Tagungsbericht 2/1995

Mathematische Optimierung

08.01. bis 14.01.1995

Die diesjährige Tagung über mathematische Optimierung in Oberwolfach fand unter der Leitung von Bernhard Korte (Bonn) und Klaus Ritter (München) statt. Über 40 Teilnehmer aus 10 Ländern — mehr als ein Drittel von ihnen waren zum ersten Mal Gäste dieser Tagung — repräsentierten ein weites Spektrum der zur mathematischen Optimierung zählenden Themen. Zum ersten Mal wurde der Versuch unternommen, das Tagungsprogramm mit weniger aber dafür längeren Vorträgen zu gestalten. Die Teilnehmer haben diesen Versuch positiv aufgenommen; Diskussionen und Zusammenarbeit wurden dadurch vertieft.

Besonders intensiv waren dieses Mal die Interaktionen zwischen den zwei großen Bereichen der Mathematischen Optimierung, der kontinuierlichen Optimierung einerseits und der diskreten Optimierung andererseits. Penalty- und Barrier-Methoden (interior point-Methoden) geben weiterhin Impulse für neue Verfahren und Ansätze in der diskreten Optimierung, und bei großen Anwendungen der diskreten Optimierung werden häufig auch Algorithmen der kontinuierlichen Optimierung eingesetzt.

So bildeten Trust Region- und Interior Point-Methoden sowie Verbesserungen von Algorithmen für die lineare und nichtlineare Optimierung Tagungsschwerpunkte im Bereich der kontinuierlichen Optimierung. In der diskreten Optimierung wurde der Bogen von neuen Ergebnissen aus der Graphen- und der Matroidtheorie bis hin zum erfolgreichen Einsatz von Methoden der Diskreten Mathematik im Chipdesign und anderen Anwendungen gespannt. Beide Optimierungsbereiche profitieren von eindrucksvollen Fortschritten beim Computereinsatz zur Lösung von LPs. Neue Entwicklungen sowohl in Theorie und Softwaredesign als auch in der Hardwaretechnologie haben zu einen enormen Verschiebung der Schranken geführt, bis zu der Probleme als praktisch lösbar gelten. Ein exakt gelöstes TSP mit 7397 Knoten ist ein Beispiel.

Die freie Zeit wurde ausgiebig zu Diskussionen in kleinen Gruppen genutzt. Auch dabei zeigte sich, daß beide Gebiete der Optimierung voneinander profitieren können und daß der weitgesteckte Themenkatalog dieser Konferenz vielen Teilnehmern neue Anregungen gab.

Veranstalter und Teilnehmer danken — wie stets — dem Mathematischen Forschungsinstitut und seinen Mitarbeitern für die freundliche Aufnahme und Betreuung sehr herzlich.

David Applegate

Solving Large Travelling Salesman Problems

The travelling salesman problem (TSP) is one of the most thoroughly studied NP-complete combinatorial optimization problems. The most effective method for exactly solving large TSPs is due to Dantzig, Fulkerson, Johnson (1954), who used a linear programming relaxation and cutting planes to solve a 49-city problem. Although the basic method remains the same, better computers, computing environments, and linear program solvers have combined with new cutting plane heuristics, the addition of branching, and better interactions between the linear programm solver and the TSP solver have led to the solution of significantly larger problems. I describe some of the new techniques, developed with Robert Bixby, Vasek Chvatál, and William Cook, which we used to solve a 7397-city TSP, as well as all but 6 of the smaller open problems in TSPLIB, a library of TSPs collected by Gerhard Reinelt.

Michael J. Best

Global Optimization for Non-Convex Quadratic Programming

A relationship between non-convex quadratic programming (QP) and multi-parametric linear programming is presented. This is used to determine a global minimizer, all isolated local minimizers, and some non-isolated local minimizers for some specially structured non-convex QPs. For the general non-convex QP, a decomposition procedure is given which will either find the global optimum and all local optima as above, or reduce the problem to one or more strictly concave problems having strictly smaller dimensions.

Robert E. Bixby

Progress in Linear Programming and Application to Integer Programming

The talk was broken into three parts: (1) A report on computational progress in LP; (2) application to IP, particularly the traveling salesman problem; (3) very recent results on parallel mixed integer programming and parallel interior-point network.

(1) Factors of improvements in LP codes over the last 5–10 years can be estimated at $\approx 10^5$–10^6. The origins of these improvements were discussed, including machine and algorithmic improvements (simplex and interior).

(2) The ability to solve hard, partical IPs is, in the author's opinion, the main reason for interest in LP improvements. Using joint work with Applegate, Chvatál, and Cook on the TSP as a vehicule, column and row generation network, branch-and-bound and their intersection with LP and new steepest-edge algorithms were discussed.

(3) Parallel MIP is a natural development because B&B, the underlying algorithmic framework, is inherently parallel. Preliminary results were described for an implementation that runs on networks of workstations.

Parallel barrier (interior point) methods are currently based upon parallel network for Cholesky factorization. Using work of Rothenberg and Luntig, results showing sustained perfomrance up to 2 gigaflops on real problems were demonstrated. Results were obtained on an SGI power challenge (R8000) multiprocessor.

Andrew R. Conn

Iterated Subspace Minimization Methods for Nonlinear Programming

We consider a class of methods for solving large-scale minimization problems. At each major iteration, a low-dimensional manifold, the iterated subspace, is constructed and an approximate minimizer of the objective function in this manifold item determined, subject to any constraints that may be present.
The iterated subspace is chosen to contain vectors which ensure global convergence of the overall scheme and may also contain vectors which encourage fast asymptotic convergence. We demonstrate the efficency of this approach on a collection of large problems and indicate a number of avenues of future research.
This is joint work with N.I.M. Gould (RAL, UK) and A. Sartenaer and Ph. L. Toint (Namur, Belgium).

John E. Dennis

Some Convergence Results for NLP Trust-Region Algortihms

The 1^{st} order result of Powell and the 2^{nd} order result of More and Sorensen for unconstrained optimization are taken as the goal for algorithms for nonlinear constrained problems. We find a trust-region SQP for which a result of Dennis, El Alein, and Maciel gives an analog of Powell's theorem and a result of Dennis and Vincente gives an analog of the More-Sorensen theorem. These results are only given so far for the equality constrained problem.

Roger Fletcher

A New Method for Degeneracy in LP

The difficulties caused by round-off error for the resolution of degeneracy are noted. A new example of cycling (Hall&McKinnan) is shown to cause the EXPAND anti-cycling procedure to fail. A previous degeneracy method (Fletcher 1988) is described and is proved to terminate for both exact and inexact arithmetic. Its disadvantage is that it is a primal-dual method which is not suitable for use of techniques such as steepest edge and partial pricing. A new primal based method is the main result of this talk and avoids these disadvantages.

Jean Fonlupt

Minimal Coloring of Disconnecting Sets of Perfect Graphs

We prove the following result: If $G = (V, E)$ is a critically imperfect graph, and if there exists a vertex $v_o \in V$ such that the subgraph of G induced on $\{v_0\} \cup \Gamma(v_0)$ is uniquely colorable in $w(G)$ colors, then G is an odd hole or an odd antihole. ($\Gamma(v_0)$ is the set of neighbors of v_0 and $w(G)$ the size of a largest clique of G). A consequence of this result is that the strong perfect graph conjecture reduces to the following conjecture:
In a critically imperfect graph G, there exists a vertex v_0 such that the subgraph of G induced on $\{v_0\} \cup \Gamma(v_0)$ is uniquely colorable in $w(G)$ colors.

Andreas Frank

Conservative Weightings and Plane Multi Commodity Flows

This talk reviews the recent developments of T-joins, T-cuts, and their relationship to the disjoint paths problem. The material is taken from the paper "A survey on T-joins, T-cuts and conservative weightings" to appear in the Proceedings of the Erdös Conference on combinatorics (held in Keszthaly, 1994, Ed. V.T. Sos, Vol. 2). One corallary of the new results: The edge disjoint paths problem may be formulated as follows. Given two graphs $G = (V, E)$ and $H = (V, F)$, find $|F|$ edge-disjoint circuits in $G + H$ each using precisley one edge from F. The cut condition, $d_G(X) \geq d_H(X)\ \forall X \subseteq V$, is always necessary but not sufficient even in the special case when $G + V$ is planar. We prove that for this planar case the edge disjoint paths problem has a solution if $d_G(X) \geq 2d_H(X)$ for all $X \subseteq V$. The result is not true if 2 is replaced by $2 - \epsilon$ for any $\epsilon > 0$. [This is a joint result with Z. Szigeti and will appear in Mathematical Programming: A Note on Packing Paths in Planar Graphs]. Another recent paper (A. Frank and Z. Szigeti: On Packing T-Cuts, J. Comp. Th., Series B Vol. 61, No. 2 (1994), 263–271) includes a short proof of Seymour's difficult theorem on grafts (G, T) for which $\nu(G, T, W) = \tau(g, T, W)$ for all integral $w \geq 0$.

Michael D. Grigoriadis

Coordination Complexity of Parallel Price-Directive Decomposition

We consider the general block-angular convex resource-sharing problem in K blocks and M nonnegative block-separable coupling constraints. We study the coordination complexity of approximate price-directive decomposition (PDD) for this class of problems, i.e. the number of iterations required to solve the problem to a fixed relative accuracy as a function of K and M.

First we show that a simple PDD method based on the classical logarithmic potential is optimal up to a logarithmic factor in M, in the class of all PDD methods that work with the original (unrestricted) blocks. Second, we show that logarithmic and exponential potentials generate a polylogarithmically optimal algorithm for a wider class of PDD methods that can restrict the blocks by the coupling constraints.

As an application, we obtain the fastest-known deterministic approximation algorithm for the (linear) minimum-cost multi commodity flow problem. (Joint work with L. Khachiyan.)

Reiner Horst

Decomposition Method for Biconcave Minimization Problems

A decomposition scheme is introduced for minimizing a biconcave function $f: \mathbf{R}^{n+p} \rightarrow \mathbf{R}$ over $x \in X$, $y \in Y$, $(x, y) \in D$, where X, Y are polytopes in $\mathbf{R}^n$ and $\mathbf{R}^p$, respectively, and D is a polyhedron in $\mathbf{R}^{n+p}$. The resulting algorithm combines branch-and-bound in $\mathbf{R}^n$ with lower bounding by cutting planes in $\mathbf{R}^p$. For concave minimization, a new flexible class of algorithms results as well as for indefinite quadratic problems. Numerical experiments support the approach.

T.C. Hu

Some Open Problems and Searching for Global Minimum

Given a free tree of n nodes, there are $n!$ ways of labelling the tree, some of the labellings are graceful, some are not. The conjecture is that for $n \geq 7$, the chain is the most difficult tree to label. If we denote $N_p(T_n)$ for the number of graceful labellings of a tree of n nodes, and $N_p(C_n)$ for the number of graceful labellings of a chain of n nodes then we conjecture

$$\frac{N_p(T_p)}{n!} \geq \frac{N_p(C_n)}{n!} \quad \text{for } n \geq 7.$$

Since we can always label a chain, this conjecture is equivalent to the original conjecture that every tree has a graceful labelling.
We also consider a class of combinatorial optimization problems where we define the length and the width of the problem. There exists a set of elements with positive weights and the problem is to find a configuration of a maximal weight. Some configurations are feasible, others are not. And the configurations have to be built in a certain order. Each time that we add an element, we have to check if this would make the configuration feasible. And at the end, we have to compare all feasible configurations which are maximal and select one which is global maximum.
The maximal number of independent configurations is the width of the class of optimization, while the amount of work in checking the feasibility times the number of elements in the maximal configuration is the length of the problem. This would provide a way of measuring why a given problem is hard.

Johannes Jahn

Contingent Epiderivatives and Optimality Conditions in Set-Valued Optimization

In this talk the concept of the contingent derivative for a set-valued map is introduced which modifies a notion given by Aubin (1981) as upper contingent derivative. It is shown that this kind of a derivative has important properties and is one possible generalization of directional derivatives in the single-valued convex case. For optimization problems with a set-valued objective function optimality conditions based on the concept of the contingent epiderivative are proved which are necessary and sufficient under suitable assumptions.

Ellis Johnson

Some Airline Applications

The monthly airline planning process begins with schedule development, then assignment of fleet types to flight legs followed by making up routes for the planes, and finally crew scheduling. Computational experience with daily fleet assignment problems from Delta Airlines is presented. Crew scheduling consists of pairing optimization followed by rostering. Pairing optimization consists of partitioning the flight legs into trips that the crew can make. Three rather different pairing problems are discussed: American Airlines daily problem, Singapore Airlines weekly problem, and a 747 Federal Express monthly modell. Finally, some considerations and methods being developed with Northwest Airlines for crew recovery are presented.

BERNHARD KORTE

Mathematics of VLSI Design, Part I: L_1-Steiner Trees, Balanced Trees

This and the following talk by Jens Vygen give an overview of different combinatorial optimization techniques which we apply succesfully in the design of highly complex logic chips (e.g. microprocessors).

The routing, i.e. the connection of several pins of an electronic circuit by a net, is done by L_1-Steiner trees. The first Steiner tree problem was stated by Fermat: "Given three points in the plane; find a fourth point such that the sum of its distances to the other three is minimal." The general Steiner tree problem can be defined as follows: Given a graph $G = (V, E)$ and $T \subseteq V$ a set of terminals. A tree B in G with $\{v \in V(B) : |\delta_B(v)| = 1\} \subseteq T \subseteq V(B)$ is called a Steiner tree for T in G.

A Steiner Tree in $\mathbf{R}^2$ with different normes can be formulated analogously.

The Steiner tree problem, i.e. finding a Steiner tree of minimal length (= network design problem) is named after the Swiss geometer Jacob Steiner. However, he did not contribute to the problem at all (the first modern formulation is due to Jarnik and Kössler [1934]). In "What is mathematics?" Courant and Robbins attributed this problem wrongly to Steiner. They also wrote "generalization of the problem to more than three points is sterile". Of course, they did not know about NP-hardness.

Indeed, the Steiner tree in graphs and in the plane is NP-hard, also the L_1-Steiner tree problem for which the graph is a special grid graph.

We were able to design a very efficient algorithm for this problem. For complex logic chips L_1-Steiner tree problems have to be solved up to a million times for nets with 2 to 50 terminals.

Our algorithm is based on a decomposition theorem which states that every Steiner tree in a grid can be decomposed in firs. These are subgraphs with a stem and alternating branches. Actually, the theorem states that we have to consider only five different types of firs. This decomposition together with many technical and elaborate reductions allow to solve this problem optimally for any practical size. (An efficient algortihm for an optimal embedding of Steiner trees disjointly is not yet available.)

The second problem we report on deals with the construction of totally balanced trees for the clock distribution at a chip. This problem is solved by a bottom-up approach using minimum bottleneck perfect matchings.

CLAUDE LEMARECHAL

On Column Generation

The classical Dantzig-Wolfe algorithm for large-scale linear programming is known to be slow in practice. Here, we propose an acceleration device, which is a straight forward adaptation of bundle methods. The idea which has already proved efficient in various contexts is to replace the linear master program by a quadratic one, in a way related to the augmented Lagrangian techniques.

Thomas M. Liebling

On Vertex Enumeration and Related Problems

Avis and Fukuda showed in 1992 that the simplex method is in a sense optimal for enumerating all vertices of a simple convex polyhedron. Their remarkably simple idea of reverse search has since been applied for enumerating various combinatorial structures exhibiting approximate neighborhood relations. Here we study the applicability of backtrack techniques for vertex enumeration and face enumeration of general convex polyhedra given by systems of linear inequalities. We show there is a linear time backtrack algorithm for the face enumeration problem with polynomial space complexity in the input. The vertex enumeration problem requires to solve a decision problem, called the restricted vertex problem which is shown to be NP-complete. While the particular backtrack algorithm does not settle the complexity of vertex enumeration it makes it more likely to be NP-hard. Some other NP-complete problems associated with a system of linear inequalities are also discussed. They include the optimal vertex problem for polyhedra and for linear arrangements. (This talk is based on work with Komei Fukuda and Francois Margot.)

Rolf H. Möhring

Using Network Flows for Surface Modeling

We apply network flow techniques (bidirected flows) to a problem arising in the computer aided design of cars, planes etc.. Refine a mesh of spheric polygons approximating the surface of a workpiece such that the resulting mesh consists only of conforming quadrangles, that the density is within given, locally defined bounds, and that only certain "nicely shaped" refinement templates are permitted.

We show this problem to be strongly NP-hard. For a fixed choice of templates, we obtain a reduction to a bidirected flow problem. We present an algorithm based on bidirected flows that yields much better density control than the usual greedy-like procedures used in practice. (Joint work with Matthias Müller-Hannemann and Karsten Weike)

Kazuo Murota

Valuated Matroid Intersection

The independent assignment problem (or the matroid intersection problem) is extended as follows:

Given a bipartite graph $G = (V^+, V^-; A)$, valuated matroids $M^+ = (V^+, \beta^+, \omega^+)$ and $M^- = (V^-, \beta^-, \omega^-)$ and arc weights $w: A \to R$, find a matching M ($\subseteq A$) that maximizes

$$\Omega(M) \equiv w(M) + \omega^+(\partial^+ M) + \omega^-(\partial^- M)$$

subject to the constraint $\partial^+ M \in B^+$, $\partial^- M \in B^-$. Based on two new lemmas, "upper bound lemma" and "unique-max lemma" for the exchangeability in a single valuated matroid, two optimality criteria are shown; one in terms of potentials and the other in terms of negative cycles in an auxiliary graph. Strongly polynomial primal and primal-dual algorithms are given, which are the natural extension of the standard algorithms for the independent assignment problem.

DENIS J. NADDEF

Some Fast and Efficient Heuristics for Comb Separation for TSP

Good comb separation is essential for a good branch & cut performance in solving TSP problems. In this talk we give heuristics based on another heuristic that finds sets of a small coboundary containing a given set. This heuristic is a generalization of PRIM's algorithm for minimum spanning trees. Computational results show that these heuristics are really efficient. They can also be used to find violated cliquetree inequalities.

WERNER OETTLI

Generalized Strong Isoperimetric Inequality in Locally Finite Networks

Let $G := \{X, Y, K\}$ be a directed, locally finite graph without self-loops where X is the countable set of nodes, Y is the countable set of arcs, and $K: X \times Y \to \{-1, 0, 1\}$ is the node-arc incidence function. For all $y \in Y$, $r(y) \geq 0$ is a given resistance. Let $L(X)$ denote the set of all real-valued functions defined on X, and let $L_0(X)$ denote the set of all real-valued functions defined on X having finite support. For $u \in L(X)$ the discrete derivative $du \in L(Y)$ is defined by

$$du(y) := -\frac{1}{r(y)} \sum_{x \in X} K(x, y) u(x).$$

For $\emptyset \neq A \subseteq X$ let $\partial A \subseteq Y$ denote the cocycle generated by A. $|A|$ and $|\partial A|$ denote the cardinality of A and ∂A. Fix a real number $p > 1$. For all $x \in X$ let

$$\nu_p(x) := \sum_{y \in Y} |K(x, y)| r(y)^{1-p}$$

We consider:

(GPS) Generalized Poincare-Sobolev inequality: There exists $\gamma > 0$ such that

$$\sum_{x \in X} \nu_p(x) |u(x)|^p \leq \gamma \sum_{y \in Y} r(y) |du(y)|^p$$

for all $u \in L_0(X)$.

(GSI) Generalized strong isoperimetric inequality: There exists $c > 0$ such that

$$\sum_{x \in A} \nu_p(x) \leq c \sum_{y \in \partial A} r(y)^{1-p}$$

for every finite nonempty subset $A \subseteq X$.

Theorem 1. (GPS) holds if, and only if, (GSI) holds.

For $r = 1$ and $p = 2$ we obtain from Theorem 1 a result by Ancona (Lecture Notes in Math. 1344, pp. 1–23).

Theorem 2. (GSI) holds if, and only if, there exist $c > 0$ and $w \in L(Y)$ such that $|w(y)| \leq c \cdot r(y)^{1-p}$ on Y, $\sum_{y \in Y} K(x,y)w(y) = \nu_p(x)$ on X.

(Joint work with Maretsugu Yamasaki (Matsue))

GIANNI DI PILLO

A New Version of Price's Algorithm for Global Optimization

We present an algorithm for finding a global minimum of a multimodal, multivariate function whose evalution is very expensive and whose derivatives are not available. The proposed algorithm is an improved version of the well known Price's algorithm and its distinguishing feature is that it tries to employ as much as possible the information about the objective function obtained at previous iterations. The algorithm has been tested on a large set of standard test problems and it has shown a quite good computational behavior. The algorithm has been also used to solve efficiently some difficult optimization problems deriving from the study of eclipsing binary star light curves.

FRANZ RENDL

Solving Large Scale Trust Region Subproblems

An algorithmic framework is presented that solves the trust region subproblem

$$\min x^t A x - 2a^t x \quad \text{s.t. } x^t x = s^2$$

by means of the smallest eigenvalue of the matrix

$$D(t) = \begin{pmatrix} t & -a^t \\ -a & A \end{pmatrix}$$

for the "right" value $t = t^*$.

Determinig t^* is equivalent to maximizing a one dimensional concave function on an interval.

STEPHEN M. ROBINSON

Sample-Path Optimization in Simulation: Current Progress Report

We are concerned with systems depending on parameters, with respect to which we want to optimize some measure of performance in the limit (steady state). These systems can be observed only through simulation: there is no analytical expression for them.

The method of sample-path optimization proceeds by generating a single sample path of the system and optimizing it, thereby converting a stochastic problem to a deterministic approximation. We summarize what is currently known about the theoretical justification and the practical applicability of this method, including computational results on tandem queues and PERT networks that appear to be the largest problem of their kind solved in the literature to date.

INGO SCHIERMEYER

Exact and Approximation Algorithms for k-Colorability

We first describe and analyse four improved algorithms for deciding the 3-, 4-, 5- and 6-colorability problem. If G is a simple graph on n vertices then we will show that these algorithms test a graph for 3-, 4-, 5- and 6-colorability, i.e. an assignment of three, four, five or six colors to the vertices of G such that two adjacent vertices obtain different colors, in less than $O(1.398^n), O(1.585^n), O(1.938^n)$ or $O(2.155^n)$ steps.
We next describe a polynominal time approximation algorithm to color a 3-colorable graph G with $3f(n)$ colors, if G has minimum degree $\delta(G) \geq \frac{\alpha n}{f(n)}$, where $\Omega(1) \leq f(n) \leq O(n)$ and α is a positive constant. We also discuss NP-completeness and #P-completeness of restricted k-colorablity problems.

DAVID SHANNO

Penalty and Penalty-Barrier Methods
for Linear and Nonlinear Optimization

Logarithmic barrier methods have been very successful in deriving algorithms for linear programming which are extremely efficient for solving large and degenerate problems. Recent results in determining infeasability and dealing with dense columns and lower bounds are discussed. The barrier method is modified to apply to nonlinear programming problems, with a penalty method used when infeasibility is large, and Polyak's modified barrier method used for small infeasibility or feasible constraints. Extensive computational results are given, together with directions for future research.

STEFAN ULBRICH

Parameter Identification in Systems Governed by Hyperbolic PDE's

After a brief discussion of parameter identification theory in function spaces and its connection to equality constraint optimization in Banach spaces the discretized problem is considered. For the case of hyperbolic systems in one space dimension two efficient methods to compute the gradient of the objective function with respect to the parameters are described. One of them is very well suited for Gauß-Newton type methods. Finally it is shown how these computations can be done in parallel.

MICHAEL ULBRICH

Parameter Identification in Systems governed by Hyperbolic PDE's, Part II

Under consideration are ill posed parameter identification problems in fluid dynamics. After a brief discussion of regularization methods, a homotopy method is introduced to find a local minimum of the regularized problem. This method is very robust and ensures that every reached stationary point is a minimum. Another homotopy is applied to implement an a posteriori regularization parameter choice strategy. Finally, the principle of predictorcorrector continuation methods is outlined and numerical results are presented.

Jens Vygen

Mathematics of VLSI-Design, Part II

Disjoint Paths, Large-Scale QPs, Maximum Mean Cycles

We continue the survey on combinatorial optimization problems arising in VLSI-Design. We start with the problem of finding disjoint paths in graphs. We consider several results concerning the polynominal solvability of the edge-disjoint paths problem in certain cases (by Rothschild and Whinston, Ibaraki and Poljak, Nash-Williams, Lucchesi and Younger). We report on NP-completeness results which show that all these theorems are - in a sense - best possible. Moreover the edge-disjoint paths problem in directed and in undirected grids is shown to be NP-complete (these are the important cases for VLSI-Design).
Next we outline a program for VLSI-Placement which has proven to be successful for the most complex processor chips. Some mathematical methods applied here are presented, including solving large-scale QPs (with several hundred thousand variables), certain minimum-cost-flow and knapsack problems etc.
Finally we consider the problem of determining the optimum arrival times of the clock signals at the latches of a chip in order to minimize the overall cycle time. We prove that this problem is equivalent to a maximum mean cycle problem in a certain directed graph, leading to a very efficient solution.

Dominique de Werra

Restricted Colorings

In timetabling we often have to consider the following problem: Given a bipartite multigraph G where each edge has a set $\varphi(e)$ of feasible colors, find an edge k-coloring where each edge e gets a feasible color (i.e. color $e \in \varphi(e)$). This is called a restricted coloring. This problem is NP-complete for general bipartite graphs.
We consider an LP relaxation of the problem: $\max\{\Delta \underline{u} | \Delta \underline{u} \leq \Delta \underline{j} \geq \underline{0}\}$. Duality arguments provide a certificate of non-colorability which looks like Hall conditions for systems of district representatives. We show that the following statements are equivalent for a connected graph G:
1. G is a tree
2. the constraint matrix A is balanced
3. for any choice of sets φ, there exists a restricted coloring or a certificate of non-colorability.

As a consequence, the problem of restricted coloring can be solved in polynominal time for trees. An algorithm in $O(nk(\Delta + k)^2$ has been derived. ($n = \#$ nodes, $k = \#$ colors, $\Delta =$ maximum degree of G).
(Joint work with H. Gröflin, A. Hoffmann, N.V.R. Mahadev, V. Peled)

Uwe Zimmermann

Optimal Lines for Railway Systems

We discuss the optimal choice of traffic lines with periodic timetables on a railway system. A chosen line system has to offer sufficient capacity in order to serve the known amount of traffic on the system. The line optimization problem aimes at the construction of a feasible line system optimizing certain objectives. We introduce a new mixed integer linear programming formulation. For real world data we succeed in solving the model by means of suitable relaxation and sufficient strong cutting planes with the commercial LP-solver CPLEX 3.0.

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