's Training College, Szeged
author: Gabor Galambos
keywords: lower bounds, bin packing problem, geometrical packing, vector packing, heuristics

In the classical bin packing problem there are given a list of elements $L_n = \{a_1, a_2, \ldots, a_n\}$, with sizes $s(a_i) \leq C$, $i = 1, 2, \ldots, n$, and an infintevely number of empty bins with capacity C. We have to pack the items into minimal number of bins in such a way that the sum of the sizes in the same bins may not be larger than the bin capacity. Since the problem is known to be NP-hard, a lot of heuristics have been developed to give an approximation solution. Some of them are on-line: in these type of algorithms we have to pack the elements on order of the appeariance without knowing anything about the subsequent elements. The packed elements are not allowed to move later. Most of these algorithms have been analyzed from worst case point of view.

The talk is divided into two parts: in the first one we overview the on-line algorithms for the classical problems and we present the lower bounds for that class of heuristics. We show a very simple example to construct such lower bound and we will give the best known bound too. In the second part we define different generalizations of the classical problems: the geometrical packing and the vector packing will be considered. We will show some on-line algorithms for these generalized problems and we give the lower bounds too.

Partitioning a graph to satisfy all vertices

WED-I Graphs I, 11:30-12:00

MICHAEL GERBER
Swiss Federal Institute of Technology
authors: Michael Gerber, Daniel Kobler
keywords: graphs, graph partitioning, satisfactory, complexity

In a given graph, we want to partition the set of its vertices in two subsets, such that each vertex is satisfied in that it has at least as many neighbours in its own subset as in the other. By introducing weights for the vertices and the edges, we generalize the problem. We discuss the complexity of these problems and exhibit some sufficient conditions for the existence of a partition where all vertices are satisfied.

Commercial and Research Implementations of Tailored Metaheuristics for Integer Programming

WED-Plenary, 13:30-14:30

FRED GLOVER
University of Colorado
authors: Fred Glover, Arne Løkketangen, David Woodruff
keywords: metaheuristics, integer programming, commercial implementation, research implementation

Metaheuristics such as the evolutionary methods of genetic algorithms and scatter search, the Markov-based processes of simulated annealing, the adaptive memory approaches of tabu search, and a variety of others have captured attention in recent years for their applications to a wide range of combinatorial optimization problems. Up to now, however, these developments have focused on creating specialized methods for particular classes of problems, or for creating extremely general "software shells" that are mainly for convenience (as in preliminary implementations).

A new step is now being launched with the development of a commercial grade software system for solving zero-one mixed integer programming (MIP) problems, with associated extensions to handle general MIP problems. This work integrates previous developments in creating adjacent extreme point methods for zero-one MIP problems based on tabu search and scatter search, motivated by the finding that this type of zero-one MIP approach has matched the best solutions found by specialized methods on a number of classical benchmarks for special problems. The new advanced system is currently being embedded in routines that can be implemented in association with XPRESS-MP.

We describe the fundamental design and implementation issues of creating such a metaheuristic system for integer programming, and of effectively exploiting routines that have been created for branch and cut methods. We also identify how this work can be additionally integrated with branch and cut methods, by means of the developments underlying star-path procedures, which provide theory and rules for "jumping across" solution spaces.

Configurations in Steven Vajda's books on combinatorics

THU-V Parallel aspects, 12:00-12:30

HARALD GROPP
Universitaet Heidelberg
author: Harald Gropp
keywords: steven vajda, configurations, designs

Steven Vajda was born in Budapest in 1901 and died in England in 1995. He was one of the leading scientists in the field of linear programming. Vajda published a lot of books, two of which do not belong to his main field of research. However, they are his "central" books, no. 8 and no. 9 out of his list of 16 published books: *Patterns and configurations in finite spaces* and *The mathematics of experimental design* (1967).

The first book discusses prerequisites from abstract algebra and finite geometry in order to prepare the last chapter on configurations where triple systems, designs and similar combinatorial structures are dealt with.

The two prefaces of Vajda's books are identical. Vajda describes his point of view as follows.

The topics with which the two companion volumes ..... are concerned have a long history, but the main stimulus to new developments has come from the interest of statisticians in the efficient design of experiments. The origin of some of the patterns can be traced to recreational mathematics, or to problems in pure mathematics, particularly in number theory.

Vajda's words are an interesting source of information given by a scientist of our century who still listened to lectures on geometry by Hilbert in Göttingen in 1925. During the time of Vajda's scientific work the field of modern combinatorial theory developed into one of the main fields of mathematics of today.

In this talk the topic of configurations will be discussed from the point of view of Vajda's books, from the point of view of their general history, and from the point of view of modern research.

An Optimal Algorithm for Rectangle Placement

WED-IV Applications, 15:30-16:00

PATRICK HEALY
University of Limerick
authors: Patrick Healy, Ago Kuusik
keywords: rectangle layout, rectangle placement, stock cutting

Rectangle layout is an important problem with applications in many industries. A commonly used strategy for inserting rectangles into a two-dimensional layout is the *bottom-left placement* heuristic. Chazelle has given an $O(n)$-time placement algorithm when the layout has the bottom-left property *i.e.,* every rectangle in the layout touches some other rectangle (or a boundary) along its bottom and left sides. In this paper we consider the problem of finding efficiently a location at which to insert a rectangle in a two-dimensional layout that may not have the bottom-left placement property. This situation arises when we apply any one of a number of iterative improvement algorithms to the *cutting stock* problem or its variants. We show that the running time of the algorithm in this more general situation is $\Theta(n \log n)$-time.

With appropriate representations, in time linear in the number of rectangles already placed in the layout, it is possible to effect the placement of a rectangle in a layout. However, finding a location at which the rectangle may be placed orthogonally and without overlapping previously placed rectangles must be performed prior to this. We call such a location a *feasible* location.

To find a feasible location we firstly generate all possible locations at which the rectangle can be placed in a bottom-left manner and then choose the bottom-leftmost such location that respects feasibility. We show that there can be at most $O(n)$ bottom-left locations and that each of these steps can be performed in $O(n \log n)$-time.

By reducing the ϵ-*closeness* problem to the 1-D version of the rectangle placement problem, we show that the algorithm is optimal.

We also present computational results of an implementation of the algorithm.

A ring network design problem

FRI-XII Networks, 11:00-11:30

KAJ HOLMBERG
Linkoping University
authors: Mathias Henningsson, Kaj Holmberg, Mikael Ronnqvist, Peter Varbrand
keywords: network design, telecommunication, rings, heuristics, column generation

The development of optical fibers in telecommunications has brought on large changes in the field. When designing a telecommunication network, capacity nowadays is cheap, and the minimal cost design tends to be a tree. Since such a design is very vulnerable for link or node failures, one often wish to include some kind of survivability requirement, for example that the network should be 2-edge-connected or 2-node-connected.

Another form of design model is to prescribe that the network should be composed of connected rings of links (SDH/SONET). The network design problem is then to choose links from a given network, and compose them into a number of rings. Furthermore, the rings should be connected at certain transit nodes. Each possible ring is associated with certain fixed costs. All links in a certain ring are given the same capacity, and the corresponding costs are staircase formed. The traffic between rings may pass through other rings, and this is an important part of the problem. Finally, reserve capacity allocation according to certain principles is included.

We describe the problem, modeled as a linear integer programming problem, and discuss different formulations and different solution methods. As the problem is quite difficult, we focus on heuristic solution methods, including elements of column generation and Lagrangean relaxation.

Lamarckian genetic algorithms applied to the linear ordering problem

THU-VI Heuristics, 11:00-11:30

Olivier Hudry
Ecole nationale superieure des telecommunications
authors: Irene Charon, Olivier Hudry
keywords: hybridization of metaheuristics, genetic algorithm, simulated annealing, noising method, graph theory, feedback arc set problem, median orders

The NP-hard problem of linear ordering can be stated as follows. Given a weighted tournament T (that is, a complete asymetric digraph), find a minimum-weighted subset of arcs such that reversing these arcs in T transforms T into a transitive tournament (that is, into a linear order). This problem, also known as the feedback arc set problem, occurs in different fields: in the social sciences, in electrical engineering, in statistics, in mathematics... For instance, in voting theory, the vertices of T may represent candidates; an arc from candidate x to candidate y means that a majority of voters prefers x to y; the weight of such an arc (x, y) denotes the intensity of this preference; then, in this context, the linear ordering problem consists in finding a collective ranking (called a median order of T) of the candidates which summarizes the preferences of the voters as best as possible.

To find good approximate solutions, we hybridize some metaheuristics with a genetic algorithm. More precisely, at each generation of the genetic algorithm, we consider a population of linear orders that we cross to get new linear orders. Then, instead of the classic operator of mutation, we apply a metaheuristic based on elementary transformations (namely, an iterative improvement method, a simulated annealing or a noising method) to each new linear order L got by such a crossover in order to improve L. For the linear ordering problem, our experiments, made on tournaments with 100 to 240 vertices and with maximum weights ranging from 1 to 1000, show that such a hybridization brings improvements to the already good methods that we hybridize.

Minimizing maximum lateness for discrete-continuous scheduling problems

FRI-XI Scheduling III, 11:00-11:30

Joanna Józefowska
Institute of Computing Science
authors: Joanna Józefowska, Marek Mika, Rafał Różycki, Grzegorz Waligóra, Jan Węglarz
keywords: discrete-continuous scheduling, maximum lateness, heuristics

We consider the problem of scheduling independent nonpreemptable jobs on parallel identical machines with an additional continuous resource with the objective to minimize the maximum lateness. The continuous resource can be allotted to jobs in amounts (unknown in advance) from a given interval. The processing rate of a job is a continuous, nondecreasing and concave function of the amount of the continuous resource allotted to this job at a time. The problem is to find an assignment of jobs to machines and, simultaneously, a continuous resource allocation which minimize the maximum lateness. A feasible sequence is a sequence of combinations of jobs which fulfils the following conditions:
(i) number of jobs in any combination does not exceed the number of machines,
(ii) each job appears in at least one combination,
(iii) nonpreemptability of each job is guaranteed.
For a given feasible sequence an optimal continuous resource allocation can be found by solving a nonlinear mathematical programming problem. An optimal schedule for a given instance can be found by solving the mathematical programming problem for each feasible sequence for that instance and choosing the best solution. However, in general, the number of all feasible sequences grows exponentially with the number of jobs which makes this approach computationally intractable. We propose a branch and bound algorithm to solve this problem. We also identify some special cases for which the problem can be solved in polynomial time.

The Chic-2 Methodology: An efficient and effective methodology for combinatorial optimisation in practice

THU-VIII CHIC2 I, 13:30-14:15

ERIC JACQUET-LAGREZE, PHILIPPE WOLFF
Euro-Decision
authors: Jean-Marc David, Eric Jacquet-Lagreze, Philippe Wolff
keywords: hybrid algorithms, large scale combinatorial optimisation (lsco), methodology, project development, project management, project life cycle

The Chic-2 Methodology aims at proposing refinements or adaptations to 'generic' methodologies in order to enhance their ability to deal efficiently with large scale combinatorial optimisation (LSCO) projects. It is developed based on the internal methodologies and experiences of the members of the Chic-2 ESPRIT Project. Its objectives are to reduce the time required to handle new problems, to lower the expertise level needed and to enhance the quality of solutions measured in term of user satisfaction but also time and cost of development.

The Chic-2 Methodology focus on the specificities of LSCO projects in three main areas: project management, problem definition and problem design. Typical problems that are particularly relevant to LSCO projects are for instance: the management of risks due to changes in the problem definition that may strongly modify the solution design, the capture and validation of the customer's requirements that may be a difficulty due to its lack of familiarity with the optimisation techniques, the mapping of a problem on the most adequate resolution technique that may not be straightforward, particularly when considering the possibility of designing of hybrid solutions... The Chic-2 Methodology propose then an adapted project life cycle, as well as specific techniques for project management (project planning, risk management, ...), problem definition (conceptual model, validation of the problem definition, ...) and problem solving (characterisation of the problem, hybrid algorithms, prototyping, tuning, ...).

On some properties of DNA graphs

WED-I Graphs I, 11:00-11:30

Daniel Kobler
EPFL, Swiss Federal Institute of Technology
authors: Jacek Błażewicz, Alain Hertz, Daniel Kobler, Dominique de Werra
keywords: dna chain recognition, graph theory, graph labeling

The field of molecular biology consists in studying the structure and functions of DNA and proteins. It has stimulated research in different scientific disciplines, discrete mathematics being one of them. One of the problems considered is that of recognition of DNA primary structure: what is the sequence of bases (letters A, C, G or T) of a given DNA chain. Among the different methods are available for solving this problem, some of them are reducable (in their computational part) to graph theoretic problems involving labeled graphs. In this talk properties of these graphs will be presented.

A linear algorithm for the pos/neg-weighted 1-median problem on a cactus

WED-III Graphs II, 16:00-16:30

JAKOB KRARUP
DIKU, University of Copenhagen
authors: Jakob Krarup, Reiner E. Burkard
keywords: graphs

The 1-median problem in a network asks for a vertex minimizing the sum of the weighted shortest path distances from itself to all other vertices, each associated with a certain positive weight. Inspired by a so-called "Complementary Problem" proposed and incorrectly solved by Courant and Robbins in 1941, we allow for negative weights as well and devise an exact algorithm for the resulting "pos/neg-weighted" problem defined on a cactus, that is, a network in which no two cycles have more than one vertex in common. The algorithm is shown to run in linear time since each vertex is considered exactly once.
Reference: R.E. Burkard and J. Krarup, "A linear algorithm for the pos/neg-weighted 1-median problem on a cactus", to appear in Computing.

Creating and Evaluating Hybrid Algorithms for Inventory Management Problems

THU-VIII CHIC2 I, 14:15-15:00

CLAUDE LE PAPE
Bouygues - Direction des Technologies Nouvelles
authors: Philippe Baptiste, Yves Caseau, Tibor Kökény, Claude Le Pape, Robert Rodosek
keywords: inventory management, resource allocation, scheduling, hybrid algorithms, linear programming, constraint programming

Many industrial optimization problems are mixed problems. For example, industrial scheduling problems include resource allocation sub-problems, industrial vehicle routing problems include scheduling and packing sub-problems, etc. In such cases, it is a real challenge to design and implement robust problem-solving algorithms that efficiently account for the different aspects of the overall problem. Indeed, different optimization techniques, e.g., linear programming, constraint programming, genetic algorithms, local search, etc., tend to perform well on some - but not all - aspects of the complete problem. As a result, one of the most promising strategy consists in developing an algorithm that combines different optimization techniques, i.e., ahybrid algorithm. The aim of this paper is to present (1) an industrial inventory management problem, which consists of two main sub-problems, i.e., a resource allocation sub-problem and a scheduling sub-problem, and (2) the algorithms that have been developed so far for this problem, in the context of the European project CHIC-2 (ESPRIT Project 22165). It is shown that both linear programming and constraint programming can effectively contribute to the resolution of this problem.

Transformations of graphs for the stable set problem

THU-IX Graphs III, 15:30-16:00

VADIM LOZIN
University of Nizhny Novgorod
authors: Vladimir Alekseev, Vadim Lozin
keywords: graph transformations, stability number

We study graph transformations which change the stability number by a constant or which preserve it. Such transformations have been repeatedly used both for reducing [1] and for solving [2,3,4] the stable set problem.

First, we introduce the concept of transformation scheme that permit us, in particular, to restrict ourselves by investigation of transformations preserving the stability number. Next, we characterize stability-preserving transformations by two criteria and propose a method for systematic development of such transformations. We apply this method to produce a number of transformations including the vertex splitting [1] and demagnetizating [4].

Also we describe a class of transformations providing a general technique for computing the stability number of any graph. This technique generalizes the struction method proposed in [2]. It is known, in some cases the struction method leads to polynomial algorithms (for example, see [3] for some subclass of claw-free graphs). The extended class of transformations we proposed enlarges the efficiency domain for the method. Particularly, we show that it contains transformations which provide polynomial solvability of the stable set problem for any claw-free graph.

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Parallel tabu search for two-dimensional cutting

THU-V Parallel aspects, 10:30-11:00

Adrian Moret-Salvador
Institute of Computing Sciencie. Poznan University of Technology
authors: Jacek Błażewicz, Adrian Moret-Salvador, Rafal Walkowiak
keywords: cutting, tabu search, parallel algorithms

Tabu local search generally uses candidate list strategies to systematically reduce the size of very big or expensive to evaluate neighbourhoods. A new problem-independent candidate list strategy for tabu search heuristics will be presented. Due to this strategy, the tabu method will inherit a probabilistic behaviour. This behaviour will be described and compared with a classical probabilistic tabu search and with tabu heuristics without this implementation. Experimetal results of both the new and the classical probabilistic tabu search will be shown when applied to the problem of cutting irregular shapes from a rectangular piece of material in order to minimize the waste. This sequential heuristic was used to build up a multiple-walk parallel heuristic for the same problem. The way of performing this parallelism will be discussed. An experimental comparison between the parallel and sequential versions will be carried out.

Periodic Loading Problem: Exact And Heuristic Algorithms

THU-VI Heuristics, 10:30-11:00

JERZY NAWROCKI
Poznan University of Technology
author: Jerzy Nawrocki
keywords: scheduling, real-time systems, dynamic programming, heuristics

In many real–time systems such as aircraft controller, power plant controller etc. there are tasks (activities) which are periodic by nature, i.e. they have to be repeated with a given frequency or with a period π, which is the reciprocal of the frequency. Some of the tasks are vital to the system and if they are completed too late, it can cause a serious damage or even loss of life. Such tasks are called hard real–time tasks and they have to be scheduled carefully.

One of possible approaches to scheduling hard real–time tasks is periodic loading proposed by Schweitzer, Dror and Trudeau. In this approach processor time is divided into consecutive equal–sized time intervals called frames. Assume each frame is τ time units wide. If a task T_i has a period π_i, then one can say that T_i is to be executed every $p(i)$ frames, where $p(i) = \pi_i/\tau$. Let $f(i)$ denote phase of a task T_i, i.e. T_i is executed within frames of numbers $f(i) + k \cdot p(i)$, $k \in \{0, 1, 2, \ldots\}$. Now scheduling means finding such $f(i)$ for every task T_i, that total execution time of tasks assigned to each frame is not greater than τ. To make the problem easier some authors assume that periods are binary, i.e. periods have to form a geometrical progression with quotient equal to 2.

In the paper the periodic loading approach to scheduling hard real–time tasks with binary periods is investigated. It is shown that the problem is strongly NP–hard. It means that practically there is no chance to find an algorithm solving the problem in polynomial or pseudo–polynomial time. Hence, a greedy heuristic strategy is presented which complexity is $O(N \cdot P)$, where N denotes number of tasks and P is the maximal period. From computational experiments it follows that this heuristic is quite interesting. Moreover, an exact algorithm is described. Obviously, that algorithm has exponential complexity, but it has managed to solve a practical problem of scheduling tasks for F–16 aircraft in 28 seconds. We have also used that algorithm to build a heuristic strategy, which first reduces a given instance of the problem to a tractable one and then uses the exact algorithm to find a solution.

Exhaustive search and combinatorial optimization: Exploring the potential of raw computing power

THU-Plenary, 9:00-10:00

Jürg Nievergelt
Institut für Theoretische Informatik, ETH Zürich
author: Jürg Nievergelt
keywords: complexity, parallel computing, combinatorial optimization

For half a century since computers came into existence, the goal of finding elegant and efficient algorithms to solve "simple" (well-defined and well-structured) problems has dominated algorithm design. Over the same time period, both processing and storage capacity of computers have increased by roughly a factor of a million. The next few decades may well give us a similar rate of growth in raw computing power, due to various factors such as continuing miniaturization, parallel and distributed computing. If a quantitative change of orders of magnitude leads to qualitative advances, where will the latter take place? Only empirical research can answer this question.

Asymptotic complexity theory has emerged as a surprisingly effective tool for predicting run times of polynomial-time algorithms. For NP-hard problems, on the other hand, it yields overly pessimistic bounds. It asserts the non-existence of algorithms that are efficient across an entire problem class, but ignores the fact that many instances, perhaps including those of interest, can be solved efficiently. For such cases we need a complexity measure that applies to problem instances, rather than to over-sized problem classes.

We present case studies of combinatorial enumeration and optimization problems designed as experiments to explore the practical limits of computational feasibility. And ZRAM, a program library of parallel search algorithms used for rapid prototyping of large discrete computations.

Using a Gallois Lattice for Constructing a Minimal Set of Capacity Constraints in Stock Management

WED-IV Applications, 15:00-15:30

Yves Niquil
Electricite de France
authors: Yves Niquil, Michel Gondran
keywords: stock management, gallois lattice, constraints, preprocessing

In the context of nuclear fuel re-use, plutonium stock management consists in choosing the optimal :

output operations : assigning plutonium batches to new fuel manufacturing campaigns.

input operations : assigning used nuclear assemblies to reprocessing campaigns.

An efficient decomposition consists in starting by computing first *output operations*, but considering initial stock plus every plutonium batch that could be created by an input operation. The difficulty comes from the fact that each used nuclear assembly can be reprocessed only by some reprocessing campaigns. The first stock output computation has to take into account a binary array, stating to which reprocessing campaign each assembly can be assigned, in order not to exceed the capacity of campaigns to handle each kind of assembly towards this array.

The problem is *to construct the minimal set of capacity constraints for stock output computation.*

The first step of the resolution consists in clustering used nuclear assemblies, regarding the corresponding profile extracted from the binary array. We have then a partition of the assemblies, and to each assembly subset corresponds a set of authorized campaigns.

From this initial set of classes, we construct a half Gallois lattice using closure by union on the campaigns sets. For every element of the lattice, we set a constraint on stock output computation, limiting the amount of the considered assemblies to be selected, to the total capacity of the considered campaigns. The other half lattice can be constructed, but since its elements contain no assemblies, it is not useful for the resolution.

We show that this set of constraints is the *minimial set* to ensure that stock output computation will take into account the whole set of input constraints.

Using a Genetic Algorithm for Optimizing the Location of Phase Shifters in the French Electric Network

THU-VI Heuristics, 12:00-12:30

Yves Niquil
Electricite de France
authors: Pierre Paterni, Yves Niquil
keywords: genetic algorithm, network optimization, optimal power flow, phase shifters

For minimizing electric production cost, knowing the production, the maximum flow for each line, and an electric load scenario, an optimal power flow is computed.

This plan has to be easily modified, in every case where one line is not working ("N-1" simulation). For avoiding that an overflow situation may occur in some of these cases, phase shifters are installed on the network to favor a better repartition of the flow. Where to settle these phase shifters is a difficult question, since the influence of these equipments on the power flow is complex, and therefore the optimal location is not necessarily on the bottlenecks.

Each possible solution has to be evaluated using the complex power flow computation module.

This problem is resolved by a genetic algorithm, coding the possibilities of location of the different phase shifters. As an objective function, we consider the financial rate of return, which is the ratio between the annual gain and the investment cost.

Scheduling tasks and vehicles in Flexible Manufacturing Systems.

FRI-XI Scheduling III, 12:00-12:30

GRZEGORZ PAWLAK
Institute of Computing Science, Poznań University of Technology
authors: Jacek Błażewicz, Marie-Laure Espinouse, Gerd Finke, Grzegorz Pawlak
keywords: scheduling, flexible flow shop, flexible manufacturing systems, vehicle routing

A development of Flexible Manufacturing Systems forces one to consider new scheduling models. Of special interest are the models which take into account the simultaneous scheduling jobs on processors and vehicles. The model considered is a flexible flow shop (with parallel machines) and with cyclic transportation system which automatically delivers parts (jobs) to machines. The system consists of some stages. Each stage contains one or more identical parallel machines. Routing of AGVs is cyclic in a steady cycle.

It is known for some time that scheduling tasks in the flow shop with two stages and parallel machines is NP-hard in a strong sense even if at one of these stages there is only one machine. Thus, the scheduling problem for the above model with parallel machines at the stages and with transportation system, is surely strongly NP-hard. In the paper it is shown for some specific problem assumptions that one can transform the scheduling model to the circular arc graph representation. Then the problem of finding a minimal fleet size for the given schedule is equivalent to finding a minimal cover by cliques for such graphs. The problem of finding a minimal number of vehicles for the general model leads to the problem of restricted coloring for circular arc graphs. The B&B algorithm and heuristics are proposed and the results of some computational experiments are presented.

An overflow model for network design problems

FRI-XII Networks, 11:30-12:00

FRANZ SALZBORN
University of Adelaide
authors: Franz Salzborn, Saeedeh Ketabi
keywords: network design, routing, undirected network

In this paper we propose a formulation of network routing problems using overflow variables, which are double indexed variables, one representing a link and the other a node of a complete network. These variables indicate how much of the load on the link overflows via the node. This includes the offered load for the corresponding OD–pair and also the overflow loads caused by the rerouting decisions.

This approach is particular usefull for undirected networks, but can also be employed for directed networks.

This is a new model and contrasts with the standard multicommodity flow formulations using path or flow variables and provides new insights and possibly suggestions for solving these type of problems.

The paper will concentrate on the application of this model to the network feasibilty problem: for given offered traffic for each OD–pair and given capacities of the links, determine whether all the traffic can be routed through the network. As this is a subproblem for most network design problems a good solution method could therefore be of benefit for a much larger class of problems.

The network feasibility problem is shown to be equivalent to a problem that can be formulated in a surprisingly simple way: for given link values $p_e|e \in E$, where E is the set of links of a complete graph, determine whether $\sum_{(i,j)\in E} p_{ij}u_{ij} \leq 0$ for all vectors $u = \{u_{ij}|(i,j) \in E\}$ satisfying the triangle inequalities $u_{ij} \leq u_{ik} + u_{kj}$.

Although this problem can be solved as a linear program, its combinatorial nature seems to suggest that there should be better polynomial methods. We will discuss one attempt to do this, although so far this has not been entirely successfull.

The ECLiPSe Approach to Solver Integration and Cooperation

THU-X CHIC2 II, 16:15-17:00

JOACHIM SCHIMPF, MARK WALLACE
IC-Parc, Imperial College
authors: Joachim Schimpf, Mark Wallace
keywords: constraint logic programming, hybrid techniques, cooperating solvers, problem modelling

Large-scale combinatorial optimisation problems are usually tackled by applying one of the established solving techniques, in particular Mixed Integer Programming, but also heuristic search techniques, Constraint Programming or various problem-specific algorithms. However, it is increasingly recognised that for many problems hybrid approaches might be more appropriate.

The ECLiPSe platform, which is being developed at IC-Parc, focuses on (1) High-level problem modelling (2) Flexible mappings to different solvers and (3) General mechanisms for combining solvers and search methods.

High-level problem modelling: The need for high-level modelling is quite obvious from the success of modelling languages for mathematical programming. A modelling language for a hybrid platform must be sufficiently declarative and at the same time be a full-blown programming language. We will explain why we believe that Constraint Logic Programming languages ideally fit this description.

Flexible mapping to solvers: Once a problem is modelled on a high enough level, the way of solving it can largely be specified separately. We will show that this is indeed practical and present some of the mechanisms we have used to map model constraints to solver constraints.

Combining solvers: The Constraint Logic model has shown to be a good unifying paradigm that enables very different solvers and search mechanisms to communicate with each other. We will present some examples of solver cooperations and their impact, and show how easy it can be to experiment with different solvers and solver combinations.

The Machine Representation of the Disjunctive Graph

WED-II Scheduling I, 11:00-12:30

MAŁGORZATA STERNA
Institute of Computing Science, Poznań University of Technology
authors: Jacek Błażewicz, Erwin Pesch, Małgorzata Sterna
keywords: disjunctive graph, graph machine representation, job shop scheduling

The work is concerned with a new time and memory efficient representation of a disjunctive graph. The disjunctive graph is a popular model used for describing instances of the job shop scheduling problem which contains all information in order to describe its partial or complete solution. Hence, the proper representation of the graph significantly influences the efficiency of an algorithm solving the job shop scheduling problem.

The proposed data structure for the disjunctive graph's description has the form of a graph matrix and combines advantages of a few classical graph representations enabling easy manipulation of the problem data. The graph matrix, of the size $(n+1)(n+1)$ where n is the number of non-dummy tasks, delivers combined information on a job shop in four different ways: as a classical neighborhood matrix and as lists of predecessors, successors and moreover as a list of tasks for which no precedence relation has been disclosed during the solution process. Using this data structures it is possible to obtain information about the mutual order of any pair of tasks in a constant time (by checking the value of a single matrix entry) and to get an immediate access to the mentioned three lists for each task.

The computational experiments showed the superiority of the proposed machine representation of the graph over classical ones, especially with regard to the time of extracting information on different relations among tasks. The flexible definition of the graph matrix allows one to easily adjust this data structure for particular requirements of an implemented algorithm solving the job shop scheduling problem. In addition, notwithstanding it is a data structure specialized for the disjunctive graph model, it can be also used to represent any graph structure.

Batching policies for shop scheduling problems

WED-II Scheduling I, 12:00-12:30

Vitaly Strusevich
School of Computing and Mathematical Sciences, University of Greenwich
author: Vitaly Strusevich
keywords: scheduling, batching, job shop scheduling

We consider two–machine flow shop and job shop scheduling problems to minimize the makespan under various batching policies.

In our first model, the jobs are divided into batches in advance. When scheduling the jobs, a batch can be split into smaller sub–batches. Setup is incurred each time when a machine either starts a new (sub)batch or switches from processing a job in one batch to processing a job from another batch. The setup times are both machine–dependent and batch–dependent. We discuss the complexity and approximation aspects of the flow shop problem.

The second model assumes that the decision–maker can group jobs into batches arbitrarily. The processing time of a batch is equal to the sum of processing times of its jobs. All jobs in a batch become available for further processing only when the whole batch is completed, so that no two batches containg a common job can be processed simultaneously. Machine–dependent setup is incurred when a new batch starts. Again, we concentrate on the flow shop results.

Our last model is similar to the second one. There are, however, two points of difference: (i) no setup is incurred, and (ii) the processing time of a batch is equal to the largest processing time of its jobs. We present algorithms and complexity results for the job shop environment.

A Comparison of Heuristic Algorithms for Flow Shop Scheduling Problems with Setup Times and Limited Batch Size

FRI-XIII Combinatorial optimization, 15:30-16:00

THOMAS TAUTENHAHN
Otto-von-Guericke-Universität Magdeburg
authors: Dan Danneberg, Thomas Tautenhahn, Frank Werner
keywords: flow shop scheduling, setup times, local search, insertion algorithms, heuristics

In this paper we propose different heuristic algorithms for flow shop scheduling problems, where the jobs are partitioned into groups or families. Jobs of the same group can be processed together in a batch but the maximal number of jobs in a batch is limited. A setup is necessary before starting the processing of a batch, where the setup time depends on the group of the jobs. In this paper we consider the case when the processing time of a batch is given by the maximum of the processing times of the operations contained in the batch. As objective function we consider the makespan as well as the weighted sum of completion times of the jobs. For these problems, we propose and compare various constructive and describe iterative algorithms that are based on different types of local search algorithms. Except standard metaheuristics, we also apply multi-level procedures which use different neighbourhoods within the search. The algorithms developed have been tested on a large collection of problems with up to 120 jobs.

An Object Oriented Approach To Generalized Generating Sequences

THU-IX Graphs III, 16:30-17:00

IGOR USHAKOV
QUALCOMM, Inc.
author: Igor Ushakov
keywords: generating sequences, object oriented approach

Method of Generalized Generating Sequences (GGS) is convenient and efficient for computerized enumeration and evaluations of alternative scenarios. Such problems arise frequently in discrete optimization. The GGS method is introduced in this paper and is applied to the problem of optimal redundancy. A concrete illustration is provided by a numerical example.

To facilitate the description, a polynomial representation of GGS is given at first. Next, resemblance of the GGS approach with standard generating function approach is demonstrated. A numerical example concerning spare allocation optimization conveys the essence of the method.

Then the GGS method is re-formulated in object oriented language. It is mapped into a hierarchy of objects determined by statistical attributes. Terminology of an ancient Roman military units: legion, cohort and maniple is adopted to characterize the object hierarchy. The GGS method may now be described in terms of interaction within and between legions, cohorts and maniples (LCM). In a sense, main idea of the LCM approach is close to the philosophy of an object oriented programming language like C++. A computer implementation using C++ is in progress.

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Aspects of structural Analysis in Shop Scheduling Problems with Makespan Objective

WED-II Scheduling I, 11:30-12:00

Per Willenius
Otto von Guericke Universitaet Magdeburg
authors: Heidemarie Braesel, Martin Harborth, Thomas Tautenhahn, Per Willenius
keywords: open shop scheduling, job shop scheduling, stability, structural optimal sequences

In a clasical shop problem n jobs have to be processed on m machines where either the machine orders of the jobs are given (job shop), or both job orders and machine orders can be chosen arbitrarily (open shop). A feasible (i.e., acyclic) combination of all job orders and machine orders is called a sequence. We use also two other models which represent a solution of a classical shop scheduling problem with makespan, namely the comparability graph (two vertices are adjacent if there is a from a path induced precedence relation between the corresponding operations) and the interval graph (two vertices are adjacent if the corresponding operations are scheduled simultaneously).

A sequence (and comparability graph) is defined independent of the processing times. Thus it is possible to investigate the set of sequences which are structurally optimal in the sense that for each set of processing times there is at least one structurally optimal sequence with minimal makespan. Direct application of this idea leads to an algorithm which generates all structurally optimal sequences and find in this set an optimal solution. We get a more practical approach if we use some of the information which is given by the processing times in the process of generating the structurally optimal sequences. One way to do this is to use a combination of interval graphs and comparability graphs.

We study the following problems: What operation sets and processing times are easy in the sense that an optimal solution can be found polynomially? What can we say about optimal schedules which remain optimal if the processing times vary a bit.

The Extended Car Sequencing Problem: initial results from the Chic-2 Project

THU-X CHIC2 II, 15:30-16:15

PHILIPPE WOLFF
Renault DOII-IPIA
authors: Jean-Marc David, Philippe Wolff
keywords: car sequencing problem (csp), constraint programming, hybrid algorithms, linear programming, simulated annealing

The Car Sequencing Problem (CSP) usually consists in computing a sequence of cars that satisfies some sequencing constraints, i.e. where vehicles having some characteristics in common are spaced by a minimum number of places. In practice, this problem is encompassed into the more general problem of scheduling cars over several days on one or several assembly lines. In addition to the sequencing constraints, this extended-CSP takes then into account daily production capacities or volume of supplies constraints. The objective is to find the longest sequence of vehicles that minimise the number of violations of the sequencing constraints and that optimise the performance of the production, for instance the volume of non consumed supplies or the average lateness on the cars expected production date.

The extended-CSP is one of the industrial combinatorial optimisation problem that are studied in the Chic-2 Project. Four approaches based on different resolution techniques have been proposed. However, due to the problem complexity, all of them are using a hybrid decomposition of the problem into two co-operating sub-problem, thus leading to potentially sub-optimal results. The first sub-problem consists in allocating vehicles to days and lines of production with an anticipation of the sequencing constraints while the second sub-problem is a succession of independent CSP for each day on each line. It appears that linear programming is the best approach for the allocation sub-problem. For the CSP, several techniques give very satisfactory results even on real size data sets (600 vehicles per day and line, 25 sequencing constraints and more than 75 configurations): constraint programming, heuristic, simulated annealing as well as linear programming. The use of a hybrid algorithm combining some of these approaches allows to improve the solution. Further improvements will require to enhance the interactions between the two sub-problems or to consider a global approach to the extended-CSP.

Exact Algorithms for Plane Steiner Tree Problems

WED-III Graphs II, 15:30-16:00

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keywords: exact algorithms, integer programming, branch-and-cut, steiner trees

We present the main results from a recent computational study of exact algorithms for the Euclidean and rectilinear Steiner tree problems in the plane. These algorithms — which are based on the generation and concatenation of full Steiner trees — are much more efficient than other approaches and allow exact solutions of problem instances with more than 1000 terminals. The full Steiner tree generation algorithms for the two problem variants share many algorithmic ideas and the concatenation part is identical (integer programming formulation solved by branch-and-cut). Performance statistics for randomly generated instances, public library instances and "difficult" instances with special structure are presented. Also, results on the comparative performance on the two problem variants are given.

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