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This conference was organized by Rainer E. Burkard (Graz), Horst W. Hamacher (Kaiserslautern) and Hartmut Noltemeier (Würzburg). There were approximately 40 participants coming from all over Europe as well as from Israel, the US, Canada and the Far-East (China, Japan). In recent years the application of methods from various fields of mathematics to problems in manufacturing and logistics has turned out to be very successful. It can be observed, however, that similar problems are considered in different research communities, which do not know each other very well. To meet the challenges of the future and to make further progress, it will be necessary to join forces and to put a stronger emphasis on the development of integrated models and solution approaches. The aim of the conference was to bring together researchers from different communities to enable them to exchange their newest results and ideas and to learn from each other. The main focus of the conference was on the following three areas:

- locational analysis and transportation,
- flexible manufacturing and online aspects in logistics, and
- assembly/disassembly and motion planning.

The scientific program of the conference consisted of 35 presentations of 25 minutes each (clustered into sessions dealing with related subjects), two working group meetings on Tuesday evening (one on transportation and location and the other on motion planning) and a large number of meetings in small groups. A short report on the two working group meetings can be found after the listing of the abstracts of the presentations. The speakers had been asked by the organizers to give their talks in a way understandable to the participants from other areas. This objective has been met quite successfully. The excellent scientific program as well the special atmosphere of conferences at Oberwolfach stimulated many fruitful discussions among the participants and helped to initiate new research contacts and joint projects.

The organizers and all participants of this meeting would like to the thank the Mathematical Research Institute for its hospitality and for a wonderful week.

Abstracts

Duty Scheduling in Public Transit

Ralf Borndörfer
(joint work with Martin Grötschel and Andreas Löbel)

Duty scheduling in public transit is the task to construct the daily work schedules for the bus, tram, and subway drivers. This is a central operational issue, it is important for employee satisfaction, and it is of economic significance, because the average (German) bus company spends about half of its operational budget on driver salaries. Duty scheduling problems involve large scheduling digraphs and a great variety of rules for the formation and the pricing of duties. This data may be complicated, but it constitutes the degrees of freedom available for optimization. We have developped a duty scheduling system, based on column generation, that aims at exploiting all of these degrees of freedom. The general design principle is to resort to approximation in order to be able to work in the entire search space. As one example, the talk discusses the approximate solution of the master LP relaxation with an approximate pricing routine. It is based on the observation that many duty scheduling rules are linear resource constraints on quantities such as working time, driving time, etc. in an individual duty. A Lagrangean relaxation of such constraints produces a lower bound that is useful in a constraint shortest path algorithm for the approximate pricing problem. With this and similar techniques, it is possible to tackle duty scheduling problems with several thousand duty elements.

Graph Matching – Recent Advances and Applications to Pattern Recognition and Computer Vision

Horst Bunke

Graphs are widely used in science and engineering. Particularly in pattern recognition and computer vision graphs are a versatile and powerful formalism for object representation. When graphs are used to represent objects from a certain problem domain, then the task of object recognition can be solved by means of graph matching. Generally speaking, graph matching is the process of comparing two graphs with each other in order to determine their similarity. A number of graph matching algorithms have been proposed recently. But the number of algorithmic tools available in the graph domain is still very limited when compared to the numerical domain. In this talk a few novel concepts will be introduced. They include the median of a set of graphs, which allows us to represent a set of (similar) objects by just a single representative. Furthermore, we introduce the weighted median of a pair of graphs, which can be interpreted as an interpolation procedure for graphs. Finally it will be shown that by means of these two concepts a number of clustering procedures, which were originally proposed for object representations in terms of vectors in the n-dimensional real space, can be applied in the graph domain. It is expected that the new algorithmic tools introduced in this talk will be useful in developing more powerful computer vision systems for industrial assembly, quality control and other tasks.

On the Airline Crew Rostering Problem

Paola Cappanera
(joint work with Giorgo Gallo)

The problem of finding a work assignment for airline crew members in a given time horizon, is addressed. In the literature such a problem is usually referred to as the Airline Crew Rostering problem and consists of constructing monthly schedules for crew members by assigning them pairings, rest periods, leaves, training periods, union activities, and so forth, so as to satisfy the collective agreements and security rules. We formulate the Airline Crew Rostering problem as a 0-1 Multicommodity Flow problem where each employee corresponds to a commodity; determining a monthly schedule for an employee is the same as computing a path on a suitably defined graph while satisfying the clauses of the union conventions. A preprocessing phase is performed which reduces the dimension of the graph. In order to tighten the linear programming formulation of our model we propose some families of valid inequalities which have proven to be computationally effective; some of them have the characteristic that can be treated implicitly in the construction of the graph. Computational results obtained with a commercial integer programming solver (CPLEX) are analyzed.

Fixturing Hinged Polygons

Jaesook Cheong
(joint work with Ken Goldberg, Marc Overmars and Frank van der Stappen)

We study the problem of fixturing a chain of hinged objects in a given placement with frictionless point contacts. We define the notions of immobility and robust immobility—which are comparable to second and first order immobility for a single object—to capture the intuitive requirement for a fixture of a chain of hinged objects; robust immobility differs from immobility in that it additionally requires insensitivity to small perturbations of contacts. We show that $(p+2)$ frictionless point contacts can immobilize any chain of $p \neq 3$ polygons without parallel edges; six contacts can immobilize any chain of three such polygons. Any chain of p arbitrary polygons can be immobilized with at most $(p+4)$ contacts. We also show that $\lceil \frac{6}{5}(p+2) \rceil$ contacts suffice to robustly immobilize p polygons without parallel edges, and that $\lceil \frac{5}{4}(p+2) \rceil$ contacts can robustly immobilize $p \neq 3$ arbitrary polygons; eight contacts can robustly immobilize three polygons.

Robust Heuristic Algorithms for the Quadratic Assignment Problem

Zvi Drezner

We extended the search of a hybrid genetic algorithm in five ways and obtained very strong results for the solution of the Quadratic Assignment Problem on a set of 29 test problems ranging from 30 to 100 facilities. All variants found the best known solution at least twice out of 20 runs for all problems, with one variant finding it at least six times out of 20 for every problem. All variants found the best known solution in all 20 runs for at least 14 of the problems, and one variant found the best known solution in all 20 runs for 19 of the 29 problems. The average solution for each problem was less than 0.04% over the best known solution, and for one variant it was less than 0.02% over the best known solution. Computational experience with a sixth variant are in progress during the conference, and so far 24 problem were solved with an average not exceeding 0.003% over the best known, the best known solution found at least 16 times out of 20, and the best known solution found 20 times out of 20 for 20 of the 24 problems.

Locating Landfills: Issues & Approaches

Horst J. Eiselt

The presentation first discusses the main issues in the location of landfills. Then a number of different approaches in the literature are discussed, among them vector optimization, goal programming, and tools from decision analysis, such as ELECTRE. The presentation then examines the recent location of landfills in New Brunswick, Canada, and recreates the results obtained in a six-year process that involved extensive consultations, by a simple p-median model with very rough estimations about population densities and cost parameters. It is then shown that the results are not transferable to third-world countries. However, it is possible to modify pertinent systems so as to align objectives, thus resulting in compromise solutions that are acceptable by most or even all stakeholders.

On the Continuous Weber and k-Median Problems

Sándor P. Fekete

(joint work with Joe Mitchell and Karin Weinbrecht)

We give the first *exact* algorithmic study of facility location problems that deal with finding a median for a *continuum* of demand points. In particular, we consider versions of the "continuous k-median (Weber) problem" where the goal is to select one or more center points that minimize the average distance to a set of points in a demand *region*. In such problems, the average is computed as an integral over the relevant region, versus the usual discrete sum of distances. The resulting facility location problems are inherently geometric, requiring analysis techniques of computational geometry. We provide polynomial-time algorithms for various versions of the L_1 1-median (Weber) problem. We also consider the multiple-center version of the L_1 k-median problem, which we prove is NP-hard for large k.

Scheduling on Batch Processing Machines

Gerd Finke

(joint work with Haris Gavranovic)

The standard hypothesis in the classical scheduling theory assumes that a machine cannot treat more than one task at a time. In batch scheduling, this assumption is relaxed. A so-called batch machine is executing a group (or batch) of tasks in a single macro-operation. The processing time of such a batch is in general a function of the individual processing times of the tasks belonging to it. One of the most important functions is the maximum of the processing times, leading to a max-batch machine. Max-batch machines are frequently related in industry to burn-in operations in a furnace where the products are first grouped together and then heated. The exposure time to heat has a lower bound for each item given by its processing time. This implies that the total length of the burn-in operation is given by the maximum processing time in the batch. A particular class of batching problems will be considered. Based on a problem in the sheet-metal industry, the concept of a compatibility graph is introduced. The grouping is not arbitrary since only 'compatible' jobs may be included in the same batch. In general, one has a compatibility graph for the tasks as the vertex set and the objective is to find the smallest number of batches (consisting of compatible jobs) in order to minimize the total execution time. This is equivalent to partitioning the graph into the smallest number of cliques. For the given application, the compatibility graph is related to an interval graph. In the proposed solution procedure, all maximal cliques are first enumerated (which can be done in polynomial time) and then a set covering problem is solved.

Location Problems in Telecommunication

Martin Grötschel
(joint work with Andreas Bley and Thorsten Koch)

I will present several location problems that arise in the design of telecommunication networks. I will discuss, in particular, the location of the nodes of the backbone network of the German G-WiN (providing Internet access for all German scientists) and of the Austrian switching network. The modeling phase of such problems brings up major challenges. Some of the issues are:

- Can one separate node location from the design of the link and capacity structure of the network without losing too much information?
- Is it possible to simplify the structure of the backbone and access network to obtain an approximation of the cost function for the network links that looks reasonable?
- After the many simplifications necessary, do the resulting models still provide practically useful information?

Despite all these difficulties we came up with integer and mixed integer programs modeling some of the aspects of location problems above. The practical instances we obtained were of large scale, but they could be solved, in some cases easily, in others with some effort. Our results have been utilized by our project partners (DFN-Verein and Austria Telekom). I will report about expected and some rather unexpected outcomes.

The Sliding Simplex Method for Solving Location Problems

Pierre Hansen
(joint work with Nenad Mladenovic)

Many location problems aim at minimizing set-up costs for facilities and distribution costs to satisfy user's demand. They can be expressed as large linear programs in 0-1 variables, with a particular structure and numerous variables and constraints in the primal and the dual. We show how to solve exactly this dual through a linear program which evolves over time by addition and deletion of variables and constraints, always including only a small fraction of those of the dual itself. This leads to practically efficient algorithms for approximate and exact solution, as illustrated in the case of the Simple Plant Location Problem.

Scheduling Trucks for Supply Management

Christoph Helmberg
(joint work with Stefan Röhl)

Our industrial partner operates several warehouses in the same city. Some of these warehouses are too small to hold sufficient stock of each product for the day; therefore, a shuttle service consisting of several trucks constantly transfers pallets of goods between the warehouses. Part of the demand is known in advance, part is stochastic and has to be estimated from available statistical data. The task is to find a schedule that distributes the goods between the warehouses by means of the trucks so that demand can be satisfied on time with high probability. We present first results based on a multicommodity flow model discretized over time. We give several reasons why solving this model exactly does, in general, not lead to better solutions in practice. Rather, it will be the goal of further work to incorporate the uncertainty in demand and transportation capacity in this model. We point out some possibilities to do so.

On Preemptive Resource Constrained Scheduling: Polynomial-Time Approximation Schemes

Klaus Jansen

(joint work with Lorant Porkolab)

We study resource constrained scheduling problems where the objective is to compute feasible preemptive schedules minimizing the makespan and using no more resources than what are available. We present approximation schemes along with some inapproximability results showing how the approximability of the problem changes in terms of the number of resources. The results are based on linear programming formulations (though with exponentially many variables) and some interesting connections between resource constrained scheduling and (multi-dimensional, multiple-choice, and cardinality constrained) variants of the classical knapsack problem. In order to prove the results we generalize a method by Grigoriadis et al. for the max-min resource sharing problem to the case with weak approximate block solvers (i.e. with only constant, logarithmic, or even worse approximation ratios). Finally we present applications of the above results in fractional graph coloring and multiprocessor task scheduling.

Continuous Location Problems with Barriers

Kathrin Klamroth

Continuous location problems with barriers have many applications in the development of realistic location models. The non-convexity of the objective function typical for barrier problems leads to global optimization problems that have challenged location scientists mainly in the last decade.

After giving an overview over recent developments and solution approaches, the close relationship to geometric shortest path problems is highlighted. This connection implies problem decompositions based on series of convex subproblems for which, for example, MIP formulations can be found.

On Some Geometric Problems in Locational Planning

Rolf Klein

(joint work with Frank Dehne and Raimund Seidel)

Let C be a planar, simple polygonal chain of n edges. For any two points p, q on C let $d(p, q)$ denote the ratio of the length of the chain segment that connects p with q over the Euclidean distance pq. By $d(C)$ we denote the maximum of all these values. We show how to compute $d(C)$ within time $O(nlog^3n)$ by a deterministic algorithm (joint work with P.

Agarwal, Ch. Knauer, and M. Sharir). Let n points in the plane be given, and let D be a compact set in the interior of the convex hull of these points. We want to place a new point in D in such a way that its Voronoi region with respect to the given points has a maximum area. We show that this area function has at most one local maximum within each cell of constant Voronoi neighbors if these neighbors are in convex position

The Transportation Paradox Revisited

Bettina Klinz

(joint work with Vladimir Deĭneko and Gerhard J. Woeginger)

This talk revisits the transportation paradox, also known as more-for-less paradox for the transportation problem. Let $\mathrm{T}P(C, a, b)$ denote the optimal objective function value of the instance of the transportation problem with cost matrix C, supply vector a and demand vector b. The transportation paradox arises for this instance if there exist a supply vector $a' \geq a$ (componentwise) and a demand vector $b' \geq b$ such that $\mathrm{TP}(C, a, b) > \mathrm{TP}(C, a', b')$. In other words, an *increase* in the supplies and demands leads to a *decrease* in the optimal transportation cost. If no such vectors a' and b' exist, C is called *immune against the transportation paradox.* We characterize the class of $m \times n$ cost matrices which are immune against the transportation paradox. The conditions we obtain can be verified in $O(mn)$ time. Finally, we extend our result to the algebraic transportation problem which includes the classical transportation problem and the bottleneck transportation problem.

Object Tracking and Motion Coordination for Mobile Robots

Boris Kluge

In this talk two problems which arise in the field of mobile robotics are considered. First, the problem of tracking objects in the vicinity of the robot is addressed. An approach to data association is presented which is based on network algorithms and allows robust tracking of multiple objects even in the presence of clutter in the environment and uncertainty in the object extraction step. Second, the problem of generating collision-free motion in dynamically changing environments is considered. A heuristic approach based on the "velocity obstacle" paradigm is presented which enables the robot to coordinate its motion with that of another object, i.e. to accompany a guiding person. Both approaches are implemented on a mobile robot and evaluated under real-world conditions.

A Dynamic Model for Traffic Networks

Ekkehard Köhler

(joint work with Katharina Langkau, Rolf Möhring and Martin Skutella)

Traffic networks are one of the standard examples for the application of combinatorial optimization. In the standard static traffic models, static flows are routed through the network instead of discrete vehicles. This static approach is appropriate, for example, for describing and routing traffic at rush-hours. However, for getting a realistic model also for the general case of traffic routing it is necessary to model traffic as dynamic flow, i.e. flow moves through the network over time. Unfortunately, most of the existing dynamic network models are not suitable for describing traffic flows.

A major obstacle for applying standard dynamic network models and algorithms for dynamic flows, is the property of traffic flows to have flow-dependent travel times on the edges. In particular, this means that with increasing traffic on a street the time to traverse this street increases. While for the case of fixed transit times there are both pseudo-polynomial and polynomial algorithms for example for maximizing dynamic s,t-flows, these algorithms are not applicable in the case of flow-dependent travel times.

In this talk we suggest a dynamic model for traffic networks that allows for using standard flow algorithms in the case of flow-dependent transit times. As an example for the application of this model we consider the quickest s,t-flow problem, i.e. the problem of sending a fixed amount of flow D from a source s to a sink t as quick as possible. While finding an optimal solution for this problem is NP-complete, we present approximation algorithms for the quickest flow problem both in the case of positive, monotone increasing travel time functions and positive, monotone increasing, linear travel time functions.

Online Dispatching of Service Vehicles

SVEN O. KRUMKE

(joint work with Willem de Paepe, Diana Poensgen, Jörg Rambau, Leen Stougie and Luis Miguel Torres)

The German automobile club *ADAC* (*Allgemeiner Deutscher Automobil-Club*), the second largest automobile club worldwide, maintains a heterogeneous fleet of over 1600 service vehicles in order to help people whose cars break down on their way. All service vehicles (*units*, for short) are equipped with GPS, which helps to exactly locate each unit in the fleet. In five ADAC help centers (*Pannenhilfezentralen*) spread over Germany, human operators (*dispatcher*) constantly assign units to incoming help requests (*events*, for short) so as to provide for a good quality of service (i.e., waiting times of less than 20–60 minutes depending on the system load) and low operational costs (i.e., short total tour length and little overtime costs). Moreover, about 5000 units of service contractors (*conts*, for short)—not guided by ADAC—can be employed to cover events that otherwise could not be served in time. This manual dispatching system is now subject to automatization.

The above dispatching problem is an real-time online problem. A problem is online when decisions have to be made before all data of the problem are known. And we speak of a real-time online problem when online decisions have to be computed within very tight time bounds.

In the first part of our talk we report on preliminary computational experience with a code for the offline dispatching problem (all requests are known) based on dynamic column generation and set partitioning. which yields solutions on heavy-load real-world instances in real-time, which are no worse than 1% from optimum.

The second part of the talk addresses the online aspect of the problem. We investigate the problem from the viewpoint of competitive analysis. However, it turns out that for the most interesting objective functions there can not be competitive algorithms. The offline adversary is simply too powerful and allows only trivial competitiveness results. We present two new concepts to obtain decision support for the choice of online algorithms: reasonable load and fair adversaries. The concepts enable us to obtain new performance bounds for online algorithms and to distinguish the performance of some particular algorithms, which seems to be impossible by means of classical competitive analysis.

New Formulation and Resolution Method for the p-Center Problem

MARTINE LABBÉ
(joint work with Sourour Elloumi and Yves Pochet)

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 it is allocated. We present a new integer linear programming formulation for this Min-Max problem with a polynomial number of variables and constraints, and show that its LP-relaxation provides a lower bound tighter than the classical one. Moreover, we show that an even better lower bound LB^*, obtained by keeping the integrality restrictions on a subset of the variables, can be computed in polynomial time by solving at most $O(log_2(NM))$ linear programs, each made of N rows and M columns. We also show that, when the distances satisfy triangle inequalities, LB^* is at least equal to half of the optimal value. Finally, we use LB^* as a starting point in an exact solution method and report extensive computational results on test problems from the literature. For Euclidean instances, our method outperforms the runtime of other recent exact methods by an order of magnitude. Moreover, it is the first one to solve large instances of size up to $N = M = 1817$

Optimal Rail Car Allocation Problems

MARCO E. LÜBBECKE
(joint work with Uwe T. Zimmermann)

The practical background of this talk is the rail car management at industrial in-plant railroads. Production terminals demand for materials or cars. These requests are characterized by a track, a car type, and the desired quantity. Substitution types may be delivered, but is discouraged. The planning task consists of allocating cars to requests at a minimal total transportation cost (measured e.g., in minutes). If available, use cars from (virtual) stock, otherwise reject the request or hire additional cars. Usually, requests are not fulfilled as a whole, but split into *shunting units*, each of which can be seen as an unsplittable duty element for the performing locomotive.

The design of shunting units naturally decomposes into two levels. At an upper level, a rough distribution of cars from one region to another takes place. Here, the underlying model merely is a transportation problem, but immediate extensions are $\mathcal{NP}$-hard. At a lower level, for each region, a collection of shunting units which fulfill the demand for each car type is sought, minimizing the total amount of shunting. The corresponding problem is shown to be $\mathcal{NP}$-hard. We present simple approximation algorithms and an exact integer program for the lower level. Encouraging preliminary computational experience is given. We conclude with potential further research directions.

Scheduling under Uncertainty

ROLF H. MÖHRING
(joint work with Andreas Schulz and Marc Uetz)

Deterministic models for project scheduling and control suffer from the fact that they assume complete information and neglect random influences that occur during project execution. A typical consequence is the underestimation of the expected project duration and cost frequently observed in practice.

To cope with these phenomena, we consider scheduling models in which processing times are random but precedence and resource constraints are fixed. Scheduling is done by policies which consist of an an online process of decisions that are based on the observed past and the a priori knowledge of the distribution of processing times. We give an informal survey on different classes of policies, and show that suitable combinatorial properties of such policies give insights into optimality, computational methods, and their approximation behavior. In particular, we present recent constant-factor approximation algorithms for simple policies in machine scheduling that are based on a suitable polyhedral relaxation of the performance space of policies. These are based on joint work with Andreas Schulz and Marc Uetz.

Discrete Ordered Median Problem

Stefan Nickel

(joint work with Natashia Boland, Patricia Dominguez-Marin and Justo Puerto)

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 exact procedures (tight formulations, branch and bound) and heuristics for solving the problem. Some computational results on randomly generated test problems will also be shown.

Motion Planning

Marc Overmars

In its basic form the motion planning problem asks for computing a collision-free path for a moving body amidst a collection of obstacles. Motion planning is becoming an important topic in many application areas, ranging from robotics to virtual environments and games. In this talk I reviewed some recent results in motion planning, concentrating on the probabilistic roadmap approach that has proven to be very successful for many motion planning problems. The method is probabilistically complete but its performance seems very hard to analyze. A number of improvements exist that try to reduce the number of samples required or try to place them at important places. A problem with the PRM approach is that the resulting paths can be ugly. I described some recent results for improving the paths by making them first order continuous and reducing their length.

Optimal Distance Separating Halfspace

Frank Plastria

One recently proposed criterion to separate two datasets in discriminant analysis, is to use a hyperplane which minimises the sum of distances to it from all the misclassified datapoints. Here all distances are supposed to be measured by way of some fixed norm, while misclassification means lying on the wrong side of the hyperplane, or rather in the wrong halfspace. In this paper we study the problem of determining such an optimal halfspace.

In dimension d, we prove that there always exists an optimal separating halfspace passing through d affinely independent datapoints. This shows that the problem is polynomially solvable in fixed dimension by an algorithm of $O(n^{d+1})$.

If a different norm is used for each dataset in order to measure distances to the hyperplane, or if all distances are measured by a fixed gauge, then there always exists an optimal separating halfspace passing through $d-1$ affinely independent datapoints.

The one-dimensional problem is extremely easy to solve: it suffices to find a balancing separating point, i.e. yielding an equal number of misclassifieds for each dataset, which can be done using a simple $O(n \log n)$ algorithm. But this separation criterion may misbehave, yielding more than 50% of misclassified datapoints. Therefore the criterion should include refusal of such a situation.

It also follows that in any dimension any optimal separating halfspace always balances the misclassified points.

Location Problems with respect to Set-Existing Facilities

Justo Puerto

Let X be a real separable Banach space and let μ be a positive measure σ-finite relative to the Borel structure on X. Let $T \subseteq X$ be a Borel subset with $\mu(T) > 0$. Let $f(t,x)$ be a function on $T \times X$ with values in $[0, +\infty]$. Let us denote by f_t the function on X, defined by the equality $f_t(x) = f(t,x),\ x \in X$. We are interested in those functions $f(t,x)$ with the property that (i) the f_t are convex and not identically equal to $+\infty$ for almost all t, and (ii) the $f(t,x)$ are $\mu - measurable$ and continuous for each $x \in X$. We set

$$\varphi(x) = \begin{cases} \int_T f(t,x)\mu(dt) & if \quad f(t,x) \in L_1(T, \mathbb{R}) \\ \infty & otherwise. \end{cases}$$

The objective of this talk is the geometrical characterization of the complete set of optimal solutions of two different average-distance problems with respect to sets.
We shall consider the following models:

1. $$\inf_{x \in X} \varphi(x) := \int_T f_t(x)\mu(dt) \qquad (P_f)$$

   An interesting application of this problem is the following average-distance problem. With each $t \in T$ a norm γ_t is associated. Let B_t be its unit ball, which is convex, closed, bounded with zero in its interior. The distance from an existing facility located in $t \in T$ to a new facility located in x is assumed to be given by $\gamma_t(x-t)$. The problem is now

   $$\inf_{x \in X} \bar{\varphi}(x) := \int_T \gamma_t(x-t)\mu(dt). \qquad (P_\gamma)$$

2. Let $\Upsilon = \{\mu_1, \ldots, \mu_m\}$ where each $\mu_i,\ i = 1, \ldots, m$ is a positive measure σ-finite relative to the Borel structure on X. Let $\Phi(\cdot)$ be a monotone norm in $\mathbb{R}^m$. We consider the following minimization problem

   $$\inf_{x \in X} F(x) := \Phi(I(x)), \qquad (P_{\bar{\Phi}}(\Upsilon))$$

   where $I(x) = (\int f_t(x)\mu_1(dt), \ldots, \int f_t(x)\mu_m(dt))$. It is worth noting that for particular choices of the monotone norm Φ, we get different well-known problems in Location Analysis as the center, cent-dian, k-centrum, ordered median,...

We shall study the sets $M_f(T)$ and $M_\gamma(T)$ of optimal solutions to problems $P_f(T)$ and P_γ, respectively; and the set $M_{\bar{\Phi}}(\Upsilon)$ of optimal solutions of problem $P_{\bar{\Phi}}(\Upsilon)$.

Two-Level Lot-sizing Problems in Supply Chain Planning

Dolores Romero Morales
(joint work with Stan van Hoesel, H. Edwin Romeijn and Albert P.M. Wagelmans)

We study a two-level serial lot-sizing problem that appears in supply chain planning when integrating the production and distribution processes. In the classical lot-sizing problem, the demand of each period has to be delivered on time, which means that only the facility can build inventory. Moreover, the timing of transportation is rather limited coinciding always with the demand periods. We propose the analysis of lot-sizing models where this assumption is relaxed and therefore, the demand can be transported to the retailer before he faces it. Transportation decisions come naturally in the model when allowing for inventory at both the facility and the retailer. This model is suitable when dealing with economies of scale in transportation costs, which are frequently used by LTL (Less than Truck Load) carriers.

We consider that the production and the transportation costs are given by general concave functions, and the inventory holding costs at the facility as well as at the retailer are given by linear functions. The facility faces production capacities. The serial structure of the problem allows us to find polynomially solvable cases when the production capacities are stationary. In particular, we develop dynamic programming algorithms when the transportation costs are linear or given by fixed-charge cost functions with no speculative motives. We discuss the multiple-retailer case and show that for fixed-charge production and transportation costs the problem is NP-Hard.

Solving the Travelling Purchaser Problem

Juan-José Salazar
(joint work with Gilbert Laporte and Jorge Riera)

Let us consider a set of locations, one being the domicile of a client and the others representing markets. We assume to know all the travel costs between locations. The client wants to purchase a set of products and each market provides some of the products at different prices. The "Travelling Purchaser Problem" looks for selecting some markets and routing the selected markets (and the domicile) within a simple cycle, such that the sum of the routing and pricing costs is minimized. We also considered a capacitated version of the problem where it is also required a given demand of each product while each market offers a limit amount.

We present a heuristic and an exact method based on a 0-1 linear programming model. The model is strengthened with new valid inequalities, some of which are proven to be facet-defining inequalities for the uncapacitated version. The overall algorithm is embedded in a branch-and-cut approach, and the performance of the proposal is tested on four classes of randomly-generated instances (two of them already used in literature). The proposal allows to solve to optimality instances with up to 200 markets and 200 products.

Locating Stops in a Railway Network

Anita Schöbel
(joint work with Annegret Liebers, Horst W. Hamacher, Dorothea Wagner and Frank Wagner)

In this talk we consider the location of stops along the edges of an existing public transportation network. This can be the introduction of bus stops along some given bus routes, or of railway stations along the tracks in a railway network. The positive effect of new stops is given by the better access of the potential customers to their closest station, while the increasement of travel time caused by the additional stopping activities of the trains leads to a negative effect. In the first variant of the problem the goal is to cover a given set of demand points with a minimal amount of additional travelling time, where *covering* is defined with respect to an arbitrary norm (or even a gauge). In the second variant we maximize the covered demand with a given number of new stops. Unfortunately, both problems are NP-hard, even if only the Euclidean distance is used. We give a reduction to a finite dominating set. In the first variant this leads to a set covering problem, those coefficient matrix “nearly” has the consecutive ones property. To solve this problem we suggest a transformation to a shortest path problem in an acyclic digraph. For the second variant we derive an efficient dynamic programming approach which is also based on the consecutive ones property.

Flows Over Time with Load-Dependent Transit Times

Martin Skutella
(joint work with Ekkehard Köhler)

Flow variation over time is an important feature in network flow problems arising in various applications such as road or air traffic control, production systems, communication networks (e.g., the Internet), and financial flows. Another crucial phenomenon in many of those applications is that the time taken to traverse an edge varies with the current amount of flow on this edge. Since it is already a highly nontrivial problem to map these two aspects into an appropriate and tractable mathematical network flow model, there are hardly any algorithmic techniques known which are capable of providing reasonable solutions even for networks of rather modest size.

Our work is inspired by the groundbreaking result of Ford and Fulkerson on ‘dynamic’ s-t-flows in networks with fixed transit times on the edges and a fixed time horizon. They showed that there always exists a maximal flow over time which sends flow on certain s-t-paths at a constant rate as long as there is enough time left for the flow along a path to arrive at the sink.

Although this result does not hold for the more general setting with load-dependent transit times on the edges, we can prove that there always exists a provably good solution of this structure. Moreover, such a solution can be determined very efficiently by only one minimum convex cost flow computation on the underlying ‘static’ network. Finally, we show that the time-dependent flow problem under consideration is NP-hard and even cannot be approximated with arbitrary precision in polynomial time, unless P=NP.

Fixtures for Polygonal Parts – Synthesis and Existence

Frank van der Stappen

Many manufacturing operations, such as machining, assembly, and inspection, require a part to be fixtured, that is, to be held by a collection of contacts along its boundary in such a way that the part can resist all external wrenches. We consider the two-dimensional version of fixturing which appears for example in preventing all sliding motions of a part on a table. We give near-quadratic algorithms for computing all frictionless form-closure and second-order immobility fixtures of a polygonal part. In addition we show that any polygonal part can be put in form closure by four contacts that are restricted to lie on a regular grid of perpendicular lines, a constraint present in modular fixturing systems.

Estimation of the Sizes of Wire Bundles in Manufacturing

Kokichi Sugihara

There are many electric devices in automobile; they include various types of sensors, actuators, lights and entertainment systems. These devices altogether result in a complicated electric circuit system, and hence a large number of electric wires run in a car. We want to estimate the sizes of the bundles of wires in order to make space and through holes in a car for placing these wires. Thus, the problem is: given a set of discs of various sizes, find a placement of these discs in a plane without overlap so that the enclosing circle is sufficiently small. If we aim at the strictly smallest enclosing circle, the problem coincides with the so-called circle packing problem, which is known very hard. Fortunately, however, what we want to get is not the strictly optimal solution, but we just want to know what happens when we hold a set of wires in our hand tightly. Hence, we simulate the process of holding wires. Starting with an arbitrary placement of discs and their enclosing circle, we choose a slightly smaller "target" circle and try to push all the protruding circles into the interior of the target circle. If we succeed, we make the target circle still smaller; otherwise we choose a circle between the current enclosing circle and the old target circle as a new target circle. In this binary-search manner, we simulate the wire holding process. This method was applied to a set of wires actually arises in a car, but the resulting enclosing circle was much smaller than the actual size of the bundle. This gap comes mainly from neglecting friction and 3-d structures. In order to overcome this gap, virtual radii of the discs were generated by adding a common constant to real radii, and thus we could practically estimate the sizes of the wire bundles.

Improved Algorithms for Some Location Problems

Arie Tamir

(joint work with Włodzimierz Ogryczak)

We consider improved polynomial time algorithms for a class of single facility problems in R^d with polyhedral norms, as well as for some class of multifacility weighted center problems defined on tree networks. For the former class we use a compact linear representation of the objective to derive $O(n)$ algorithms for a fixed dimension d, where n is the number of demand points. In particular, the algorithm will find a point $x \in R^d$ minimizing the sum of the largest k functions in a collection of n linear functions, in $O(n)$ time for any (variable) k and fixed d. For the second class we present the first subquadratic time algorithm for multi- facility center problems with multiple coverage demands.

Parallel Machine Scheduling to Maximize the Weighted Number of Just-In-Time Jobs

MILAN VLACH
(joint work with Shao Chin Sung)

The interest in just-in-time production has led to a number of machine scheduling models with various types of earliness and tardiness penalties. Most of the literature focused on single machine problems of minimizing the total sum of earliness and tardiness penalties, or on minimizing the maximum of earliness and tardiness penalties. The problem of minimizing the number of late and early jobs has received relatively little attention despite the fact that the primary role of penalizing both earliness and tardiness is to guide schedules toward the meeting due dates exactly.

We are concerned with the problem of scheduling a finite number of jobs without preemption on a system of parallel machines so as to maximize the weighted number of just-in-time jobs; that is, to minimize the weighted number of penalized jobs. This problem is known to be solvable in polynomial time for identical parallel machines. We show that it is strongly NP-hard for unrelated parallel machines. However we present a polynomial time algorithm for unrelated parallel machines, provided the number of machines is fixed. We do not know the problem complexity status for uniform parallel machines if the number of machines is a part of input.

Solving Practical Lot-Sizing Problems by Classification and Reformulation

LAURENCE WOLSEY

A classification of single-item lot-sizing problems is proposed. Based on this classification, we indicate the existence and complexity of valid inequalities, optimization and separation algorithms, and extended formulations describing the convex hull for the many variants. We then consider a variety of multi-item instances, classify them and then use the extended formulations to provide a formulation that can be solved by a standard mixed integer programming system. Finally, computational results are presented.

Scheduling on a Single Batch Processing Machine with Nonidentical Job Sizes

GUOCHUAN ZHANG
(joint work with Xiaoqiang Cai, Chung-Yee Lee and Chak-Kuen Wong)

We deal with the problem of minimizing makespan on a single batch processing machine. In this problem, each job has both processing time and size (capacity requirement). The batch processing machine can process a number of jobs simultaneously as long as the total size of these jobs being processed does not exceed the machine capacity. The processing time of a batch is just the processing time of the longest job in the batch. An approximation algorithm with worst-case ratio 3/2 is given for the version where the processing times of large jobs (with sizes greater than 1/2) are not less than those of small jobs (with sizes not greater than 1/2). This result is the best possible unless P=NP. For the general case, we propose an approximation algorithm with worst-case ratio 7/4. A number of heuristics by Uzosy (1994) are also analyzed and compared.

Inverse Optimization Problems

JASON ZHANG

In this talk, we shall first introduce inverse optimization problems, then give a general but not polynomial solution method. We will further elaborate some strongly polynomial methods and discuss some issues relating to computational complexity. Finally, we generalize the concept of inverse optimization problem and consider some more challenging problems.

Meetings of Working Groups

Working Group "Location and Transportation"

CHAIR: HORST HAMACHER

The participants of the conference who felt that their major area of work lies within the area of "Location and Transportation" – these were approximately 20 – met for brainstorming and discussion of research issues on Tuesday evening. As a result a list of topics was produced, which were considered to be the most urgent to work on. This list includes (by order of votes on importance):

1. Theory of location in integrated systems (Examples: Location plus Routing, Location plus Scheduling, Location plus Network Design, etc.)
2. Dealing with uncertainty and classification.
3. Robustness, undesirable facilities and theory of algorithms applied to locations and transportation.

These topics were also considered to be the most promising for seeking support from funding agencies.

A large amount of time was spent in discussing the importance of applications vs. "pure" theory. All participants agreed, that the success stories (mentioned were, for instance, radar positioning, cutting wood, tobacco industry, printed circuit board production) all required additional features in the models, which originally were developed in a "pure" environment. As such, the area of location and transportation does not seem to be different from other branches of applications in which mathematics is used as model. As current important applications participants mentioned the positioning of read/write heads in computers and data mining.

Working Group "Motion Planning"

CHAIR: MARC OVERMARS

The main focus of the brainstorming meeting of this working group was to identify challenges for future work in the area of motion planning and of related fields. The group arrived at the following list of main challenges:

- Coordinated planning of
  - multiple robots
  - robots and their manipulation tasks
  - motion and the transportation goals
- Dealing with uncertainty and making approaches robust to errors in the data, errors in the executed motions, failing devices (e.g. pins), etc.

- Analyzing the complexity/quality of the approaches under “realistic” assumptions on the input.
  - Stochastic properties of the input
  - Geometric properties of the input
- Approaches with good real-time behavior
  - Planning on the fly
  - Any-time algorithms
  - Educated guesses
- Experimental evaluation
  - Reference problems
  - Better reporting of experimental results
  - Better experimental infrastructure and support staff

Edited by Bettina Klinz

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