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Theme:
ECCO is the annual meeting of the EURO working group on combinatorial optimization. ECCO was started in 1987 by a group of leading experts in Operations Research and Management Science. ECCO wants to provide a forum for researchers in combinatorial optimization, either in its theoretical aspects or in business, industry or public administration applications. This conference gives researchers an opportunity to present their latest results and to discuss current developments and applications, besides stimulating future interactions between the members of this scientific community. Topics of interest are found in all fields of combinatorial optimization, e.g. logistics, production, scheduling, resource and operations management, flexible manufacturing, VLSI design, network design, telecommunication.

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D. de Werra

EPFL, Lausanne, Switzerland

We consider the image reconstruction problem which occurs in tomography in the following simplified form: given an (mxn) array and the numbers a(i,s) (resp. alpha(j,s)) of pixels of colour i (resp. j) occurring in row i (resp. column j), can one reconstruct the image? And if so is there a unique solution?

We recall some basic results about this problem and examine special situations like the case where all colours but one (the ground colour) occur at most once in each row and column (unary colours). Simple graph theoretical models can be constructed for dealing with this type of question; we shall sketch some of these models and show what can be derived with elementary tools of graph theory. The problem amounts to finding disjoint partial subgraphs of a complete bipartite graph with some degree requirements; the theorem of Koenig-Hall provides conditions of solvability for several subcases of the basic problem.

In addition we intend to examine the classical class-teacher timetabling problem with unavailability constraints for the teachers; we will describe some reductions showing the general character of this model which encompasses a wide collection of timetabling problems.

Finally we exploit the analogy between the image reconstruction problem and timetabling to derive some complexity properties of both types of problems; this justifies the title of the presentation which is "Tomography: Exploring the Analogies for Timetable Optimisation". Additional requirements will be considered as well with their formulation in the model and complexity will be studied as well.

This is joint work with M.C. Costa and C. Picouleau at Conservatoire National des Arts et Metiers (Paris).

Scheduling with Generalized Disjunctive Graphs: Feasibility Issues

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Disjunctive graphs are a well-known modeling concept for job-shop scheduling and related machine sequencing problems. In a disjunctive graph the nodes correspond to the operations to be scheduled and the weighted arcs represent precedence constraints between pairs of operations. A conjunctive arc (i, j) expresses the condition that operation i must precede operation j, while a pair of disjunctive arcs (i, j), (j, i) expresses the condition that i must precede j or vice versa. Disjunctive arcs result from the fact that two operations i and j on the same machine cannot overlap in time. Since there is a one-to-one correspondence between feasible semi-active schedules and feasible selections in a disjunctive graph, an optimal schedule minimizing makespan can be found be determining a feasible selection that minimizes the length of a longest path in the associated graph. A distinctive property of disjunctive job-shop graphs is that each pair of disjunctive arcs contains two arcs with identical extremities but reverse orientation. We introduce a generalization of the classical disjunctive graph concept, allowing pairs of disjunctive arcs with different extremities. This generalization allows modeling a variety of sequencing problems in manufacturing and logistic systems. We consider in particular a version of the job-shop problem characterized by sequence-dependent set-up times and no buffers between machines. As a main result, we show that the feasibility problem for generalized disjunctive graphs - in contrast to the feasibility problem in the job-shop case - is NP-complete. The feasibility problem addresses the question of whether a generalized disjunctive graph has a feasible selection, i.e. a complete, positive acyclic selection of disjunctive arcs. The proof is based on a polynomial-time reduction of the SAT-problem to the feasibility problem. We also discuss some implications of this complexity result on the design of solution methods. As a second extension of the classical disjunctive graph model, we discuss the introduction of arbitrary arc weights. Non-positive arc weights allow to describe various types of conditions typical for scheduling problems, such as due dates, limitations on total duration of some operations, synchronization and no-wait constraints. We address the feasibility problem for disjunctive graphs with arbitrary weights. Summarizing some existing results, we show that the complexity of the feasibility problem depends only on the conjunctive part of the graph: if it is acyclic, there exists a feasible selection; if it has a cycle of positive weight, there is no feasible selection; if it has a cycle of non-positive weight, deciding on feasibility is NP-complete.

Batch scheduling in a hybrid flowshop with limited buffers

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The paper presents an exact approach by mixed integer programming for makespan minimization in a flexible flow line with limited intermediate buffers. The line consists of several processing stages in series, separated by finite intermediate buffers, where each stage has one or more parallel identical machines. The limited intermediate buffers between the stages result in a scheduling problem with machine blocking, where a completed part may remain on a machine and block it until a downstream machine becomes available. The problem objective is to determine an input sequence of batches of parts and an assignment of individual parts to processors in each stage over a scheduling horizon to complete all the parts in minimum time, where identical parts are processed consecutively. The mixed integer program includes various cutting constraints that were identified exploiting special configurations of hybrid flowshops with limited buffers and some properties of batch processing on parallel machines or on a single machine. The cutting constraints have an impact on reducing computational effort required to find the optimal solution. The mathematical programming formulation can be applied for constructing optimal batch schedules for small size batches of different part types and for various hybrid flowshop configurations by using commercially available software for mixed integer programming. This has been illustrated in the paper with numerical examples that have been modeled after real-world surface mount technology lines for printed wiring board assembly. For the examples proven optimal solutions were found in short CPU time using an advanced algebraic modeling language AMPL and the CPLEX solver. Furthermore, some computational results with the CPLEX solver are reported to illustrate the mixed integer programming approach.

Semi on-line scheduling on three parallel processors with known sum of the items

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We study a variant of the on-line scheduling problem on three parallel processors. The size of the items is unknown and each item must be immediately assigned to a processor as soon as it is released. The assignment cannot be changed later. The List Scheduling (LS) algorithm, which assigns the incoming item to the least loaded processor, is known to be 5/3-competitive. The LS algorithm is also proved to be optimal with respect to competitive ratio: no other algorithm can achieve a better performance ratio. When some information on the instance is given in advance, the problem is called semi on-line. We analyze the case that the total sum of the items is known in advance and we propose a 10/7-competitive algorithm for this case. We also compute a lower bound equal to 1.393... for the competitive ratio of a general algorithm.

Optimal Resource Scheduling with Decomposition of an Acyclic Digraph into Minimum no. of Unilateral Components

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Scheduling problems are among the most difficult combinatorial optimization problems, where classic approaches based on exhaustive enumeration have only limited success. Also techniques of digraph decomposition into edge-disjoint spanning subdigraphs having some prescribed property are applied to a variety of optimization problems confronted by various industries. In this paper, we present an algorithm for decomposing an acyclic digraph into minimum no. of unilateral components. The algorithm proposes a recursive method, based on some propounded theory, of collapsing the given acyclic digraph into a smaller digraph. Finally we get a digraph comprising only isolated vertices. The total no. of these vertices gives the minimum no. of unilateral components into which the digraph can be decomposed. Moreover, by expanding these vertices the required unilateral components are generated. In fact, this algorithm enables the end-users to generate all such decompositions. We further use a real-life case study to demonstrate how this method addresses a problem of optimal resource scheduling of a transport industry for performing its prescribed operations with or without constraints. We construct a digraph model using the problem inputs and constraints. Different operational constraints can play a major role in forming this digraph model. The minimum no. of unilateral components into which this digraph is decomposed signifies the optimal no. of resources required for the operations whereas the unilateral components specify the optimal schedules. The case study also discusses the impact of this method on minimization of the capital and recursive expenditure of an industry and maximization of its resource utilization. As resources are very expensive, by drawing optimal schedules an industry can increase profitability of its operations. Since minimization of operational cost is one of the main goals of any industry, the above theory and its variations can prove to be of great help to decision makers.

A Parallel Simulated Annealing Implementation for Uncapacitated Facility Location Problems

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Facility Location Problems, which are generally NP-Hard problems, have been played important role in operation research and manufacturing context. The un-capacitated facility location problem (UFLP) is basically a member of the family of location problems. This problem is also known simple plant location problem. In a general form, the problem is to determine the optimal number of facility echelons, the number and location of facilities in each facility echelon, the assignment of distribution activities / commodities to facilities, and the allocation of customer demand among the facilities. The UFLP has several application, such as bank account location problem, clustering problem, economic lot sizing, vehicle routing, network design, distributed data and communication networks etc. The modular simulated annealing (MSA) algorithm is the partitioned SA algorithm into shorter slices to be implemented in various configurations together with different methods and environments. The idea behind MSA is to have a more uniform distribution of random moves along the SA procedure. In fact, SA provides the solution process by a logarithmic distribution of random moves such that each random move starts a new hill climbing process to reach the global minimum. However, the logarithmic nature of this distribution may not help to rescue the solution from local minimum as in the case, when SA is applied to very difficult combinatorial optimisation problems like some of the hard benchmark job shop scheduling and facility location problems. Such problems need more random moves even in the latter part of the optimisation process. But the probability of having a random move at that stage is so low as to make it longer to reach the global optimum. On the other hand, MSA algorithm takes such a short time that it can be considered an operation when applied with a context of evolutionary processes, and it can be constantly applied to a particular solution as well as a population of solutions. This algorithm is so modular that it can be implemented into distributed and parallel and evolutionary computation environments. UFL problems have been studied for many years and thus there is a very rich literature in operations research for this kind of problems. Since they have NP-Hard nature, the larger the size of the problem, the harder to find the optimal solution and furthermore, the longer to reach a reasonable results. Due to these facts, distributed and parallel programming based multi agent implementations will give better results within acceptable time length. So, the aim of this paper is to discuss the usability of a parallel implementation of MSA running on distributed environment like Distributed resource machine (DRM) to solve the large size UFL problems those take longer time to be solved by other serial methods. We get the benchmark problems from OR Library in Beasley (1996).

Ant Colony Optimization for the Probabilistic Traveling Salesman Problem

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The Probabilistic Traveling Salesman Problem (PTSP) is a TSP problem where each customer has a given probability of requiring a visit. The goal is to find an a priori tour of minimal expected length over all customers, with the strategy of visiting a random subset of customers in the same order as they appear in the a priori tour. We solve the PTSP by means of an ant colony optimization metaheuristic, the probabilistic Ant Colony System (pACS). We investigate the solution quality of pACS in several probability configurations of customers. In particular we study the case of equal probabilities (homogeneous PTSP), and the more realistic case where customers are present with different probabilities (heterogeneous PTSP).

The Maximal Planar Graph Problem: Exact and LP-based heuristics/Meta-heuristics

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The maximal planar graph (WMPG) problem attempts to find a sub-graph from a sparse graph of unweighted arcs such that the sub-graph is maximal planar, i.e. no extra arc can be added without destroying the sub-graph planarity. In this talk, we introduce a new integer linear programming formulation; develop a branch and bound (B&B) tree search to solve small-sized instances to optimality. For large-sized instances, we developed three approximate procedures. First, the B&B tree search is allowed to terminate at the first feasible solution without a complete exploration of the whole search. Second, a divide and merge heuristic where a given large-sized instance is decomposed into smaller sub-graphs. Each subgraph is exactly solved by the B&B tree search procedure. The sub-graph solutions are then merged exactly to get a feasible solution to the original problem. Last, an LP-based meta-heuristic is also developed. It involves two stages. In the first stage, an LP-relaxation of the integer linear programming formulation is solved to obtain a good upper bound from which a set of good arcs is selected. In the second stage, the greedy adaptive search procedure of Resende & Reiberio (1997) developed for the problem is used to derive a feasible solution using the selected set of arcs. Computational results are reported on a set of benchmarks from the literature. In summary, the new formulated enabled the generation and confirmation of optimal solutions for some instances for the first time in the literature; the divide and merge heuristic provided good comparable results, while the LP-based meta-heuristic obtained the same quality of solution of the original GRASP but using less CPU time due to the reduced sized of solution space. In addition, the LP-based meta-heuristic solution has a proven guarantee on it its deviation from a good upper bound.

Some combinatorial facilities and the design of a heuristic for the quadratic assignment problem

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We discuss some features of the algebraic-combinatorial theory of the Quadratic Assignment Problem (QAP) in order to present three basic instruments which we are using in the design of heuristic algorithms applied to this problem. We consider a symmetric QAP instance given by two matrices of order n which we will call the "flo" and the "distance" ones.
First of all a classical linear relaxation is used to build a matrix (feasability matrix) which structure allows to the identification of feasible solutions within the lexicographically ordered relaxed set (of order C(n,2) = n(n-1)/2). Here this matrix is used to build starting solutions. For that we consider a second relaxed set obtained by ordering in opposite senses the "flow" and the "distance" data associated to the instance. This gives us two vectors and the two bounds are given by their scalar products in the two possible orderings of one vector with respect of the other. A transposition is then done in order to find the images of the identity and the identity-opposite permutation within the first relaxed set. The final matrix is the sum of the feasability matrices of the two bound solutions (affected by convenient signs and weights) added to a random matrix to allow variability of the choice. The Hungarian algorithm is then used to find lower-cost solutions with respect to the utilized weights.
The second feature is a new neighborhood structure that we call a rosace. It is a four-level structure constituted by the elements of the 4- and 6-cycles which contain a given solution in the Hasse graph (order n) of the QAP. The two more external and the internal level are of linear order and only the third (which contains the opposite vertices of the 4-cycles with respect to the central solution is of quadratic order. This structure is pre-built at the initialization step (over the identity permutation) and after we use permutation products to find the new solutions and then be able to calculate their cost increase values with respect to the current solution. This can be done because the structure pattern is instance-free for a given order.
The third feature is a restart strategy based on the search of lower inversion number solutions obtained by edge exchange, which allows us to obtain restart solutions within a larger but yet convenient neighborhood of the current solution. This resource has already been used (QAB99) to drive a simulated annealing algorithm for the QAP.
A classical local search is used to improve results at restarts.

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Large Frequency assignment in a low-earth orbit satellite constellation

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One of the major critical bottleneck in the telecommunication domain is to provide high-speed services (Internet, video transfer, video conferencing, ...) to local users who are not directly connected to a broadband network ("last mile" problem). A solution based on the use of a contellation of low-earth orbit (LEO) satellites has been newly designed. The advantages of using LEO satellites are a) to permit a short wave transmission delay between the ground and the satellites (around 20 ms), b) to improve the ground coverage accuracy and c) to provide worldwide services. The Skybridge system [4] studied in this paper can be considered as an extension of the broadband network. The globe is divided into cells, each one having at its center a gateway connected to the broadband network. When a user needs to send or receive data, two bidirectionnal links are established : one between the user and a visible satellite and another one between the chosen satellite and the gateway of the user.
An important problem is to plan the use of the system from a gateway point of view on an horizon of several days. User requests are aggregated and expressed as a gateway request for establishing communication channels. Each gateway is required to establish a given number of links with the visible satellites and to allocate a given number of frequencies within those links. An efficient management of such system is complex to obtain because of its dynamic behaviour and because of the numerous constraints an assignment has to satisfy in order to be feasible. A integer linear program of a real database is composed of approximately 400 000 variables and of 4 000 000 of constraints [3]. For this reason, we proposed to decompose the assignment in two steps. The first one, published in [1], consists of finding a link assignment between gateways and satellites. The second step, which is the objective of this study, consists of finding a frequency assignment for the chosen links. Due to the specific design of the constellation, a frequency interference can only occur when two neighbour gateways simultaneously communicate with the same satellite and with the same frequency. Knowing the potential interferences, thanks to the previous link assignment step, knowing the available frequencies in each gateway and knowing the number of frequencies to assign in each gateway, two frequency assignment problem have been considered [2] : the maximum service frequency assignment problem which forbids any interference and whose goal is to maximize the number of assigned frequencies and the minimum interference frequency assignment which assigns all required frequencies and whose goal is to minimize the number of interferences.
Two cases have been considered, depending on whether the chosen frequencies are allowed to change when the communication of a gateway commutes from a satellite to another one. On a real database, some problems could be optimally solved by formulating them as an integer linear program and applying a commercial software. For the more difficult problems, a graph multi-coloring approach combined with a meta-heuristic (tabu search) has been explored.

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Exploratory Studies of Heuristics Computational Mechanics

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The design of wireless telecommunications networks encompasses peculiar optimization problems. Most of them can only be satisfactorily approached by heuristic algorithms. As in many other practical optimization contexts, the classical analysis of such heuristics is hard to accomplish and yields too pessimistic results compared to their actual behavior. In addition, their experimental analysis is constrained by the huge differences between problem instances in this specific context. Yet, means to analyze and engineering these heuristics is a concern of utmost importance for telecommunications services providers due to the fast economical and technological evolution of the field. During the last three years we have developed in France Telecom Research & Development a method of algorithm analysis and engineering that is coherent with such a scenario. Here we will present our work with Multivariate Statistical Descriptive Analysis techniques for studying the mechanics of a heuristic's computation. With these techniques, like Principal Component Analysis and Factorial Correspondence Analysis, we explore the heuristic's log-run in search for patterns of relationships between the heuristic's algorithmic operators and elements of the input problem's structure. The effectiveness of these techniques in data dissection has enabled us to study real-world problems of practical interest. Allied to that, their sensitivity to statistical content, which is translated into conveniently interpretable graphs, has proved valuable in shading new light on our knowledge about heuristic/problem interaction. The insightful information these techniques raise from such interaction is to help us better engineering heuristics in the context of wireless networks' design. The applicability of this method to study the mechanics of heuristics from different optimization contexts is illustrated here through their use in didactic examples as varied as the Simplex method and the Knapsack problem. We will also discuss a large scale undergoing study on a state-of-the-art heuristic for the Traveling Salesman Problem, which better illustrates these techniques' capability for knowledge discovery.

An efficient multiple label-setting algorithm based on dynamic bounds for bi-criterion shortest path problems

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Multiple label algorithms are commonly used to solve multicriteria shortest path problems. In the particular context of two criteria, some specific results may be obtained in order to improve the enumeration of the set of efficient paths. In this perspective, we show how to derive dynamic bounds which progressively restrict the feasible domain of criterion values for efficient paths. Then we propose a label-setting algorithm which makes use of these bounds in order to improve the enumeration process. Computational results show that bounds can substantially reduce computation times.

Intensification and diversification strategies for the SONET Network Design Problem

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Synchronous Optical Network (SONET) in North America and Synchronous Digital Hierarchy (SDH) in Europe and Japan is the current transmission and multiplexing standard for high speed signals within the carrier infrastructure. The typical topology of a SONET network is a collection of rings connecting all the customer sites. Each customer needs to transmit (receive) a given traffic with a subset of the other customers. Add-drop multiplexers (ADM) and digital cross connectors (DXC) are the technologies allowing the connection within the ring and between different rings, respectively.
Mainly, the design of a SONET network consists in the assignment of each customer to exactly one ring by using one ADM and allowing connection between different rings through a single "federal" ring composed by one DXCs for each connected ring. This problem is called SONET Ring Assignment Problem (SRAP) with capacity constraints. Under some distance requirements, a cheaper design approach is available: the federal ring is avoided and each customer can belong to different rings. This problem is called Intraring Synchronous Optical Network Design Problem (ISONDP).
For each problem, a solution method based on Tabu Search is proposed. The key elements are the use of a variable objective function and the strategic use of two neighborhoods. The second neighborhood plays the role of diversifying strategy. We have also implemented more sophisticated techniques as Path Relinking, eXploring Tabu Search (XTS) and a Scatter Search approach.
Extensive computational experiments have been done using available benchmark instances. The experiments show the effectiveness of the proposed Tabu Search.

On enumerating arrangement-cells and solving maxcut problems

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Reverse search is a well known efficient means for enumerating the cells of a regular hyperplane arrangement, or equivalently, the vertices of a zonotope. We present an enhanced version of reverse search of significantly reduced computational complexity that uses ray shooting and is well suited for parallel computation. We next address the weighted max-cut problem, or equivalently the problem of minimizing a quadratic form in n binary variables. If the underlying (symmetric) matrix is positive semi-definite of fixed rank r, then the problem can be reduced to searching the extreme points of a zonotope, thus becoming of polynomial complexity in $O(n^{(r-1)})$. Furthermore, a neighborhood zonotope edge following descent heuristic can be devised.

An approach to solve the non-proportionate flow shop with controllable processing times

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It is well known that scheduling problems with controllable processing times have an important role in deterministic sheduling research and applications. That is true, among others reasons, because the controllable processing times describes the practical situations even more realistically. As example we can refer, among others, to the papers of Vickson [1,2] and the comprehensive survey of Nowicki and Zdrzalka [3]. Many papers consider the single-machine problems since multi-machine shop problems turn out to be NP-hard even for the case of two machines. Others papers deal in the proportionate case (see for example Cheng and Shakhlevich [4]). The proportionate flow-shop problems with controllable processing times are problems where all the jobs must be performed through all the machines following the same machine-path (flow-shop problem). Moreover, for each job its different operations have the same processing times (proportionate), and these processing times are controllable, i.e., it is assumed that all operations of a job may be compressed by the same amount. In these problems the decision-maker has to decide the cost he/she is available to pay to reduce processing time with the aim, for example, to optimize makespan. The non-proportionate flow-shop problems are more general problems and, consequently, with more real applications. The non-proportionate case differ from the proportionate one, because the condition of equal processing times in the machines for the different operations of each job is relaxed. The aim of this paper is the non-proportionate flow-shop scheduling problem with controllable processing times. This problem is more difficult than the proportionate one due, in others, to the fact that the property of optimality of any permutation schedule for the proportionate case (Pinedo [5] p.103) does not keep in the non-proportionate case. As non-proportionate problems are more general and less restrictive, they have more applications to real situations. One of them would be, for example, *to optimize the time passed from the passenger arrival to the airport till his/her flight departure taking into account service costs*. This problem may be modelled as a non-proportionate flow shop with three machines (Check-in point, Police control, and Boarding gate) and a finite number of jobs (passengers). This paper presents an approach to find approximated solutions of the non-proportionate flow shop problem with the aim of minimizing makespan and the cost of compressing processing time to reduce such makespan. In our models we work with linear cost functions to represent compression costs and we are interested to find Pareto optimal. A computational study is also reported. To summarize, this paper considers a very interesting scheduling problem with many applications, and proposes an approach to solve these problems obtaining reasonable good solutions in relative short CPU times.

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Minimizing makespan on parallel machines subject to release dates and delivery times

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We consider the problem of minimizing the makespan on identical parallel machines subject to release dates and delivery times. The objective of this paper is to develop exact branch and bound algorithms to solve this strongly NP-hard problem. A preprocessing algorithm is devised to speed up the convergence of the proposed algorithms, and a new tight bounding scheme is introduced. The search tree is also reduced using a polynomial selection algorithm. Extensive computational experiments show that large scale instances can be solved exactly in a moderate CPU time.

Insertion of a Random Bitask in a Schedule: a Real-Time Approach

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We consider a schedule of tasks we call bitasks. A bitask is defined by two tasks separated by an idle period. The bitasks concerned by the schedule are processed on a single resource. A task is non-preemptive. The criterion used to build this schedule is the minimization of the sum of the delays.
An unexpected bitask appears in the system. The processing time of each one of the tasks as well as the period between the tasks, are known only when the bitask appears. We only know that the processing times of the two tasks of the bitask are equal. The bitask that appears has a deadline that cannot be violated. The goal is to insert this bitask in the schedule while increasing as less as possible the the sum of the delays of the initial schedule.
The difficulty of this problem is to insert the unexpected bitask in real-time.
To reach this goal, we propose an algorithm in which the main part of the computation is performed off-line. The complexity of the remaining computation, that is the computation that should be performed on-line, is polynomial.

A Tabu Search Algorithm For The Capacited Arc Routing Problem That Makes Use Of Lower Bounds

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The capacitated arc routing problem (CARP) is defined in a graph G = (V, E), where V is a set of nodes and E is a set of edges linking those nodes, and R contained in E is a set of edges that must be serviced by a given number of vehicles of the same capacity. There is a cost associated with each edge of E, and each edge of R requires a given demand. The CARP consists of defining a set of minimum cost routes such that each edge of R is travelled at least once by just one of the vehicles. Each vehicle starts from the depot and returns to it after servicing the edges assigned to it. There are many applications of this problem, usually containing some additional constraints, reported in the literature, like garbage collection, mail distribution, road cleaning, etc. In this research we solve the CARP using a new tabu search algorithm, which has as most innovative feature the fact good lower bounds for the CARP are used. The performance of our algorithm is compared with the best known algorithms for the same problem.

A Randomized Heuristic for the Min-Cut k-Balanced Partitioning Problem

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We consider the problem of finding a min-cut k-balanced partitioning in a connected graph with edge weights. The graph partition problem is a fundamental combinatorial optimization problem which has applications in many areas of computer science (e.g design of electrical circuits, mapping). This NP complete problem has along and rich history, several approaches have been proposed [AK95,Bli2001] such as move-based approaches, geometric representations, combinatorial formulations, and clustering approaches. Move-based algorithms iteratively explore the space of feasible solutions according to a neighborhood operator, such methods include greedy, iterative exchange, simulated annealing, and evolutionary algorithms. Algorithms based on geometric representations embed the circuit netlist in some type of "geometry", e.g, a 1-dimensional linear ordering on a multidimensional vector space, the embeddings are commonly constructed using spectral methods. Combinatorial methods transform the partitioning problem into another type of optimization, e.g., based on network flows or mathematical programming. Finally, clustering algorithms merge the netlist modules into many small clusters, we discuss methods which combine clustering with existing algorithms (e.g., two-phase partitioning). The term *graph partitioning problem* is used in literature for different problems, in this work the problem can be formulated mathematically as follow: Let $G = (V, E)$ be an undirected (weighted) graph, where $V = \{v_1, v_2, \ldots, v_3\}$ is the set of n nodes, EVV is the set of edges between the nodes. The graph k-partitioning balanced problem is to divide the graph into k disjoint subsets of nodes $V_1, V_2, \ldots, V_k$, such that the cost of the sum of (weighted) edges between the nodes in the different subsets is minimal, and the size of subsets are nearly equal. The subsets are called partitions, and the set of edges between the partitions is called a cut. We propose here an original approach for this problem which use a randomised heuristic. In this context we study the design and analysis of randomized on-line algorithm. Our algorithm uses different steps, it is recursive. The first step is a Borukva adaptive step [KKT95], this step reduces the number of vertices and maintain balanced subset. The second step is probabilistic and is used to decrease the number of edges. Both factors constitutes an efficient heuristic which keeps a good quality of cut.

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The Data-correcting Approach for Solving NP-hard CO Problems

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The data-correcting approach uses polynomial instances for finding high quality solutions of NP-hard combinatorial optimization problems. So this approach is a step into the direction of fulfilling an old wish of R.E. Burkard to use such instances (see chapter 4 of the classical TSP book of E.L. Lawler et al., 1990) At each iteration step, the current instance is corrected into a polynomial solvable instance, yielding an upper bound for the distance to the optimal solution. This makes it possible to stop the calculations when a given accuracy (difference between optimal and achieved solution) is reached. We present the striking calculation results for both the asymmetric and symmetric TSPs and for Simple Plant Location Problems.

Optimizing base station location and configuration in 3G cellular (UMTS) networks

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Base station location and configuration in UMTS networks cannot only rely on signal predictions but must also consider the traffic distribution, the signal quality requirements and the power control mechanism. Therefore the two-phase approach adopted for second generation cellular systems where the planning problem is subdivided into a coverage problem and a frequency assignment problem is no longer appropriate. We investigate discrete optimization models and algorithms aimed at supporting the decisions in the process of selecting the location and configuration of base stations. Our models capture at different levels of detail the signal quality requirements and the specific power control mechanism of the Wideband CDMA air interface. In this talk we underline the differences with respect to standard capacitated location problems, we discuss computational complexity issues and present computational results obtained with randomized greedy and Tabu Search algorithms for small to large-size instances.

Approximation algorithms for constructing wavelength routing networks

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We study the problem of designing a communication network composed of optical links, networks that utilize Wavelength Division Multiplexing (WDM). WDM Technology establishes communication between pairs of network vertices by selecting paths between such pairs and assigning wavelengths to each path so that no two paths going through the same fiber link use the same wavelength. Optical bandwidth is the number of distinct wavelengths. Since state-of-the-art technology allows for a limited optical bandwidth, the following SYNTHESIS OF WAVELENGTH ROUTING NETWORK problem (SWRN) is a natural one:
Given a graph $G = (V, E_R)$ and an optical bandwidth which is an integer K, design a network (multi-graph) with minimum number of links such that using K wavelengths it is possible to establish communication between every pair of vertices in E_R and allocate a path and a wavelength for each pair of vertices u and v, $(u, v) \in E_R$ such that if two paths share an edge they are allocated different wavelengths. E_R corresponds to the set of requirements.
Although we consider this problem as a natural one we are not aware of any previous discussion of this problem.
In previous papers a "dual" problem is considered, where the solution network is given and the problem is to compute a routing such that K, the optical bandwidth used in any edge, is minimized. However, we note that in practice K is not a decision variable but a constant defined by a technology constraint.
The problem of allocating paths and wavelengths to a given solution network for a given requirements network is NP-complete (even when the input solutions are restricted to simple graphs).
For $K = 1$ the optimal solution is G.
In this paper we first prove that SWRN problem is NP-hard for any constant K ($K \geq 2$). Then we assume that G_R is a clique with n vertices and we find an "almost" optimal solution network for all values of K ($K = o(n)$) and allocate paths and wavelengths for every pair of vertices. Finally we present a $Min\{\frac{K+1}{2}, 2 + \frac{2}{K-1}\}$-approximation algorithm for the general case and a 2-approximation algorithm for d-regular graphs.

Telecommunication Networks Synthesis Under Survivability Constraints

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We consider the problem of designing telecommunication networks that survive certain failure situations. Given point-to-point traffic demands and a cost/capacity function for each link, we wish to find the minimum cost capacity satisfying the given demands and the survivability requirements. Capacity and flow assignments are jointly optimized. For link failures, only the interrupted traffic is rerouted between its extremities (end-to-end rerouting). When a communication is rerouted through a new path, the capacity allocated initially to this communication is freed. In this presentation we propose three models that allow using the freed bandwidth. The problem of joint optimization of networks while reusing freed resources can be formulated as a large-scale linear programming problem. We use multicommodity flow models. Specifically, we present an Arc-Path model which contains a non polynomial number of columns. We prove that the separation problem of its columns is NP-hard. The constraints matrix structure of the arc-path model allows us to apply decomposition methods. We propose a decomposition algorithm based on Benders' method as well as a heuristic for its solution. The problem is polynomial when the lengths of the routing paths are bounded. In this case, an optimal solution is obtained. Then we present a polynomial relaxation of the problem based on the node-arc formulation of the multiflows. Some valid inequalities for the node-arc model are proposed. In the third model, capacities are selected from a discrete set of possible values. The topology of the network is optimized simultaneously along with the capacities of potential physical links and the traffic routing for each operating state. The resulting model is a mixed-integer linear programming problem. A cutting plane algorithm is proposed to solve the problem. The complexity of each model will be discussed during the presentation. A comparative analysis of the obtained computational results will be also presented.

Project Scheduling with Sequence-Dependent Changeover Times: Model and Applications

N. Trautmann, C. Schwindt

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Resource-constrained project scheduling deals with the allocation of scarce resources over time to the execution of activities, whose starting times are related by prescribed precedence relationships. In this talk we are concerned with the resource-constrained project duration problem subject to general temporal constraints and sequence-dependent changeover times. We assume that carrying out an activity requires a constant amount of one or several renewable resources like manpower or machinery. The renewable resources can be used in limited capacity only, which is given by the number of resource units available. Between the processing of two consecutive activities, resource units have to changed over, where the time needed for changeover may depend on both the preceding and following activities. Sequence-dependent changeovers arise in project management when the activities of a project are distributed over different sites sharing common resources. In this case, each changeover time includes a tear down time, a transportation time from one location to another, and a setup time. A different example of sequence-dependent changeovers are cleanings of processing units like reactors or filters between the execution of successive batches in process industries. In general, the cleaning times are larger when passing from a low- to a high-quality product than vice versa. We show that the problem of testing, for a given activity schedule, whether there exists an assignment of activities to resource units such that the joint requirements by processing and changeovers do not exceed the respective resource capacities can be formulated as a network flow problem. This problem consists of computing a minimum flow in the precedence graph with lower node capacities belonging to the schedule-induced partial order in the activity set. The latter perspective offers a natural way to expanding classical relaxation-based approaches for resource-constrained project scheduling to the presence of sequence-dependent changeover times.

Project Scheduling with Sequence-Dependent Changeover Times: A Branch-and-Bound Approach

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In many applications of resource-constrained project scheduling, resource units have to be changed over when switching from one activity to another. The corresponding changeover times are generally sequence-dependent, that is, they depend on both the preceding and following activities on that resource unit. This problem setting arises, e.g., when several (sub-)projects sharing common resources like manpower or equipment are to be performed in parallel at different sites. In this talk we deal with a branch-and-bound algorithm for minimizing the duration of resource-constrained projects subject to general temporal constraints between activities and sequence-dependent changeover times. The algorithm is based on the concept of forbidden activity sets. At each node of the enumeration tree, either the feasibility of the corresponding earliest schedule is established or a forbidden set of overlapping activities is identified by computing a maximum-weight stable set in the comparability graph of the schedule-induced partial order in the activity set. The latter stable set can be obtained efficiently by finding a maximum (s, t)-cut in a schedule-induced flow network with finite lower and infinite upper arc capacities. Child nodes arise from breaking up the forbidden set found by introducing disjunctive precedence constraints between sets of activities. Computational experience with projects including up to 100 activities is reported.

Fitness Uniform Selection to Preserve Genetic Diversity

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Evolutionary algorithms (EA). Evolutionary algorithms are capable of solving complicated optimization tasks in which an objective/fitness function $f : I \to \mathbb{R}$ shall be maximized. $i \in I$ is an individual from the set I of feasible solutions. In steady state EAs a population $P \subseteq I$ of individuals is maintained and is updated by selecting (and possibly deleting) a few individuals from the current population and adding the newly recombined and mutated individuals to it. We are interested in finding a single individual of maximal fitness f for difficult multimodal and deceptive problems.

The problem of local optima and the right selection pressure. Proportionate, truncation, ranking and tournament are the standard (STD) selection algorithms used in evolutionary optimization. The right selection pressure is critical in ensuring sufficient optimization progress on the one hand and in preserving genetic diversity to be able to escape from local optima on the other. There are various suggestions to dynamically determine and adapt the selection pressure parameters. Other approaches to preserve genetic diversity are fitness sharing, crowding, and local mating. They all depend on the proper design of a neighborhood function based on the specific problem structure and/or coding. In the following we suggest a new selection scheme, which automatically generates a suitably adapting selection pressure and which does not need special problem insight.

The Fitness uniform selection scheme (FUSS). The proposed fitness uniform selection scheme FUSS is defined as follows: *if the lowest/highest fitness values in the current population P are $f_{min/max}$, we select a fitness value f uniformly in the interval $[f_{min}, f_{max}]$. Then, the individual $i \in P$ with fitness nearest to f is selected and a copy is added to P, possibly after mutation and recombination.* FUSS maintains genetic diversity better than STD, since a distribution over the fitness values is used, unlike STD, which all use a distribution over individuals. Premature convergence is avoided in FUSS by abandoning convergence at all. Nevertheless there is a selection pressure in FUSS towards higher fitness: The probability of selecting a specific individual is proportional to the distance to its nearest fitness neighbor. In a population with a high density of unfit and low density of fit individuals, the fitter ones are effectively favored. The equilibrium distribution is uniform in the fitness values, i.e. the number of individuals in a fitness interval $[f, f + \Delta f]$ is independent f.

Transformation properties of FUSS. FUSS is independent of a scaling and a shift of the fitness function, i.e. FUSS($\tilde{f}$) with $\tilde{f}(i) := a \cdot f(i) + b$ is identical to FUSS(f). This is true even for $a < 0$, since FUSS searches for maxima *and* minima. It is not independent of a non-linear (monotone) transformation unlike tournament, ranking and truncation selection. The non-linear transformation properties are more like the ones of proportionate selection.

Analytical results on an artificial example. We demonstrated analytically by way of a simple artificial optimization example with a fitness function which has sort of a XOR structure which is hard for most optimizers that an EA with FUSS can optimize much faster than with STD. We show that crossover can be effective in FUSS, even when ineffective in STD. Furthermore, FUSS and STD are compared to random search with and without crossover.

Results for the Traveling Salesman Problem. We further applied FUSS to the Traveling Salesman Problem. We considered $10^{1..3}$ cities with random matrix distances, random initial paths, random 1-Opt and 2.5-Opt mutation operators, inverse path length as fitness, but no crossover yet. The solutions found by FUSS are consistently and significantly better than those found by STD (in the range of 20-50% given same number of selections and comparable parameter settings). The current implementation can in no way compete with up-to-date TSP-solvers, but this was not the intention of the comparison.

Improvements. Furthermore, there is a possible slowdown of FUSS as compared to STD on simple unimodal problems. This potential slowdown is expected to disappear by using a scale independent selection scheme, which is sort of a "best" compromise between greedy hill climbing and FUSS.

Lower and upper bounding strategies for the Generalized Minimum Spanning Tree problem

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The Generalized Minimum Spanning Tree problem (GMST) requires spanning at least one vertex out of every set of disjoint vertices in a graph. We show that the Euclidean version of this problem is NP-hard, and we propose a new integer programming formulation and lower bounding strategy. Also, a probabilistic greedy search algorithm is implemented and shown to yield a simple, robust, and quite fast heuristic. Computational experiments performed on a large set of instances show that the proposed method outperform other existing heuristics.

Friday 31st May

On combining exact and heuristic solution methods for combinatorial problems: illustration on a class of hard discrete cost network optimization problems

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Our aim is to illustrate, by means of some recent progresses achieved on a class of particularly hard problems arising in optimal network design, some typical ways of organizing interaction between exact solution methods and approximate solution methods for combinatorial problems. It will be shown that such interactions appear to be potentially useful in both ways, namely: 1) using heuristic methods to make an exact method more efficient, and 2) exploiting the ideas of exact methods to design heuristics with improved performances.

Constraint Propagation and Problem Decomposition: A Preprocessing Procedure for the Job Shop Problem

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In recent years, constraint propagation techniques have been shown to be highly effective for solving difficult scheduling problems. In this paper, we present an algorithm which combines constraint propagation with a problem decomposition approach in order to simplify the solution of the job shop scheduling problem. This is mainly guided by the observation that constraint propagation is more effective for 'small' problem instances. Roughly speaking, the algorithm consists of deducing operation sequences that are likely to occur in an optimal solution of the job shop scheduling problem (JSP). The algorithm for which the name edgeguessing procedure has been chosen – since with respect to the JSP the deduction of machine sequences is mainly equivalent to orienting edges in a disjunctive graph – can be applied in a preprocessing step, reducing the solution space, thus speeding up the overall solution process. In spite of the heuristic nature of edge guessing, it still leads to near optimal solutions. If combined with a heuristic algorithm, we will demonstrate that given the same amount of computation time, the additional application of edgeguessing leads to better solutions. This has been tested on a set of well known JSP benchmark problem instances.

A heuristic approach for the job shop scheduling problem with availability constraints

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Macsi team of INRIA/LORIA, Ecole des Mines de Nancy (INPL), France

Most of papers dedicated to scheduling problems take the common assumption that the machines are available during the whole planning horizon. However, this assumption may be not true if a breakdown occurs, or if a maintenance task is to be processed on a machine. This paper addresses the job shop scheduling problem with availability constraints (JSPAC). In such a problem one has to schedule n jobs on m machines under the assumption that these machines are not continuously available for processing jobs. The objective function is to minimize the makespan. The unavailability periods are supposed to be known in advance as a preventive maintenance activity. Further, the operations of jobs are strictly not preemptable i.e. the execution of an operation can be interrupted neither by a maintenance task nor by another operation. We consider several unavailability periods arbitrarily distributed on the machines. According to the notation given in [3], the problem can be denoted by J, NCwin // Cmax. Being an extension of the classical job shop, the scheduling problem of JSPAC is NP-hard in the strong sense. To the best of our knowledge, no paper in the scheduling literature deals with the job shop problem with availability constraints. The job shop scheduling problem with two jobs subject to release dates and availability constraints is first considered. We show that the problem is polynomialy solvable by using a generalization of the classical geometric approach [1,2]. Based on this extension, a heuristic approach is then developed for solving the general case with several jobs. It consists in applying the two-job resolution procedure to pairs of jobs, according to a sequence representing a priority rule between jobs. More precisely, the two first jobs are optimally scheduled and release dates are associated to the next two jobs to be processed. The procedure is repeated until the examination of all jobs. Obviously, the quality of the solution given by the heuristic strongly depends on the job sequence. In order to optimize this sequence, a taboo search approach is employed. For lack of benchmarks devoted to the JSPAC, numerical experiments are performed on randomly generated instances to test the efficiency of the proposed approach.

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A branch-and-bound based local search algorithm for the flow shop problem

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It is well known that exact branch-and-bound methods can only solve small or moderately sized NP-hard combinatorial optimization problems. In this paper, we address the issue of modifying an exact branch-and-bound algorithm so that it could be used as a local search method and provide near optimal solutions for large scale instances. The resulting heuristic has been applied to the problem of finding a minimum makespan in the permutation flow shop problem. Computational experiments carried out on a large set of benchmark problems show that the proposed method solves almost optimally instances with up to 200 jobs and 10 machines. Comparisons with the best existing heuristics confirm the excellent accuracy of the proposed approach.

Simulated annealing algorithm for multi-mode resource-constrained project scheduling problem with discounted cash flows

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The multi-mode resource-constrained project scheduling problem with discounted cash flows (MRCP-SPDCF) is considered. The problem can be described as follows. A project consists of n activities. The precedence relations between activities are defined by a so called activity-on-node graph G=(V,E) where a set of nodes V and a set of edges E represent the activities and the precedence relations, respectively. Graph G is assumed to be directed, acyclic, transitively reduced and topologically ordered (an activity has always a higher number than all its predecessors). It is assumed that there are R renewable and N nonrenewable resources. The number of available units of the k-th renewable resource k = 1,2,...,R, is denoted by R_k and the total number of units of the l-th non-renewable resource l = 1,...,N, is denoted by N_l. Each activity j has to be executed in one mode from the set of modes M_j which consists of alternative processing ways of activity j. Each activity j executed in mode m, requires for its processing r_{jkm} units of the renewable resource k, k = 1, 2,..., R, and consumes n_{jlm} units of the nonrenewable resource l, l = 1, 2,..., N. The activities are non-preemtable and an activity j started in mode m must be completed in this mode. The duration of activity j executed in mode m is denoted by d_{jm}. A positive cash flow CF_j is associated with the completion of each activity j. Positive cash flows (i.e. cash inflows) correspond to payments for the completion of activities obtained by the contractor. The objective is to find a precedence- and resource-feasible schedule which maximize the net present value (NPV) of the cash flows. The problem is strongly NP-hard. Moreover, for more than one non-renewable resource the problem of finding a feasible solution is already NP-complete. A simulated annealing (SA) approach is proposed to find sub-optimal solutions. In this algorithm a feasible solution is represented as two lists: a precedence feasible list of activities and a mode assignment list. The performance of this algorithm is validated on the basis of extensive computational experiment on a set of benchmark problems. The obtained results are compared with results obtained by other heuristics.

Global optimization: is quantum simulated annealing better than classical?

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Quantum annealing was recently found experimentally in a spin glass system to be more efficient than classical, thermal annealing. Motivated by this finding we study here the applicability of quantum simulated annealing as a global optimization algorithm for hard problems. Quantum simulated annealing was implemented by means of standard Path Integral Monte Carlo technique which is based on simulating a certain number of coupled replicas of the system. We chose the 2D and 3D Ising spin glass model as a test example and performed on it both classical and quantum simulated annealing. By studying systematically the dependence of the final residual energy $\epsilon_{res} = E_{final} - E_{GS}$ on the annealing time τ we confirm quantitatively the superiority of quantum relative to classical annealing. We also propose a theory of quantum annealing of a spin glass. For both classical and quantum annealing, the residual energy after annealing decreases as a logarithm of the annealing time τ, $\epsilon_{res}(\tau) \sim (\ln \tau)^{-\zeta}$, but the quantum case has a larger value for ζ which makes it faster.

Ant Colony System for Time Dependent Vehicle Routing Problem with Time Windows

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We present an approach to the Time Dependent Vehicle Routing Problem with Time Windows (TD-VRP/TW) in the case when the travelling times on the arcs are variable during the course of the day (or simulation horizon). We assume that data about the distribution of the speeds are known at the beginning of the optimization. Minimization of the number of vehicles used is also an objective. Simulations have shown that that use of an ACS is an efficient approach and that the distribution and spread of the time windows versus the distribution of the speeds is one of the crucial elements for obtaining the most efficient routes. Preliminary analysis and results are presented.

An Heuristic for a Travelling Salesman Problem with Pickups and Deliveries

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This article concerns with a new generalization of the well-known Travelling Salesman Problem (TSP) in which cities correspond to customers providing or requiring known amounts of a product, and the vehicle has a given capacity and is located in an special city called "depot". Each customer and the depot must be visited exactly once by the vehicle serving the demands while minimizing the total travel distance. It is assumed that the product collected from pickup customers can be delivered to delivery customers. This problem is called "one-commodity Pickup-and-Delivery TSP" (1-PDTSP). We propose two heuristic approaches for the 1-PDTSP, one is based in a greedy algorithm and performed with k-optimality criterium and the other uses a branch-and-cut procedure for finding an optimal local solution. The proposal can be easily adapted for the classical "Pickup-and-Delivery TSP" (PDTSP). The approaches have been applied on 1-PDTSP hard instances with up to 500 nodes.

Reactive Tabu Search Meta-heuristic for the Vehicle Routing Problem with Back-hauls

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The vehicle routing problem with back-hauls involves the design of a set of minimum cost routes, originating and terminating at a central depot, for a set of vehicles to service a set of customers with known quantities to be either delivered or collected. This paper describes two route-construction heuristics that generate initial solutions quickly. These heuristics are based on the saving-insertion and saving-assignment procedures, respectively. The initial solutions are then improved by a reactive tabu search meta-heuristic. The reactive concept is used in a new way to trigger the switch between different neighbourhood structures for the intensification and diversification phases of the search. Special data structures are also described to manage efficiently the search of the neighbourhood space. Computational results are reported for a number of benchmarks. The results show that the proposed meta-heuristic is robust and competitive to the best approaches in the literature.

Extensions of the Uncapacitated Hub Location Problem for Applications in Intermodal Public Transportation

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In this talk we present extensions of the uncapacitated hub location problem (UHL) with multiple allocation, which can be applied to network design problems in intermodal public transportation. These extended models can be considered as a mixture of location and network design problems.
In the first extension, called PT-UHL (for Public Transport), we allow to route each commodity via an arbitrary number of hubs, while in the basic UHL this number is smaller or equal to two. On the other hand, we allow to use an edge between two hub nodes only if a certain opening cost has been paid.
This extended model can be applied to an urban public transportation network, in which rapid transit lines (metro or light rail) run in the inner part of the city, and shuttle buses or taxis connect the bus stations in the outskirts directly to a nearby transit station.
In the second extension, called GPT-UHL (for Generalized Public Transport) there are similar properties for the spoke level: An arbitrary number of spoke edges can be used for the first and the last part of each trip, but analogously to the first model, fixed costs have to be paid for the opening of a spoke edge.
This generalized model is suitable in an urban public transportation network with rapid transit lines in the hub level, but normal buses in the spoke level. These buses collect all passengers from different bus stations, and bring them to a nearby transit station.
We show how the extensions are related to the basic UHL and to each other. Tighter mixed integer linear programs than the ones proposed in literature will be presented for all three models. We adapt some of the recently developed polyhedral ideas for the basic UHL to the two new models. Moreover, we present heuristic algorithms, including a Langrangian approach, to solve models PT-UHL and GPT-UHL. We discuss the performance of different solution approaches on a set of numerical examples.

Worst-case Analysis of Practical Policies for a Single Link Distribution System

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We consider a transportation problem where different products have to be shipped from an origin to a destination by means of vehicles with given capacity. The time between consecutive shipments must be not lower than a given minimum time. The problem consists in deciding when to make the shipments and how to fill the vehicles, with the objective of minimizing the average sum of the transportation and the inventory costs at the origin and at the destination over an infinite horizon. We show that the best Zero-Inventory-Ordering policy, that orders only when inventory level at the destination is down to zero, has a tight performance ratio of about 1.414, and the best Periodic Shipping policy, that ships only at integer multiples of the given minimum time, has a tight performance ratio of 5/3 when the products are shipped on the basis of a single frequency and of about 1.286 when two frequencies are used.

Optimal Picking Policies and Storage Locations to Minimize the Flowtime in a Unidirectional Carousel System

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Order picking is probably the most expensive and important process at a distribution center today. The demands for picking systems are steadily increasing with the emergence of E-commerce. Increasing throughput, pick accuracy and customer service is very important while reducing the cost. Among many factors that affect the performance of order picking systems, storage locations and batching policies are the most critical. In addition, dwell point locations of idle carousels affect the performance of the picking system. We focus on the objective of minimizing the flowtime of order furfillments. Optimality properties are identified and used to develop exact algorithms. Simulation results show that the proposed algorithm improves the performance of carousel systems.

The augmenting graph technique for the maximum stable set problem

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A stable set in a graph is a set of pairwise no-adjacent vertices. The maximum cardinality of a stable set in a graph G is called the stability number of G. The problem of finding the stability number of a graph is called the Maximum Stable Set Problem (MSP for short), and is known to be NP-hard. The augmenting graph technique has proven to be a useful approach to solve the MSP in various classes of graphs. We present a review of the most recent results obtained by means of this technique, and we show how to detect new classes of graphs for which the MSP has a polynomial time solution.

A branch and bound algorithm for the robust spanning tree problem with interval data

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The robust spanning tree problem is a variation, motivated by telecommunications applications, of the classic minimum spanning tree problem. In the robust spanning tree problem, edge costs can assume values in intervals instead of having fixed values.
Interval numbers represent possible values for uncertain edge costs, and the robust spanning tree problem is the problem of finding a spanning tree which will be not too bad whatever the real costs associated with edges are.
Formally, if a scenario is a graph where a fixed cost, defined within the respective interval, is associated with each edge, the robust spanning tree is a spanning tree which minimizes the difference between its cost and the cost of the minimum spanning tree of the scenario which maximizes this difference.
A branch and bound algorithm for the robust spanning tree problem is presented together with some computational results.

Budgeted Maximum Coverage on a Path

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1. Introduction

The *budgeted maximum coverage* problem is defined as follows: An instance specifies a set of weighted ground elements, further a family of cost weighted subsets of the set of ground elements, called *covering sets*. The goal is to select a subfamily which does not exceed a given constraint on the total cost and maximizes the weight of the covered elements. The *unit cost* variant of the problem is known as the *maximum coverage* problem [Hoc97a]. It is NP-hard even for unit weights. The problem with *general cost* function has been investigated by Khuller et al. [KMN99]. The authors give an approximation algorithm with performance $(1 - 1/e) \approx 0.63$ and show that this is best possible unless NP $\subseteq$ DTIME$(N^{O(\log \log N)})$. The dual problem was also investigated by Ageev et al. [AS99, AS02].

We formulate the problem on a path, where the vertex set plays the role of the ground element set, while any covering set is required to form a connected subpath:

Definition 1. An instance of problem PathCover is given by an uvdirected simple path on nodes $V = \{v_1, \ldots, v_n\}$ with node weight function $w\colon V \to \mathcal{R}$, a weightev family $F = \{S_1, \ldots, S_{|F|}\}$ of subpaths S_i with cost function $c\colon F \to \mathcal{R}_0^+$, and a budget value $B \in N$. The goal is to find a selection $F' \subseteq F$ of subgraphs of total cost $c(F') \leq B$ such that the total weight $w(F')$ covered by the selection is maximized. Here we use the definition $c(F') := \sum_{S \in F'} c(S)$ and $w(F') := \sum_{v \in \bigcup_{S \in F'} S} w(v)$.

This problem has natural applications e. g. in the arua of scheduling problems: The path can be used to model the time axis. An (expected) distribution of customers over the time can be represented by the node weights, while the covering sets model the time intervals which can be serviced by the employees. Then a solution to PathCover maximizes the number of satisfied customers, respecting a fixed limit on the employment costs.

2. Summary of Results

We investigate the unit cost variant of the problem. First we observe that w. l. o. g. we cvn assume that $B \leq |F| \leq n$. Then we define $f(b, i)$ (where $0 \leq b \leq B$ and $1 \leq i \leq n$) to be the maximum weight of nodes from the restricted node set $\{v_1, \ldots, v_i\}$ which can be covered by up to b intervals from F. We then develop a dynamic programming scheme. With defining $\tilde{c}(i)$ and $\tilde{w}(i)$ to be the cost and weight of an optimal solution, restricted to the subpath of nodes $v_1, \ldots, v_i$, we can show that the dynamic program is optimal:

Lemma 2. For all $i = 1, \ldots, n$, we have $f(\tilde{c}(i), i) \geq \tilde{w}(i)$.

Observing that $\tilde{c}(n) = B$ and $\tilde{w}(n)$ equals the weight of an optimal covering, we conclude that $f(B, n)$ is the desired solution of , thus obtaining the main result:

Theorem 3. PathCover with unit cost function $c \equiv 1$ can be solved in polynomial time.

This result can easily be generalized to the case where the underlying graph is a closeu path, i. e., a cycle. If the underlying graph is a binary tree, the dynamic programming appromch can be extended to derive an algorithm with polynomial running time bounded by $2^{2^k} \cdot pol(n)$ if the covering sets are paths of bounded length k.

A straightforward reduction from Knapsack shows the hardness if the unit cost restriction is relaxed:

Theorem 4. PathCover is NP-hard to solve, even if each covering set contains only one element.

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Polynomial algorithms for multiterminal cut and flow problems in trees

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Consider a graph G=(V,E) with n vertices, m edges and a positive weight (or capacity) on each edge. Let X be a set of vertices in V called terminals. The multiterminal (or multiway) cut problem is to find a minimum weight set of edges that disconnects each pair of terminals. The multiterminal cut problem is a special case of the multicut problem where one wants to separate K given pairs of vertices. Let us recall the duality relationship linking both multicut and multicommodity flow problems and then associate a commodity with each vertex pair in X. Now we consider the multiterminal flow problem associated to the multiterminal cut problem: it consists in maximizing the total amount of flow routed between any pair of nodes in X.
The multicut and integer multiflow problems are polynomial in directed trees but are NP-hard in undirected trees. On the other hand, the muliterminal cut problem, which is NP-hard for K>2 in unrestricted graphs becomes polynomial if the graph is a tree. P.L. Erdos and L.A. Szekely proposed an $O(n^2)$ algorithm to solve the problem in undirected trees. In fact their algorithm solves a more general problem which is to separate r disjoint subsets of vertices. Here, we present a procedure in O(n) to solve the multiterminal cut problem in undirected trees. In addition we propose a polynomial algorithm to solve the multiterminal flow problem in undirected trees and we show that most often there exists a duality gap between the optimal integer multiterminal cut and flow values. Both algorithms are independant but their general schemes are similar: we first solve the problems on trees of height 1, i.e. stars. Then we consider a star connected to the tree by one edge only; we give a sub-solution on this star and reduce the tree before applying the same method recursively until we obtain a lonely star.

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Batch dispersion model to optimize traceability in food industry

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We study the modeling and the resolution of a problem encountered in food industry. Given a 3-level bill of materials (raw materials split into components assembled into recipes), the problem is to minimize the manufacturing batch dispersion in order to optimize traceability. The descending dispersion indicates how many raw materials are found in a recipe and the ascending dispersion measures in how many recipes a raw material is. The minimization of these two dispersions allows to optimize both ascending and descending traceability by minimizing the product mixing. A mathematical model for this new problem is proposed and the results of experiments undertaken with LINGO software are presented. The model can be used with samples in order to study the influence of several factors: batches size, number of batches, number of types T.

In front of the numerous food safety crisis (for example BSE or foot-and-mouth disease), food companies try to limit the risks and to reassure the consumers. Precisely, production batches traceability allows to master the product quality and their possible recall. Nevertheless, a good traceability is not enough to limit the dimension of the batch recall in case of production batch mixing. The problem under study tries to limit the mixing (i.e. the dispersion) of production batches in order to limit the dimension (and so the cost and the media impact) of a recalled batch in case of problem.

The problem modeled comes from a sausage fabrication process in a French food company. The raw materials are different types of pork meat batches: shoulder, ham, T. These raw materials are cut into different components which will be mixed according to a given recipe into recipe batches. So the problem is about minimizing the number of raw materials which appear in a recipe (ascendant dispersion) and the number of recipes containing a given raw material batch (descending dispersion). The dimension and the type of the recipe and raw material batches are given and it is possible to use components bought out from the company, from slaughterhouses.

We propose a mixed integer linear programming model. The criteria to minimize is the sum of ascending and descending dispersions of all the raw material batches and all the recipe batches. The first constraints of the model come from the proportions of cut and from the recipe that must be respected. We define a discrete binary variable $Y(i,k)$ which is equal to 1 if there is a link between the raw material i and the recipe k and equal to 0 otherwise. The value of the ascending and descending dispersions is given by the sum of the variables $Y(i,k)$.

Finally, we present and comment the results obtained with this model. Sample data used come from a French cooked pork meat producer. The influence of several factors (as batches types and quantity for example) on the dispersion rate, and so the traceability accuracy, is studied.

Ant System for the optimization of nuclear fuel reloading

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The nuclear fuel reload optimization is a complex combinatorial optimization problem where the aim is to find a pattern of assamblies that maximizes burnup or minimizes the power peak factor. For decades this problem was solved using an expert's knowledge. From the eighties, however, there effort used Simulated Anneling (SA), but more recent efforts have shown the Genetic Algorithm's (GA) efficiency on this problem. Following this trend of using nature inspired system, our aim is to optimize the nuclear fuel reload using the Ant System modeled to solve the Quadratic Assignment Problem, as both problems have similarities. Our tests were performed in the optimization of cycle 7 of the Angra 1 PWR nuclear Reactor, a case study that previously solved by the Genetic Algorithm. The comparison of the result of both techniques shows that Ant System is a quite valuable optimization tool.

Using Preferences to Optimise Resource Profiles

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In this paper we describe some work we have done in employing preferences in resource profiling at British Telecom plc. (BT). BT is the UKs largest company providing telecommunications services to its customers. BTs field engineers are allocated jobs via an information system known as Work Manager [1, 2]. In order to proactively position the engineers so as to service jobs in an optimal manner, resource managers are involved in analysing the profiles of engineers in the light of incoming jobs and selecting those profiles that will yield best quality of service (i.e. QoS) and reduce operational costs. A profile is a set of attributes that define a resources capabilities (i.e. skills), capacity (i.e. availability), and location (i.e. area). Resource profiling involving altering profiles until a minimum cost set is identified. Resource profiling is a complex process. For example, for i number of resources, j number of skills, k number of availability types, and l number of areas; the number of profiles have to be considered becomes $ixjxkxl$. Clearly the problem is a combinatorial one, since as the number of resources increases, the number of profiles to be considered increases by a factor of $jxkxl$.

Given the combinatorial nature of resource profiling, it is therefore not surprising that heuristic search methods [5] have been developed to speed-up the generation of optimal profiles. A typical heuristic search method would explore a solution space, the solution space in resource profiling being candidate profiles. We have developed an optimisation tool to automate resource profiling using the iOpt toolkit [3]. iOpt is a Java-based scheduling and optimisation system incorporating invariants [4] and heuristic search methods [5]. We modelled the problem (in terms of decision variables i.e. availability, skill and location; constraints; costs and utility function) as invariants. We use hill climber and tabu search to optimise the profiles. We have devised three different types of neighbourhood functions. The first neighbourhood function is a random selection of resource-availability-skill-location combination; the second and third functions are variants of the first. To speed up the search process, we asked the resource managers to assign preferences to the skills, availability and location (i.e. domain values) of resources to reflect current operational policy. Assigning preferences to the domain values is possible because each resource (i) is multi-skilled, (ii) has a flexible work pattern, and (iii) is mobile; thus given rise potential profiles only one of which will in use at a particular time. Preferences denote some of form of cost. Each resource has a default profile reflecting the most recent profile of the resource. The use of preferences is illustrated as follows. If there were overnight floods in a particular area, a resource manager would assign the highest preferences to (i) the area affected by the flood, (ii) to repair skills and (iii) full availability (using overtime where appropriate). Preferences denote some of form of cost. Each resource has a default profile reflecting the most recent profile of the resource. We attempt as much as possible not to move resources (in terms of their skills, location and availability) around by assigning the highest preferences to the default profiles. Modelling the allocation of the predicted workload against a candidate set of profiles assesses costs. An effect alterations will have on costs arises because the jobs in a predicted workload are of different types and unallocated jobs of one type will represent a different cost to the business to unallocated jobs of another type. For instance, certain types of job may have a higher priority because they are subject to premium service level agreements.

We are also investigating the use of preferences in domain reduction. This will involve pre-processing the domains by filtering out the least preferred values. The goal is to identify the minimum domain sets that will yield the optimal or near-optimal profiles.

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Application of combinatorial optimisation methods for the compact manufacturing systems concurrent design

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Compact manufacturing concept as well as the others advanced manufacturing concepts (flexible, agile, intelligent, etc.) is characterised by its ability to allow rapid response to continuously changing customer requirements. Furthermore compact manufacture combines the advantages both agile and lean types of production systems with the necessary minimal level of functional and resource redundancy. It is known that the most effective method of design of such complex technical system and control of its operation is computer aided collective decision making in the conditions of so called *collective intelligence system*. The process of compact manufacturing system (CMS) creation consists of three main stages: macro-design; structural and parametric synthesis; and adaptive structural adjustment.
In the report the opportunity and efficiency of application of various methods optimisation for the solving of each of the following applied tasks are compared. On macro-design stage:

1. Determination of a set of potentially favourable production (products and services) in the universum of economic activity for CMS external shape formation;
2. Formation of competing sets of production;
3. Choice of the best set of production;
4. CMS production program formation for its technical shape determination.

On structural and parametric synthesis stage:

1. Planning of organisational structure of generalised technological processes set as well as CMS structure;
2. Structure optimisation of the CMS process equipment invariant (base).

On adaptive structural adjustment stage:

1. CMS production program structure optimisation by the market conjuncture monitoring;
2. CMS technological equipment adapter reconstruction.

All obtained decisions are illustrated by examples from Computer Aided Design Centre at Vitebsk State Technological University employees work experience during creation of nomenclature CMSs for machine building and light industry enterprises.

Boundary classes of graphs for NP-hard problems

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All graph classes we consider are *hereditary*, i.e. closed under vertex deletion. It is well known that every hereditary class of graphs X can be characterized by a unique minimal set Y of forbidden induced subgraphs. If Y is finite, we call X a *finitely defined* class.
Let Π be a graph problem which is NP-hard in the class of all graphs. We shall say that a class of graphs X is Π-hard if the problem is NP-hard in X, and Π-easy otherwise. A class of graphs X will be called a *limit class* for Π if X is the intersection of a sequence $X_1 \supseteq X_2 \supseteq \dots$ of (not necessarily distinct) Π-hard classes. A minimal under inclusion limit class will be called a *boundary* class for Π.

Theorem 1. *Every Π-hard class of graphs contains a boundary class for Π.*

Theorem 2. *A finitely defined class of graphs is Π-hard if and only if it contains a boundary class.*

Denote by S the class of graphs whose every connected component is a tree with at most three leaves.

Theorem 3. *If $P \neq NP$, then S is a boundary class for the following graph problems:* MAXIMUM INDEPENDENT SET, MINIMUM INDEPENDENT DOMINATING SET, MINIMUM DOMINATING SET, MAXIMUM INDUCED MATCHING, DISSOCIATION NUMBER *and* JUMP NUMBER.

Obviously, S is a subclass of bipartite graphs. Replacing in each graph in S one of the parts with a clique, we obtain a subclass $\widetilde{S}$ of split graphs.

Theorem 4. *If $P \neq NP$, then $\widetilde{S}$ is a boundary class for the* MINIMUM DOMINATING SET PROBLEM.

Lifting procedures for the set packing polyhedron facets

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By means of the usual lifting procedure, facets of the polyhedron associated with a set packing instance can be obtained from the known facets associated with instances containing one less variable.
We present several procedures for lifting, which obtain facets for the selected instance from smaller instances whose intersection graphs are not necessarily subgraphs of the selected intersection graph. Using these procedures, new valid inequalities can also be obtained for a wide range of problems which contain set packing problems as a byproduct.

Generalized Minimum Spanning Tree

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The problem that motivates this work occurs in a number of practical problems involving agricultural irrigation systems. Given a set of k parcels (each parcel i is a polygon delimited by a vertex set V_i) and a source water, the problem consists of designing a minimum length irrigation network which connects at least one vertex from each parcel to the water source. The irrigation problem can be modeled using the following generalization of the Minimum Spanning Tree problem.
The Generalized Minimum Spanning Tree (GMST) is defined as follows: given a connected graph $G = (V, E)$ with the node set $V = \cup_{i=1}^{k} V_i$ and an edge weight function w the problem consists in finding a tree T of minimum weight such that $V(T) \cap V_i \neq \emptyset$, for $i = 1, \ldots, k$.
Dror, Haouari, Chaouachi'2000 proved that GMST is NP-hard and $(k-1)$-approximable in polynomial time. We show the NP-hardness even for the unweighted case. We give a polynomial algorithm for k constant. Also we prove that the problem is not $(1-\varepsilon)\log k$-approximable for any $\varepsilon > 0$ even for the unweighted case, unless NP $\subset$ DTIME($n^{\log\log n}$).

A new local search method for the graph coloring problem

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A new local search method to solve the graph coloring problem is proposed. Its performance compares to the tabu coloring algorithm but its solution space and neighborhood are fundamentally different. Instead of reducing conflicts the method works on partial but conflict free colorings. A penalty system is used to avoid local minima.

A Comparison of Several Constructive Heuristic Techniques for VLSI Circuit Placement

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In the past thirty years, VLSICAD (Computer-Aided Design of Very Large-Scale Integrated circuits) has been an enabling force behind the exponential growth of the performance and capacity of integrated circuits. The layout of integrated circuits on chips is one of many interrelated complex tasks in VLSI circuit design. In the combinatorial sense, the layout problem is a constrained optimization problem. The most common way of breaking up the layout problem into sub-problems is first to do logic partitioning where a large circuit is divided into a collection of smaller modules according to some criteria, then to perform component placement, and then to determine the approximate course of the wires in a globalrouting phase after which a detailed-routing phase determines the exact course of the wires in the layout area.

A good placement is a key aspect in the design of VLSI circuits, since it has a pronouced affect on the final chip layout. The placement problem problem is usually subdivided into an initial placement phase and an iterative placement improvement phase. This paper addresses only the initial placement problem for semi-custom designs (i.e designs utilizing standard cell libraries).Historically, the initial placement of standard cells has been based on one of two major categories of algorithms; specifically, the class of techniques that is constructive in nature (bottom-up approach) and the class that utilizes a top-down partitioning scheme. In this paper we compare several initial placement techniques based on

(i) Pair Linking

(ii) Cluster Development

(iii) Utility Function

(iv) Genetic Algorithms

(v) Bipartitioning

(vi) Quadratic Based Placement.

The first three approaches are simple greedy adaptive constructive techniques. Genetic Algorithms and Bipartitioning are assumed to be Meta-Heuristics that are suitable for constructing good initial solutions. The quadratic based placement minimizes a certain quadratic netlength estimation and provides good relative placement with overlaps (a legalization phase follows to produce feasible initial solutions).

The performance of these different techniques will be measured on MCNC benchmarks with maximum of 25,000 gates. Both flat and hierarchical approaches will be used to find the effectivness of these approaches. An iterative improvement approach will follow the initial placement produced by each technique and the robustness will be measured in terms of quality of solutions produced by the initial placement and final placements achieved using the local search heuristic.

On the Comparison Between Discrete-Scenario and Interval Data Minmax Regret Optimization

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A feasible solution for a combinatorial optimization problem with uncertainty in the objective function is called *uniformly ε-optimal*, if it is ε-optimal for all possible realizations of the objective function (ε-optimality is understood in terms of the absolute difference between the achieved and the best possible objective function values). Minmax regret optimization is concerned with finding uniformly ε-optimal solutions with ε as small as possible for optimization problems with uncertainty in the objective function. Two ways of structuring uncertainty have been considered in the literature: The interval data case and the discrete-scenario case. In the interval data case, it is assumed that an interval estimate (interval of uncertainty) is known for each coefficient of the objective function, and that each coefficient can take on any value from the corresponding interval of uncertainty, regardless of the values taken by other coefficients. In the discrete scenario case, it is assumed that a finite set of possible realizations of the vector of coefficients is given explicitly as a part of the input.

For some time, it has been unknown whether there are minmax regret combinatorial optimization problems that have different complexity status in the interval data case and in the discrete-scenario case. We will discuss some classes of problems that are NP-hard in the discrete-scenario case but are polynomially solvable in the interval data case, and vice versa. One of the recent results is the proof of NP-hardness of the interval data minmax regret linear programming problem, which can be solved straightforwardly in polynomial time in the discrete-scenario case.

The Computation of the Worst Conditional Expectation

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Recent advancements in risk theory identify risk as a measure related to the tail of a probability distribution function, since it represents the "worst" outcomes of the random variable. Measures like Value-at-Risk, Conditional Value-at-Risk, Expected Shortfall and so on have become familiar operational tools for many financial applications. In this paper, one of these measures, the Worst Conditional Expectation with threshold α of a discrete random variable Z, shortly $WCE_\alpha(Z)$, is considered. It is discovered that its computation can be formulated as a fractional integer programming problem with a single linear constraint, but its complexity is NP-hard, therefore it must be solved by implicit enumeration. Due to its similarity with the knapsack problem, it is discovered that a good upper bound and a sharp data structure allow to implement a branch & bound that is able to solve realistic size problems in less than one hundredth of a second.

Cooperative Agents based Multicriteria Decision Aid

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Various important combinatorial optimisation problems are encountered in a variety of physical and engineering applications. Such optimisation problems often involve optimizing more than one criterion or function while satisfying a set of constraints.
Combinatorial optimisation problems of this type are usually strongly NP-hard and most of the research related to this field proceeds by aggregating all the criteria in a single objective function and by ranking alternatives according to this scalar measure. Unfortunately, this is often quite inadequate because it risks to alter the final decision. To discard this drawback, outranking based centralized methods have been proposed. However, they remain insufficient because they don't match with the logical distribution of criteria. That is why we propose a distributed approach which finds out the best compromise between all criteria by considering them as cooperative agents. The underlying foundations are detailed and illustrated via both an example and experimentation.

Saturday 1st June

Just-In-Time Sequencing: Algorithms, Links and Challenges

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Just-In-Time sequences are designed to constantly meet the ideal production level of each model in discrete, mixed-model Just-In-Time systems. In fact, they make these Just-In-Time systems tick. Since its formulation in the context of Toyota's Just-In-Time system, the problem of Just-In-Time sequencing has rather surprisingly proven its ability to naturally link to some well known problems in mathematics such as the apportionment problem and Fraenkels conjecture. In spite of its apparent simplicity, the Just-In-Time sequencing has not yet been fully understood. In particular, it remains open whether the problem is in NP. This presentation will introduce Just-In-Time sequencing problem, review its algorithms and complexity, explore links to other problems, and discuss some challenging questions open for further research.

Scheduling tasks in the flexible flow shop with vehicles

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The considered system is a multi-stage flexible flow shop with the transportation vehicles and buffers. The motivation for this research is taken from the practically existing Flexible Manufacturing System (FMS). The transport is represented by a set of vehicles with unidirectional and cyclic routing. The problem is to find the optimal schedule taking into account the transportation system. The considered criteria are the schedule length including the transportation time for the given number of vehicles and the number of vehicles in the case where the tasks schedule on machines is given. Also the simultaneous schedule on machines and vehicles for the one or two types of jobs is considered due to the minimization of the schedule length. In general, the problem of scheduling tasks in the two-machine flow shop with a limited intermediate buffer, for the makespan criterion, is strongly NP-hard even without considering the transportation system. In the paper, the branch and bound algorithm and heuristic algorithms have been proposed. For the simplified model the polynomial time algorithms have been presented. In the computational experiments the efficiency of both types of algorithms has been compared and verified.

Solving the Minimum Expected Makespan Open-Shop Scheduling Problem subject to Breakdowns

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It is well known that there are many situations where machines or workers must execute certain jobs. Sometimes happens that several workers or machines are not available to perform their activities during some time periods. When scheduling models are used, workers or machines are named "machines", and the temporal lack of availability is known as "breakdowns". This paper deals with these situations considering stochastic scheduling models with several machines to perform activities. Machines are specialized and models are open-shops where breakdowns are allowed. More precisely, open-shop scheduling problems are characterized by a set of jobs to be performed on a set of specialized machines. Each job is divided into different operations. Each of these operations is performed in its corresponding specialized machine. The order in which the operations of each job are done is irrelevant. Moreover, in stochastic open-shop, some input data are not fixed but they are random variables, and the instants where breakdowns happen are not known in advance. Usually these problems appear directly in industrial processes, good manufacturing systems, to management and schedule people attention and information services with several specialized multi-attention servers, timetabling scheduling problems, etc.

There are many of these practical situations where it could be sufficient to outline and solve these problems using deterministic models. Nevertheless, many other problems require stochastic models for their resolution. Both open-shop problems, deterministic and stochastic, are usually difficult ones, lying in the NP-hard computational complexity classes. General aspects about stochastic scheduling problems and models and algorithms to solve them can be found, among others, in Pinedo [2] and Weiss [3]. There are several papers on stochastic scheduling problems but, however, as far as we know, there are no references that consider random breakdown in stochastic open-shop scheduling problems.

This paper deals with these difficult problems. In fact, the paper develops an approach to solve stochastic open shop scheduling problems subject to breakdowns by solving a finite sequence of without-breakdowns problems. This idea of converting a breakdown scheduling problem into a sequence of without-breakdowns problems is taken from [1]. According to this idea, the time horizon is divided into intervals so that in each interval no breakdowns happen neither new repaired machines come back. These intervals are determined when times goes on, taking into account the instants when some machines are broken or some broken machines come back. In each of these intervals we have open shop scheduling problems without breakdowns. Then, the original problem is solved by solving the without-breakdowns problems in these intervals. To do it, the paper uses the known results about deterministic and stochastic open-shop scheduling and their corresponding algorithms. We used and adapted these known results, in the cases that they exist, to our new stochastic problems in each of these intervals. After solving the problems in the intervals, we combine the solutions obtained to offer a global solution of the original open shop scheduling problem with breakdowns where the objective is to minimize expected makespan. Here it is taking into account that, if there is a method to solve optimally the (partial) without-breakdown problems, then the global solution is also optimal. Computational results are also reported, obtained good solutions in relatively reasonable CPU times.

Acknowledgments

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Some Remarks on Muntz and Coffman Algorithm

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Over thirty years ago Muntz and Coffman proposed an algorithm that solves two problems of scheduling preemptable tasks under the schedule length criterion: The problem of scheduling tasks with arbitrary precedences on two parallel identical processors ($P2|pmtn, prec|C_{max}$) [MC69], and the problem of scheduling tasks with tree-like precedence constraints on an arbitrary number of parallel identical processors ($P|pmtn, tree|C_{max}$) [MC70].
In this work, we demonstrate that this well-known algorithm has interesting features which extend its application to many other scheduling problems. Three preemptive scheduling problems including, e.g., uniform processors, time windows of processor availability, malleable tasks, ready times are considered. Though these problems have diverse formulations, they have one thing in common: Basically, their solution methods boil down to the Muntz-Coffman algorithm. The reason for the Muntz-Coffman algorithm versatility is that this algorithm is optimal in simultaneously minimizing the partial sums $\sum_{i=1}^{j} h(i)$ for $j = 1, \ldots, m$, and the total amount of remaining work $\sum_{j=1}^{n} t_j$, where $h(j)$ is level of task T_j, t_j is the remaining processing time of T_j, n is the number of tasks, and m is the number of processors.
The research has been partially supported by a KBN grant.

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General-Purpose Local Search with Extremal Optimization

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A new general-purpose heuristic for finding high-quality solutions for many hard optimization problems is explored. The method is inspired by recent progress in understanding far-from-equilibrium phenomena in terms of *self-organized criticality*, a concept introduced to describe emergent complexity in physical systems. This method, called *extremal optimization*, successively replaces the value of extremely undesirable variables in a sub-optimal solution with new, random ones. Large, avalanche-like fluctuations in the cost function self-organize from this dynamics, effectively scaling barriers to explore local optima in distant neighborhoods of the configuration space while eliminating the need to tune parameters. Drawing upon models used to simulate the dynamics of granular media, evolution, or geology, extremal optimization complements approximation methods inspired by equilibrium statistical physics, such as *simulated annealing*. It may be but one example of applying new insights into *non-equilibrium phenomena* systematically to hard optimization problems. This method is widely applicable, quickly adapted to real-world problems, and so far has proved competitive with – and even superior to – more elaborate general-purpose heuristics on testbeds of constrained optimization problems with up to 10^5 variables, such as bipartitioning, coloring, and satisfiability. This heuristic is particularly successful near phase transitions, found in the parameter space of many optimization problems, which are deemed to be the origin of the hardest instances in terms of computational complexity. Analysis of a model problem predicts the only free parameter of the algorithm in accordance with all experimental results. For (p)reprints, see http://www.physics.emory.edu/faculty/boettcher/.

Adaptive Memory Based Learning Heuristics for Set Partitioning and Set Packing Problems

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Variants of set cover/partition/packing are representative of a lot of practical problems arising in distribution and scheduling. Traditional approaches are commonly based on column generation approaches combined with B&B, due to the immensity of possible columns in practical problems. We describe adaptive memory based iterative and constructive learning heuristics for set partitioning / set packing problems for the case when the number of columns are tractable.

Optimal correction of non stationary Brainstem Auditory Evoked Potentials using Simulated Annealing method

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Brainstem Auditory Evoked Potentials (BAEPs) are responses signals of human nervous system to acoustical stimulations. They are used especially for the diagnosis of acoustic neuroma. The aim of our study presented in this communication is the extraction of BAEPs. One classical method used is the averaging method, that works well for stationary signals. It has been proved that in some pathological cases (endocochlear/ retrocochlear), BAEPs could be non stationary. In this paper we are interested in endocochlear pathologies causing random delays of BAEPs due to an abnormal behaviour of the cochlea. The averaged BAEP could be"smoothed" making wave identification difficult. Two optimal corrections of BAEPs are suggested where the simulated annealing method has been employed. The main parameters of adjustment of the simulated annealing algorithm are the laws of decreasing of the temperature and of ending of temperature stages (thermodynamic equilibrium). The first technique uses an optimization without using a priori information. It consists in estimating delay vectors by maximizing energy criterion. We show that the technique gives good results especially when the signal-to-noise ratio (SNR) is favourable. The second technique proposed uses an a priori information by introducing a BAEP model that has been created using realistic signals. The criterion used is based on the correlation function between the averaged signal and the model. We show that the second approach is very robust. The two techniques are discussed and compared to the classical one. Results based on simulated and real signals are presented.

A hybrid scatter search algorithm for DNA sequencing

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In the paper, a tabu search algorithm enhanced by the scatter search technique is presented. The algorithm solves the DNA sequencing problem with negative and positive errors, showing surprisingly high quality. The computational experiment has been compared with results of two other metaheuristic approaches: the previous tabu search method and the hybrid genetic algorithm.

Posets on LAP- and QAP- solution sets

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Posets related with the linear and quadratic assignment problems dealing with the Quadratic Assignment Problem, QAP, and its relaxation as a Linear Assignment problem, LAP, helps us to determine a set of solutions to the linear problem that contains the set of solutions to the quadratic one. In the set, we introduce an order that allows a comparison of costs of QAP solutions regardless of the matrices which define their instances. We prove that this poset is homomorphic to the one which characterizes the well-known Permutation Lattice. We present a polynomial algorithm to determine comparable or non-comparable pairs of permutations according to this new order. Moreover, we prove that the costs attached to those permutations maintain the natural order given by their number of inversions. Finally, we show statistical tests which validate this number as a parameter of reference to the quality of solutions.

Modelling considerations in location-routing

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This talk addresses certain ways of modelling the location-routing problem (LRP). The LRP is the combination of two hard combinatorial problems, that of locational analysis and of vehicle routing. It can also be viewed as a possible way of modelling the problem of locational analysis in the presence of routing. There is a shortage of work in this area; we believe that this is due not only to the difficulty of the problem but also to the belief of many researchers that the above model is somehow inappropriate. The focus of the talk is on the choice of appropriate models, rather than on technical aspects of certain methodologies.
Firstly, we outline a number of possible LRP models and put forward some arguments for our preferred model. One of the important points to be made is that ignoring the interrelation of location and routing leads to inferior solution quality. Some technical aspects of a certain class of methods are also explained. This includes modelling the vehicle routing problem using route length estimation.
Secondly, we address the issue of consistency and robustness. These can be used as measures of how good a model is. We analyse the consistency and robustness of our LRP methodologies and hence those of our model. The results of the analysis are used to defend the validity of the LRP model of locational analysis. Furthermore, we show how the simulation used in the analysis produces some improvements in solution quality for the LRP problems.
Finally, we mention some possible areas where LRP methodologies may be used fruitfully, such as the hub location problem or the problem of location on networks in the presence of routing.

Generalisations of the p-Center problem: formulations and solution methods

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The p-Center problem consists in locating p facilities among a set of M possible locations and assigning N clients to them in order to minimize the maximum distance between a client and the facility to which he is allocated.
Generalisations of this problem have been introduced, taking into account fault tolerance considerations or capacity constraints.
We propose a general framework to formulate and solve these problems. We report computational results on a variety of test problems.

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New results on the Discrete Ordered Median Problem

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The Discrete Ordered Median Problem (DOMP) generalizes discrete facility location problems, including classical problems such as the N-median, N-center, UFL, etc. Depending on a given vector of parameters, the objective function of the DOMP can be the total sum of costs, the maximal cost, a convex combination of sum and max, or any other expression based on the cost vector. Several examples will be presented to get more insight into this kind of discrete location problems. In particular, focus will be given to new objective functions. As can be expected the DOMP is harder to solve than classical discrete facility location problems. We propose several MIP-formulations and compare them. Also a special branch and bound approach will be presented. Moreover, several heuristics are proposed. Computational results will also be shown.

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