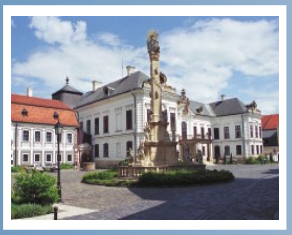

VOCAL2004

PROGRAM

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Hungarian Academy of Sciences Section of Technical Sciences

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VOCAL 2004

The Veszprém Optimization Conference: Advanced Algorithms is held at the Regional Centre of the Hungarian Academy of Sciences in Veszprém (VEAB), Hungary, December 13-15, 2004. The conference is hosted by the recently established Faculty of Information Technology, University of Veszprém.

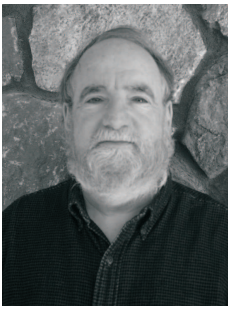
Conference scope

The VOCAL conference focuses on recent advances on optimization algorithms: continues and discrete; complexity and convergence properties, high performance optimization software and novel applications are reviewed as well.

We aim to bring together researchers from both the theoretical and applied communities in the framework of a medium-scale event. The VOCAL conference marks the foundation of the Faculty of Information Technology of the University of Veszprém.

Invited Speakers

Andrew R. Conn



Dr. Conn is a research staff member at the IBM Thomas J. Watson Research Center, Yorktown Heights, NY. He earned his Ph.D. at the University of Waterloo, Canada in 1971, and joined IBM Research in 1990. He was a member of the Department of Combinatorics and Optimization and the Department of Computer Science, University of Waterloo, Waterloo, Ontario, Canada from 1972-1991. In 1992 and 1993, he was a visiting professor in the Operations Research Department, Yale University. He currently is an adjunct Professor at the University of Minnesota, Minneapolis, where he has a Ph.D student. His current research is in the Optimization Center and he manages the Numerical Analysis Group, both in Mathematical Sciences. His research interests are in mathematical programming and is typically motivated by algorithms but includes convergence analysis, theory, applications and software. Although predominately devoted to continuous nonlinear optimization, he has had an ongoing interest in linear and discrete problems, exploiting their structure and adapting continuous techniques to their solu-

tion. In the last several years he has been especially involved in large-scale nonlinear optimization and, in particular is a co-author of the large-scale nonlinear programming package LANCELOT and the testing environment CUTE. Moreover, he has a great interest in applications of optimization to complex problems, especially those involving simulation. In particular, with Michael Henderson and Chandu Visweswariah he has been applying nonlinear optimization to circuit tuning problems. The systems they have developed have successfully handled problems with thousands of nonlinear variables and constraints, and have made a significant impact on IBM's circuit design. With Philippe Toint and Katya Scheinberg he has developed algorithms that do not model derivatives, that are called DFO, for derivative free optimization. He is a past chairman of the SIAM activity group on Optimization, and was on the editorial board of the SIAM Journal on Optimization from its foundation until 1999. He is currently on the editorial board of Mathematical Programming. In addition to two books he has authored more than seventy research papers. In 1994, he was (with Gould and Toint) a joint recipient of the Beale/Orchard-Hays Prize for Computational Excellence in Mathematical Programming.

Gianni Di Pillo

Gianni Di Pillo, born in Rome in 1942, graduated in Engineering in the University of Rome in 1966. He held different university positions in Italy; he became full professor of Operations Research in the School of Engineering of the University of Rome "La Sapienza" in 1981.

His research activity has dealt mainly with methodological subjects in System Analysis and Optimization. In particular, he provided contributions to Nonlinear Programming theory and algorithms, with main reference to methods based on exact penalty and augmented Lagrangian functions. Significant applications include the management of water resources, the management of heath power systems, the analysis of binary stars systems in astrophysics. The research activity is documented in more than 90 papers published in international journals.

He is Associate Editor of: *Journal of Optimization Theory and Applications, Journal of Global Optimization, Computational Optimization and Applications.*

He has been since 1994 the Director of the Department of Computer and Systems Science of the University of Rome "La Sapienza", a leading research and teaching institution with a staff of more than 60 professors and researchers.

Komei Fukuda

Komei Fukuda has been with Swiss Federal Institute of Technology Zurich (ETHZ) and Lausanne (EPFL) since 1996. He received the title of professor from the Department of Mathematics, ETHZ in May 1999. His major interests include convex polytopes, linear optimization and geometric computation in higher dimensions, interactions of geometry and combinatorics, enumeration problems and complexity theory.

Komei Fukuda obtained B.S. in 1974 and M.S. in 1976 from the Department of Administration Engineering at Keio University, Japan. He obtained a Ph.D. in Mathematics from the Department of Combinatorics and Optimization of University of Waterloo, Canada with dissertation titled "Oriented Matroid Programming" in 1982.

In 1982, he became assistant professor at the Department of Information Sciences of Tokyo Institute of Technology, associate professor in 1989 at the Graduate School of Systems Management of University of Tsukuba, Japan. He also worked as full professor at the School of Computer Science, McGill University, Montreal, Canada in 2001 and 2002.

Florian Jarre

Florian Jarre is currently carrying out research at the Mathematics Institute of the University of Dusseldorf as a full professor.

Florian Jarre obtained Ph.D. in Mathematics at the University of Würzburg, in 1989 and in 1984 he obtained "Habilitation" in Mathematics at the University of Würzburg.

He held visiting positions at the Institute of Statistical Mathematics, Tokyo, Japan, at the University of Trier, at the Department of Operations Research at Stanford University, Stanford, CA; and held faculty positions at the University of Würzburg, Germany and at the University of Notre Dame, USA.

Florian Jarre is the European area editor of *Optimization Methods and Software, editorial board member of Optimization and Engineering, Mathematical Method of Operations Research, and Operations Research Letters.*

Florian Jarre is author of numerous research papers, coauthor of a book. His research interest covers interior point methods, nonlinear optimization and scientific computing.

Jakob Krarup

Jakob Krarup, a full professor, is the head of the Group on Algorithmics and Combinatorial Optimisation of the Department of Computer Science, University of Copenhagen. He had visiting appointments in several countries, e.g., in Germany, France, Hungary, Austria, and Cyprus. Jakob Krarup has been the co-founder and president of the DAPS Society, he is a past vice president and president of EURO, a former EURO vice president of IFORS and the Danish representative at EURO for more than two decades.

Between 1969 and 1972 he was the secretary, between 1977 and 1979 he was the president of the DORS, Danish OR Society and he is still member of it. Jakob Krarup is the Danish representative of the IFORS, International Federation of Operations Research Societies.

He is the member of the following editorial or advisory boards: Discrete Applied Mathematics, Advances in Management Studies, Annals of OR, YUJOR – Yugoslav Journal of Operational Research, ITOR – International Transactions in OR, IJOQM – International Journal of Operations and Quantitative Management, Discrete Optimization.

Jakob Krarup has been listed in the "Who's Who in the World" since 1983. He is honorary member of the Hungarian OR Society, he is Doctor honoris causa at the Warsaw Business School. In 1999 he was awarded the Knight of the Order of Danebrog.

Arnold Neumaier

Arnold Neumaier is professor for Computational Mathematics at the University of Vienna (Austria). He published 4 books and about 130 research articles in pure and applied mathematics, optimization, statistics and physics. He maintains the 'Global (and Local) Optimization' WWW site, the most comprehensive web collection of links to online information, software and test problems on global optimization; in addition, extensive web pages on public domain software for numerical analysis, optimization, and statistics. His research group is active in developing state of the art software for global optimization by integrating methods from nonlinear programming, interval analysis, and combinatorial optimization, and an associated modeling language.

1977 Ph.D. (Free University, Berlin, D), 1987-1993 professor (University of Freiburg, Germany), 1988 visiting professor (University of Wisconsin-Madison, USA), 1993-1994 in technical staff of AT&T Bell Laboratories (USA), since 1994 professor for computational mathematics (University of Vienna, Austria), 2000 Research Fellow (Chemical Engineering, Princeton University, USA).

Franz Rendl

Franz Rendl, a full professor at the University of Klagenfurt, is heading a research group in Operations Research and Optimization. He was visiting professor at the University of Waterloo (Ontario, Canada), Massey University (New Zealand), University of Augsburg (Germany), University Paris 6 (France), and IASI Rome (Italy).

Franz Rendl is on the editorial board of the following journals: Mathematical Programming, SIAM Journal on Optimization, Computing, Journal of Combinatorial Optimization, and Discrete Optimization.

Franz Rendl has more than 60 papers in journals on mathematical optimization and operations research. His current research interest covers semidefinite programming and its applications in combinatorial optimization, in eigenvalue optimization, and to develop bundle methods for solving non-smooth optimization problems.

Kees Roos

Kees Roos (1941) holds a chair in Optimization Technology at Delft University of Technology. In the past 15 years his research concentrated on interior-point methods for linear and convex optimization, at present with emphasis on semidefinite optimization and its application to combinatorial optimization. He is (co-)author of some books and more than hundred papers in refereed journals, associate editor of SIAM Journal on Optimization and member of the editorial board of several other journals. He serves the SIAM Activity Group on Optimization as secretary/treasurer. He supervised a number of research projects, among them the Dutch nationwide NWO-project High Performance Methods for Mathematical Optimization and the project Discrete Mathematics and Optimization of the (Dutch) Stieltjes Institute.

Jean-Philippe Vial

Jean-Philippe Vial is professor in Operations Management at the University of Geneve. His research focuses on convex optimization and its applications. He has published over 80 articles and a book. He has been actively involved in the development and implementation of cutting plane methods that solve general convex problems using first order information only. He has applied this method to solve large scale optimization problems, in particular problems arising in transportation, suplly chain management and environmental planning.

In 1991 he cofounded with A. Haurie Logilab, the Logistics Laboratory, to host the research activity in logistics at the University of Geneva. He has been elected president of the Mathematical Programming Society in 1997, served as president from 1998 to 2001, and as vice-president in 1997-98 and 2001-2004. In 1997, he chaired the Tucker Prize Committee, a triennal award of the Mathematical Programming Society. His editorial service includes 10 years as associate editor in *Management Science* and 6 years in *Mathematical Methods of Operations Research*.

Technical Program

December 12, 2004 (Sunday)

3:00 pm – 6:00 pm **Registration Office Open**

December 13, 2004 (Monday)

7:00 am – 6:00 pm **Registration Office Open**

7:00 am – 8:30 am **Registration**

8:30 am – 9:00 am **Opening and Introduction**

9:00 am – 10:00 am **Plenary Session 1**

Nonlinear Optimization at Watson.
Andrew R. Conn

10:00 am – 10:30 am **Coffee break**

10:30 am – 12:00 pm **Parallel Session 1A**

Approximation algorithm for the mixed fractional packing and covering problem.
Klaus Jansen

Improved approximation algorithms for scheduling malleable tasks with precedence constraints.
Hu Zhang

Primal-dual algorithms for data depth.
Vera Rosta

10:30 am – 12:00 pm **Parallel Session 1B**

New variant of the Mizuno–Todd–Ye predictor–corrector algorithm for sufficient matrix linear complementarity problem.

Tibor Illés, Marianna Nagy

A new Mizuno-Todd-Ye type algorithm for linear optimization
Zsolt Darvay

New primal-dual interior-point methods based on kernel functions.
Mohamed El Ghami, Y. Q. Bai, Kees Roos

10:30 am – 12:00 pm **Parallel Session 1C**

A comparative study of evolutionary methods for optimal design of shallow space trusses.
Anikó Csébfalvi

Lot sizing methods - review and comparative analysis, development and advantages arising from genetic algorithms application.
Joanna Oleskow

An exact resource allocation model with hard and soft resource constraints.
Ferenc Kruzslicz

12:00 pm – 1:30 pm **Lunch**

1:30 pm – 2:30 pm **Plenary Session 2**

An SQP method for semidefinite programming.
Florian Jarre, Christoph Vogelbusch, Roland W. Freund

2:30 pm – 3:30 pm **Plenary Session 3**

Multicommodity flows.
Jean-Philippe Vial

3:30 pm – 4:00 pm **Coffee break**

4:00 pm – 6:00 pm **Parallel Session 2A**

Design and implementation of spreadsheet algorithms in production management.
Zoltán Kovács

Reducing the complexity of capacity analysis in flexible manufacturing systems by operation type based aggregation.
Tamás Koltai

Computational problems of the operation type based aggregation in flexible manufacturing systems.

Viktor Juhász, Tamás Koltai

Production planning model of an oil company.
Zsolt Csizmadia, Tibor Illés, Yu Da

4:00 pm – 6:00 pm **Parallel Session 2B**

A verified optimization technique to prove and locate chaotic regions.
Balázs Bánhelyi, Tibor Csendes, Barna Garay

Global optimization techniques for stability analysis of decision functions.
János Fülöp, Sándor Z. Németh

On the c-repacking on-line bin packing problem: lower bounds.
János Balogh, József Békési, Gábor Galambos

Matrix inverses, rigid circuit graphs, fibonacci heaps, homotopies, polyhedra and probability bounding.
Mihály Hujter

4:00 pm – 6:00 pm **Parallel Session 2C**

Local optimization algorithms and deterministic chaos.
Vitaly E. Podobedov

Metaheuristic scheme to find good solutions with running time limitation.
Ákos Ladányi, Alpár Jüttner, Tibor Cinkler

An XML-based interface to use Statecharts in specifying and dealing with Performance Models.
Ana S.M.S. Amaral, Renê Rodrigues Veloso, Nandamudi L. Vijaykumar, Carlos Renato Lisbo Francês, Edvar da Luz Oliveira

Optimization of Production Nets under Temporal Constraints
Szilvia Varró-Gyapay, András Pataricza, Ádám Nagy

8:00 pm – 9:00 pm **Organ Concert**

December 14, 2004 (Tuesday)

7:00 am – 6:00 pm **Registration Office Open**

8:30 am – 9:30 am **Plenary Session 4**

Conic Optimization and some recent applications.
Kees Roos

9:30 am – 10:30 am **Plenary Session 5**

Solving Semidefinite Programs using Bundle Methods and the Augmented Lagrangian Approach.
Franz Rendl

10:30 am – 11:00 am **Coffee break**

11:00 am – 12:30 am **Parallel Session 3A**

Sequential quadratic programming applied to control theory problems.
Catherine Buchanan

Nonnegative polynomials, linear recurrences and decomposition into rank-one Hankel matrices.
François Glineur

Systems of quadratic inequalities and the S-lemma.
Imre Pólik, Tamás Terlaky

11:00 am – 12:30 am **Parallel Session 3B**

The problem of making a digraph k-vertex connected by adding a minimum number of edges.
László Végh

Maximum even factor algorithm.
Gyula Pap

An algorithm for source location in directed graphs.
Mihály Bárász, Johanna Becker, András Frank

12:30 am – 2:00 pm **Lunch**

2:00 pm – 3:30 pm **Parallel Session 4A**

Level decomposition for two-stage stochastic programming problems.
Csaba Fábián, Zoltán Szõke

Estimation of rare event probabilities in stochastic networks with exponential and beta distributions.
Ashraf A. Gouda, Tamás Szántai

Recent developments concerning the modeling system SLP-IOR.
Peter Kall, János Mayer

2:00 pm – 3:30 pm **Parallel Session 4B**

New criss-cross type algorithms for linear complementarity problems with sufficient matrices.
Zsolt Csizmadia, Tibor Illés

Remarks on submodular functions and related set function classes.
Stephan Foldes

Exploiting symmetry in graph to efficiently compute Lovász type bounds.
Igor Djukanovic, Franz Rendl

2:00 pm – 3:30 pm **Parallel Session 4C**

Particle swarm method as a new tool for single and multiobjective optimization.
Károly Jármai

Criticality in resource constrained projects.
György Csébfalvi, Roni Levi

3:30 pm – 4:00 pm **Coffee break**

4:00 pm – 5:00 pm **Plenary Session 6**

Generating all vertices in implicitly defined polytopes
Komei Fukuda

5:00 pm – 6:00 pm **Plenary Session 7**

A family of structured set covering problems.
Jakob Krarup

7:00 pm – 11:00 pm **Banquet**

December 15, 2004 (Wednesday)

7:00 am – 6:00 pm **Registration Office Open**

8:30 am – 9:30 am **Plenary Session 8**

Complete Search for Constrained Global Optimization.
Arnold Neumaier

9:30 am – 10:30 am **Plenary Session 9**

Convergence to second order stationary points in nonlinear programming.
Gianni Di Pillo

10:30 am – 11:00 am **Coffee break**

11:00 am – 12:30 am **Parallel Session 5A**

An exact penalty method for smooth equality constrained optimization
T. Rapcsák, W. Bergsma

Use of Empirical Likelihood in Optimal Pre-control Plans
Vicent Giner, Susana San Matías

Synthesis of MIP Model for PNS
Ferenc Friedler, L. T. Fan

11:00 am – 12:30 am **Parallel Session 5B**

LEMON - a Software Library for Efficient Modeling and Optimization in Networks.
Alpár Jüttner

On the scheduling problem in the combinatorial model of the PNS problem.
Csanád Imreh

Dénes König, the father of the "Hungarian method"
Zsuzsanna Libor

11:00 am – 12:30 am **Parallel Session 5C**

Continuous vs Discrete-Time Approaches in Batch Chemical Process Scheduling - Application to Heat Integration.
Thokozani Majozi

Optimising the General Purpose Controller Network Architecture. (GPCNA)
Abdulrazzaq Ali Aburas, Omar Bashir

12:30 am – 2:00 pm **Lunch**

2:00 pm – 4:00 pm **Parallel Session 6A**

Sparse simplex methods applied to quadratic programs and quadratic mixed integer programs.
Frank E.F.D. Ellison, M. Guertler, Guatam Mitra

Recent achievements in interior point technology.
Csaba Mészáros

Algorithmic and implementation aspects of parametric and sensitivity analysis in convex quadratic optimization.

Oleksandr Romanko, Tamás Terlaky, Alireza Ghaffari Hadigheh

Current state of the dual simplex method.
István Maros

2:00 pm – 4:00 pm **Parallel Session 6B**

Engine assignment problem under some operation policy for railway transportation.
Tibor Illés, Márton Makai, Endre Németh, Zsuzsanna Vaik

Assessing store performance equitably.
Gábor Pauler, Minakshi Trivedi, Dinesh Kumar Gauri

A new resource leveling milp model for multi-mode projects based on global measure.
Etelka Szendrõi

New exact and heuristic solution procedures for the setup cost oriented resource leveling problem.
László Torjai

2:00 pm – 4:00 pm **Parallel Session 6C**

The speedup of the cluster-based approach in divide and conquer paradigm.
Trung Hoang Dinh, Abdullah Al Mamun

An efficient algorithm to determine the core of cooperative games.
Saloman R.M. Danaraj, Durga Prasad

A method for solving fuzzy number linear programming problems based on multiobjective linear programming technique.
Maryam Zangiabadi, H. R. Maleki

4:00 pm – **End of conference**

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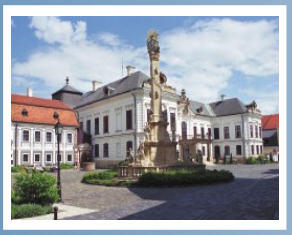

VOCAL2004

ABSTRACTS

Contents

Nonlinear optimization at Watson

Andrew R. Conn

Thomas J. Watson Research Center, IBM Research, USA

I will describe some of the ongoing nonlinear optimization research at Watson, including applications.

An SQP method for semidefinite programming

Florian Jarre, Christoph Vogelbusch
University of Düsseldorf, Germany

Roland W. Freund
University of California, USA

We present a simple sensitivity result for solutions of linear semidefinite programs under small arbitrary perturbations of the data. The result is generalized to nonlinear programs with nonlinear semidefiniteness constraints. In order to solve such nonlinear semidefinite programs (NLSDPs) a sequence of quadratic semidefinite programs approximating the NLSDP is considered, generalizing the SQP-approach for nonlinear programs.If the quadratic semidefinite subproblems are convex, they can be rewritten as linear conic programs. The sensitivity results are used to derive an elementary and self-contained proof of local quadratic convergence of the resulting sequential linear conic programming (SLCP) method. A key advantage of the SLCP method lies in the fact that the choice of the symmetrization procedure can be shifted in a very natural way to the linear semidefinite subproblems, and thus being separated from the process of linearizing and convexifying the data of the NLSDP. Globalization techniques and small scale numerical results will be discussed.

Multicommodity flows

Jean-Philippe Vial
University of Geneve, Switzerland

We propose new algorithmic developments to solve multicommodity flow problems with linear costs and capacity constraints and nonlinear costs also. We show that the Lagrangian dual is a convex optimization problem whose objective function is made of two terms: a nondifferentiable one and a smooth one. We solve the dual using Proximal-ACCPM, a recent enhancement of the analytic center cutting plane method. In the presentation, we shall discuss two further extensions. The first one applies to linear multicommodity flows and consists in an active set strategy. The second one applies the nonlinear case: the smooth component of the objective is treated via a nonlinear cut. In our numerical experiments, we use classical test problems. We show that we significantly improve on previously developed methods. In particular, we can solve huge problem instances, with up to 14000 nodes, 40000 arcs and 2000000 commodities.

Conic Optimization and some recent applications

Kees Roos
Delft University of Technology, Niederland

Linear Optimization (LO) deals with the problem of optimizing (i.e., minimizing or maximizing) a linear function over the intersection of an affine space and the nonnegative orthant. Its rich mathematical theory has been developed in the last 50 years. Although the applications are numerous, there are many real-life phenomena that cannot be described by a linear model, and hence the need for Nonlinear Optimization is apparent. Recently it has become clear that in many cases nonlinearity can be handled very well by replacing the nonnegative orthant in LO by a nonlinear convex cone, which has led to a new field, namely Conic Optimization (CO). Prototype examples of suitable cones are the Lorenz (or ice-cream, or second order) cone and the semidefinite cone. The theory of CO is extremely beautiful. Since many nonlinear optimization problems can be put in the form of a CO model, and these models, like LO models, can be solved efficiently, there is rich potential for new applications. In the lecture I will give an introduction to CO. Its use will be illustrated by discussing various recent applications, namely: minimization of a polynomial, wireless sensor location, fast distributed linear averaging and new bounds for binary codes.

Solving semidefinite programs using bundle methods and the augmented lagrangian approach

Franz Rendl

Institute of Mathematics, University of Klagenfurt, Austria

Several NP-hard combinatorial optimization problems can be approximated by Semidefinite Programs (SDP). Typically, these SDP can be strengthened by combinatorial cutting planes, leading to large-scale SDP, that are unsolvable by standard interior-point methods. We present several approaches to approximate these SDP. We proceed by dualizing some of the constraints and then work on the Lagrangian dual using various versions of the Bundle method (including the spectral bundle method). We provide computational experience with this approach applied to Max-Cut and Quadratic Assignment Problems. Finally, we propose an augmented Lagrangian approach to solve SDP. This approach is again well suited for large scale problems. We present some preliminary experience with this approach applied to relaxations of Max-Clique.

Generating all vertices in implicitly defined polytopes

Komei Fukuda

EPFL, Lausanne and Institutes for Operations Research and Theoretical Computer Science, Zurich, Switzerland

The classical vertex enumeration problem is a representation conversion problem for convex polytopes, that is, to transform a half-space representation (H-representation) of a convex polytope to its vertex representation (V-representation). In this talk, we present recent algorithmic questions for the vertex enumeration problem for implicitly defined polytopes and polyhedra where neither H- nor V-representation is available.

These include (1) the computation of the vertices of the Minkowski addition of several V-polytopes, (2) the enumeration of all Gróbner bases of a polynomial ideal and (3) the computation of the convex hull of several convex polytopes, all in general dimensional Euclidean space. We show that the reverse search scheme can be applied to these problems and lead to practical algorithms that are highly parallelizable. Recent implementations of these algorithms are also reported to indicate the power and the limits of these "super heavy" computations that require to solve a large number of small scale LPs.

A family of structured set covering problems

Jacob Krarup

DIKU, University of Copenhagen, Denmark

For a 0-1 matrix $C = c_{ij}$, column j is said to cover row i if c_{ij}=1. A cover is a subset of columns covering all rows. Unweighted SET COVER (USC) is the problem of finding a cover containing as few columns as possible.

An open optimisation problem was published in a Danish journal in 2003. Not much reflection is needed to realize that the solution of a highly structured instance C of USC will answer the question posed. The instance C or rather, the family of instances $C(k)$, is a series of square matrices of size $3^k, k$=1,2, ... Provided that $C(1)$ is known, the fractal-like structure of the matrices allows for $C(k)$ to be constructed recursively for any value of k.

Let $r(k)$ be the number of columns in an optimal solution to $C(k)$. Some preliminary investigations have enabled us to determine $r(k)$, $k = 1, 2, 3, 4$ and to show that $r(5)$ must be either 12 or 13.

12 or 13? Unfortunately LP-based bounds take us nowhere in this case since the optimum is flat as a pancake. It offers some consolation though that experiments with CPLEX were not too encouraging either. For $k = 5$, $C(5)$ is a matrix of size 243x243. Nothing was returned after 24 hours CPU time. Eventually, upon an investment of 72 hours CPU time, CPLEX managed to come up with $r(5) = 12$.

The original problem asks for $r(12)$, that is, an optimal solution to a square matrix of size 531,441. After a week the originator of the problem, using an invalid argument, announced his own answer, $r(12) = 512$, and cashed the award. We have so far shown that $r(12)$ is bounded to belong to the interval [210, 377]. We also need to conclude that no brute force approach (such as further experiments with CPLEX) is likely to work whereas paper and pencil may suffice in providing the final result.

Complete search for constrained global optimization

Arnold Neumaier
University of Vienna, Austria

Theoretical tools for the reliable solution of global optimization problems have continuously improved over the years. While, in the past, stochastic approaches of limited reliability were indispensable for all global problems of significant size, complete search techniques can now handle reliably many large problems.

Successful strategies require the intelligent combination of convex analysis, constraint propagation, and interval techniques in a branch and bound approach and the careful handling of rounding error issues. Moreover, techniques from semidefinite programming have shown high promise. There are now several powerful packages on the market exploiting these tools.

The lecture discusses complete search techniques for the solution of global optimization problems, covering the most successful methods, important software, and benchmarking results.

Convergence to second order stationary points in nonlinear programming

Gianni Di Pillo
University of Rome "La Sapienza", Italy

Let us be given the nonlinear programming problem $P : \{\min f(x) : g(x) \leq 0\}$, where $f : \mathcal{R}^n \to \mathcal{R}$ and $g : \mathcal{R}^n \to \mathcal{R}^m$ are thrice continuously differentiable. A *second order stationary point* for problem P is a point that, together with a suitable multiplier $\lambda \in \mathcal{R}^m$, satisfies not only the KKT first order necessary optimality conditions: $\nabla f(x) + \nabla g(x)\lambda = 0, g(x) \leq 0, \lambda \geq 0, \lambda' g(x) = 0$, but also the second order necessary optimality conditions:

$$\nabla g_i(x)' z = 0, \forall i : g_i(x) = 0 \Rightarrow z' \left(\nabla^2 f(x) + \sum_{i=1}^{m} \lambda_i \nabla^2 g_i(x) \right) z \geq 0.$$

We are interested in an algorithm for solving P that guarantees covergence to second order stationary points. This property makes it much more likely that the limit points of the sequence generated by the algorithm are local minimizers.

In unconstrained optimization, this kind of convergence has been obtained by using directions of negative curvature for the objective function in line search algorithms. However for the consrained problem P, very few algorithms have been described with the required property.

After a short review of existing results, we define a new algorithm that generates a sequence whose limit points are second order stationary points for P.

The algorithm is defined in the primal-dual space of the original variables x and of the multipliers λ, and is based on two main tools: a locally conver- gent truncated Newton-type iteration, and a globalization strategy using a continuously differentiable merit function.

More in particular, the local iteration produces two directions. A first order direction, which ensures local superlinear convergence toward a KKT pair, and a second order direction which is used to enforce convergence toward second order stationary points of the overall algorithm. These two directions are employed to compute the new primal-dual iterate by means of a linesearch procedure based on an exact augmented Lagrangian function. In this way 1 we get

a twofold result. On the one hand, we can assess the goodness of the search directions produced by the local algorithm and measure their progress toward a KKT pair; on the other hand, by exploiting the non-convexity of the merit function, iterates can escape from first-order stationary points and converge to second order ones.

Approximation algorithm for the mixed fractional packing and covering problem

Klaus Jansen
University of Kiel, Germany

We propose an approximation algorithm based on the Lagrangian or price - directive decomposition method to compute an ϵ-approximate solution of the mixed fractional packing and covering problem: find $x \in B$ such that $f(x) \leq (1+\epsilon)a$, $g(x) \geq (1-\epsilon)b$ where f, g are vectors with M nonnegative convex and concave functions, a and b are M - dimensional nonnegative vectors and B is a convex set that can be queried by a feasibility oracle of the form: find $\hat{x} \in B$ such that $p^T f(\hat{x}) \leq q^T g(\hat{x}) + \alpha$ where p, q are M dimensional vectors and $\alpha \in \ddagger$. We propose an algorithm that needs only $O(M(\ln M + \epsilon^{-2} \ln \epsilon^{-1}))$ iterations or calls to the feasibility oracle or an approximate version of it.

Improved approximation algorithms for scheduling malleable tasks with precedence constraints

Hu Zhang, Klaus Jansen
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In this paper we study the problem of scheduling malleable tasks with precedence constraints. We are given m identical processors and n tasks. For each task the processing time is a function of the number of processors allotted to it. In addition, the tasks must be processed according to a certain partial order. The goal is to minimize the makespan (maximum completion time).

The best previous approximation algorithm by Lepére, Trystram and Woeginger has a ratio $3 + \sqrt{5} \approx 5.236$. In the first phase a time-cost tradeoff problem is solved approximately, and in the second phase a variant of a list scheduling algorithm is used. In phase one a parameter $\rho = 1/2$ and in phase two a parameter $\mu = (3m - \sqrt{5m2 - 4m})/2$ are employed, respectively.

We consider the influence of the rounding technique and the first parameter ρ to the second phase. Furthermore, we study the linear program relaxation and rounding in the first phase carefully. As a result, we obtain an approximation algorithm with a ratio of $100/43 + 100(\sqrt{4349} - 7)/2451 \approx 4.730598$ (with $\rho \neq 1/2$). In addition, if the work functions are convex, then instead of solving the time-cost tradeoff problem, we solve a piecewise linear program and use a new rounding technique. Thus we obtain an improved approximation algorithm with a ratio of $100/63 + 100(\sqrt{6469} + 13)/5481 \approx 3.291919$

Primal-dual algorithms for data depth

Vera Rosta

Renyi Institue of Mathematics, Hungary

The halfspace depth of a point p relative to a data set S in d-dimension is the smallest number of data observations from S in any closed halfspace containing p. A point with largest depth was considered as the generalization of the median of S by Tukey. The computation of the halfspace depth of a point is equivalent tothe closed hemisphere problem, which was shown to be NP-complete by Johnson and Preparata. (It is also equivalent to the maximum feasiblity subproblem in linear optimization.) We propose primal–dual algorithms that update both an upper bound and a lower bound of the depth and terminate as soon as the two bounds coincide. We report preliminary computational experiments. (Joint work with David Bremner (University of New Brunswick, Canada) and Komei Fukuda (ETHZ and EPFL Switzerland)

New variant of the Mizuno–Todd–Ye predictor–corrector algorithm for sufficient matrix linear complementarity problem

Tibor Illés, Marianna Nagy
Eötvös Loránd University, Hungary

We analyze a version of the Mizuno–Todd–Ye predictor–corrector interior point algorithm for the $\mathcal{P}_*(\kappa)$–matrix linear complementarity problem (LCP). We assume existence of a strictly positive feasible solution. Our version of Mizuno–Todd–Ye predictor-corrector algorithm is a generalization of Potra's (2002) results for (LCP) with $\mathcal{P}_*(\kappa)$–matrices. To derive complexity result for this algorithm we are using $\|\mathbf{v}^{-1} - \mathbf{v}\|$ proximity measure like Potra. Our algorithm is different from the Miao's method (1995) in both the used proximity measure and the way of updating the centrality parameter, too. Our analysis is easier than the mentioned previous results. We also show that the complexity of our algoritm is $O((1+\kappa)^{\frac{3}{2}}\sqrt{n}L)$.

A new Mizuno-Todd-Ye type algorithm for linear optimization

Zsolt Darvay
Babes-Bolyai University, Cluj-Napoca, Romania

Recently, we proposed a new primal-dual path-following algorithm for solving linear optimization (LO) problems, based on a new method for finding search directions. These results were summarized in [1]. However, predictor-corrector type algorithms are the most efficient from the implementation point of view. In this talk we provide a new adaptive predictor-corrector algorithm, based on the methods described in [1]. This algorithm works in small neighborhoods of the central path. We prove, that the complexity of the algorithm is $O(\sqrt{n}L)$ in this case too.

New primal-dual interior-point methods based on kernel functions

Mohamed El Ghami, Y. Q. Bai, Kees Roos
TU Delft, Netherlands

Recently, Peng, Roos, and Terlaky introduced so-called self-regular barrier functions for primal-dual interior point methods (IPMs) for linear optimization. Each such barrier function is determined by its (univariate) self-regular kernel function. In this paper we present a new class of barrier functions. The proposed class is defined by some simple conditions on the kernel function and its first three derivatives. In spite of this, the best iteration bound of large-update interior-point methods based on these functions is shown to be $O(\sqrt{n}\log n\log\frac{n}{\epsilon})$, and for small-update methods $O(\sqrt{n}\log\frac{n}{\epsilon})$, which are the currently best known bounds for primal-dual IPMs of these types. This talk is restricted to linear optimization, but extension of the methods to other cone optimization problems seem to be possible in a natural way.

A comparative study of evolutionary methods for optimal design of shallow space trusses

Anikó Csébfalvi
University of Pécs, Hungary

This paper provides a comparative study of discrete optimal methods for minimal weight design of shallow space trusses. Recently used genetic algorithms (GA), simulated annealing (SA) and tabu search (TS) methods are observed for steel structures where the truss member profiles are selected from available catalogue values. In this paper, global and local stability problems are considered using a path-following method for non-linear stability investigation. The results of comparative study are presented as a numerical test problem, for commonly known 24-member shallow dome structure where structural instability constraints and member buckling are considered as well.

Lot sizing methods - review and comparative analysis, development and advantages arising from genetic algorithms application

Joanna Oleskow
Poznan University of Technology, Poland

This paper includes four essential parts. First of them outlines why the optimization of the lot sizing techniques and problem of scheduling are becoming the most important issues for each company. We have to be aware that a fundamental goal of ach firm is attempting to reach the highest possible profit and as best results as it possible. Therefore planning and application of integrated, computational tools is occurring as one way of saving money.

The second part of the work describes the set of the basic lot sizing methods which have been introduced by Joseph Orlicky such as: fixed order quantity, economic order quantity,

Least unit cost, Least total cost, Algorithm Wagner-Whitin etc. Lot sizing techniques can be categorized into those generate fixed i.e. repeatively ordered quantities, and those that generate varying order quantities. A given lot sizing technique can give either static or dynamic order quantities, depending on how it is being used. Lot sizing techniques in a current use are three basic type:

1. based on the EOQ model
2. single pass methods, of which there are a wide variety and are essentially ruled based
3. adjusted single pass methods initially make use of a specific single pass technique and then attempt to improve on the solution produced by this technique

Choosing which technique to use from the wide variety available is a major problem since each technique will only yield acceptable results under a limited range of demand and inventory cost conditions. In next section are listed and grouped other models which deal with lot sizing problems, taking into account different sets of the constraints and having more

or less complicated calculating procedures. The wide recognized lot sizing problem can refers to various aspects such as: multi-item,

multi-machine, multi-level, multi-period lot sizing determination, capacity constraints, number of assembly stages, nature of assembly system (linear, pure assembly, general assembly structure), carrying cost, setup cost, setup time and so on. The optimization approaches are valuable because typically they involve methods for finding strong lower bounds. Existing models take into account various objectives and make possible solving complex, multiple problems (such as cost minimization, time optimization, resources utilization etc.)

Review of lot sizing models place a special emphasis on distinction the most crucial and sophisticated models constructed and developed to be applied in various particular environments, providing surprising achievements.

Heuristic procedures are divided into three classes: decomposition approaches, stochastic local search procedures and Lagrangian-based procedures. Each of above classes is a very wide problem and will not be in detail referred to as in this paper. In the field of our interest are in fact genetic algorithms (Gas), which are one of the methods covered by stochastic local search procedures. The approaches involving Gas are considered in the last one part of this work. Probabilistic methods of local searches in environment with large search areas are really useful and find a wide application in different aspects.

Finally reader is able to compare which methods dealing with specified lot sizing problems is able to achieve the best and the most valuable results for him and why in particular cases practicable usage of Genetic algorithms is a solution which should be taken into account. Described models and techniques refer to multi-objective programming and present possible advantages resulting from their application.

An exact resource allocation model with hard and soft resource constraints

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In this paper we present a mixed integer linear programming (MILP) resource allocation model with hard and soft resource constraints for projects. By definition, a hard resource constraint is not resolvable within the given planing horizon, but a soft resource conflict may be managed by a flexible "hiring-firing" strategy. A "well-balanced" optimal schedule for the soft resources is characterized by a new global bicriteria measure, namely the "peak resource requirement" and the "idle time", simultaneously. The apllication of the idle time mesaure for hard resources is optional, but if used it defines a "smooth load" schedule. In the proposed approach the goal function of the MILP model is defined as a weighted combination of the single criteria mesaures. The MILP modell is created by automated transformational steps from a non-linear initial model based on the immediate precedence relations of the GANTT diagram.

The practical interpretation of the proposed model is demonstrated in an analysis of a simplified small-scale business software development environment. In the presented problem we assumed that the number of software designers is a hard constraint within the given planing horizon, but the availability of programmers and testers are soft constraints, which can be resolved by "hiring-firing" in short term base. In this example we exploited the fact that in a small-scale business software developing process the usual iterative "waterfall" structure might be replaced by a serial "designer-programmer-tester" chain.

Design and implementation of spreadsheet algorithms in production management

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Spreadsheet software became popular tool in the last two decades. Although they have tremendous advantages (easy to use, well organised data structure, what if analysis, optimisation, certain level of visualisation, etc.) due to their limitations they require a special way of thinking.

The paper attempts to compare the different way of thinking / modelling: mathematical/analytical, procedure based, spreadsheet.

We also examine the advantages of 'spreadsheet thinking" in the analytical, numerical, heuristic and (stochastic and deterministic) simulation problem solving.

Examples will include location and layout problems and scheduling as well.

Reducing the complexity of capacity analysis in flexible manufacturing systems by operation type based aggregation

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One of the major sources of complexity of the capacity analysis of flexible manufacturing systems is the possibility of alternative routing. Manufacturing operations can generally be performed on several machines; therefore the capacity of a machine to perform certain operations is not independent of the capacity of other machines. Many times, however, operations managers need route independent answer to production planning questions. How much, for example, can be produced from a certain part type, is an important question in a business negotiation, when the detailed routing is not an issue yet. The paper provides a model for the route independent analysis of the capacity of FMSs, based on the concept of operation types. An example is provided to illustrate the use of operation types, and to highlight the difference of the traditional route dependent, and the proposed route independent formulation of capacity constraints. Finally a sensitivity analysis is developed, to analyze the feasibility of a production plan, when production requirement, and machine capacity changes.

Computational problems of the operation type based aggregation in flexible manufacturing systems

Viktor Juhász, Tamás Koltai
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One of the major causes of the complexity of the capacity analysis of flexible manufacturing systems is the possibility of alternative routing. To reduce this complexity an aggregation method was developed, which uses the concept of operation types.

In this method a capacity measure for all the possible combinations of the operation types has to be calculated. Since the total number of operation type sets grows exponentially with the number of operation types, the application of this concept for large systems is not feasible.

The paper deals with the computational problems and the problem reduction possibility of the operation type concept. A method was developed to separate the redundant operation type sets, and to split a large production systems into independent or partly independent subsystems. The algorithm developed for this partition can also be used to simplify the overhead cost allocation in manufacturing systems.

The performance of the algorithm and the illustration of its computational advantages are presented with the LINGO mathematical programming software.

Production planning model of an oil company

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A production planning model of an oil company has been introduced by chemical engineers. There are quite a few program packages specialized for modelling the production planning process of oil companies in the world. These program packages usually contain Excel based model developer, a linear programming solver (XPRESSMP or CPLEX) and some other tools. As a result of the modelling and solution process, a production plan is presented in a report. The production planning model of an oil company leads to a large scale nonlinear programming problem. Currently available program packages solve this optimization problem by relaxing the nonlinear constraint in a practical way, namely fixing some variables which are related to the quality of the products. In this way a linear programming problem is obtained. Usually this LP problem is not feasible, due to the guessed and fixed quality values of the products. Chemical engineers introduced a method called distributive recursion to solve this problem.

In our talk we discuss the consequences of the nonlinearity of the model and the application of the distributive recursion technique. Furthermore, we list some alternate solution method. Finally, we ,present some numerical computations, based on a test problem defined by the experts of MOL Plc.

A verified optimization technique to prove and locate chaotic regions

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First we show that, how we can prove that a system is chaotic. Then we present a computer assisted proof of the existence of a horseshoe of the 7-th iterate for the classical Henon map ($H(x, y) = (1 + y - ax2, bx)$). An earlier, published theorem gives three geometrical conditions to be fulfilled by all points of the solution region, given by 2 parallelograms. We analyze these conditions separately and in case when all of them hold true, the proof is complete. The method applies interval arithmetic and recursive subdivision. This verified technique proved to be fast, and we can use it in a framework program.

To find a region that fulfills the respective conditions, the program combines a global optimization procedure and our interval arithmetic based checking technique described earlier. We define a nonnegative penalty function, which is zero if and only if the structure does not hurt any condition. If the program finds the optimum and it is zero, then the search is successful. We were able to locate new, previously unknown regions where the 5-th and 3-rd iteration of Henon map instance has a chaotic behavior. Then we review an another problem (forced damped pendulum), where we could use the earlier described subdivision method to prove that the system is chaotic.

Global optimization techniques for stability analysis of decision functions

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We present a global optimization technique based on monotonic optimization for sensitivity analysis of decision functions used in multicriteria decision problems. For the special case of tree-structured decision functions, a rectangular branch-and-bound algorithm based on the d.c. properties is also proposed. Computational experience is presented.

On the c-repacking on-line bin packing problem: lower bounds

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The classical bin packing problem requires packing of a list of elements from the interval (0,1] into minimum number of 1-size bins, without ,,overlapping".

The best known lower bound for the asymptotic (worst-case) performance ratio of on-line bin packing problem (OBPP) is 1.54014[1], while the best known algorithm has 1.588889 asymptotic performance ratio[2]. "Semi online" bin packing algorithms were dealt first by Galambos[3] (Buffered Next-Fit algorithm), for the bounded space on-line version of the classical OBPP, with using 2 open bins, and by Galambos and Woeginger, with using 3 open bins (Repacking 3 algorithm[4]).

The c-repacking OBPP is a semi-online modification of the classical online problem, in which c is a fixed constant upper bound on the number of items moved between bins in a step. The gap between the best known lower bound and the best asymptotic performance ratio algorithm is larger, than in the case of classical OBPP. The best algorithm has 3/2 asymptotic performance ratio (with c=3), while the best known lower bound is 4/3[5].. In this talk we present a simple proof for the 4/3 lower bound, which is similar to the technique of those article, but the idea, used in our construction, can be generalized for higher number of list-sequences. Greater lower bounds can be obtained using our technique as shown in our presentation, hence the distance from the best algorithm's asymptotic performance ratio can be decreased.

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Matrix inverses, rigid circuit graphs, Fibonacci heaps, homotopies, polyhedra and probability bounding

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Many practical applications show the usefulness of probability bounding. While only partial information is available, we need correct, simple, hopefully sharp but surely effectively computable estimates. We will show the related connections among different branches of mathematics, statistics and computer science. Recently discovered graph and hypergraph theoretical contributions will also be shown.

Local optimization algorithms and deterministic chaos

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Situations of deterministic chaos in local optimization are considered. Such situations occur when a negligible change of the optimization algorithm's initial conditions can result in considerable change of the solution. Multi-extremum functions are good testbeds for producing deterministic chaos, and a class of test functions with fixed number of local optima is proposed. Usually, statistical values like the average error of the solution or the average number of iterations are chosen as the algorithm's characteristics. However, they become unstable and inadequate in the situations of deterministic chaos. So, a novel approach of forming the efficiency characteristics of optimization algorithms is presented. It is based on the use of the diversity analysis methods.

Metaheuristic scheme to find good solutions with running time limitation

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In practical use we often encounter optimization problems that can not be solved by efficient exact algorithms. In such cases (meta)heuristics are of great importance. The running time of them and the quality of their result can be controlled typically by various parameters. Unfortunately the dependence of the running time on these parameters is hard to foretell. However, in many real life applications it is a must to know this, that is we need heuristic algorithms which running time can be determined in advance. We present a variant of simulated annealing capable of this. It works not by adjusting the temperature directly but measuring and controlling a kind of "absorbing rolling deviation" of the recently found solutions. We also present empirical tests showing the efficiency of our method and an application of this method for a specific facility location problem arising optical telecommunication network design.

An XML-based interface to use statecharts in specifying and dealing with Performance models

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Performance models have become essential in studying the behaviour of complex systems before they can be implemented in order to find out bottlenecks and other problems thus saving money and time. Usually Markov chain-based solutions are applied whenever an analytical approach is required to evaluate the performance of a complex system. As a Markov chain has a one-to-one correspondence with a Finite State Machine (FSM), then it is a matter of representing the system behaviour in FSM. However, if the system is quite complex with several parallel components, it might not be easy and clear to structure the bheaviour by using an FSM. This paper addresses the use of a high-level specification technique Statecharts in representing such complex systems and its conversion into a Markov chain in order to obtain performance evaluation. The software that has been developed to take a representation of a complex system in Statecharts and converting it into a Markov chain is written in C++ programming language and it is called as PerformCharts. The main disadvantage of the software is the interface in which the specification of the system in Statecharts has to be written in the main module in C++ language. In order to improve this situation, an XML-based interface has been developed.

Now, the specification of a complex system is written in PcML (PerformCharts Markup Language) and this language is interpreted to generate the main module in C++ language. This main module after being compiled and linked with the rest of the PerformCharts library would generate an executable code with which one can run and obtain the performance measures of the specified system. The paper also addresses the PcML and the use of Java and perl to interpret it.

Optimization of production nets under temporal constraints

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Process networks are widely used in the design of manufacturing processes especially in the chemical industry. They provide a simple means to describe production processes starting from raw materials leading to the production of a desired sets of products. From the point of view of modeling, they offer an easy-to-understand graphical notation which is closed to the engineering thinking.

¿From the theoretical point of view, *optimization algorithms* were elaborated to solve *Process Network Synthesis* (PNS) problems[6] for a wide range of objective functions and constraints like linear and non-linear functions in integer programming problems. One of the main characteristics of this problem class is the existence of very efficient solution methodologies outperforming the traditional general purpose optimization methods by several orders of magnitude both in runtime and memory complexity.

However, the general idea to model operations processing inputs and generating outputs under quantitative constraints at system level performing in an optimal way is more general than the class of pure production related problems. In the terms of mathematics at least in the case if all the items which flow in the network can be characterized by naturals, a production net is closed to *Petri nets*.

Petri nets belong to the most traditional formalisms for a variety of applications including the design and analysis of information technology systems as well. Based on the similarity detected between PNS and Petri nets, in the formal work[7] a generalized view

[6] F. Friedler, K. Tarjan, Y. W. Huang, and L. Fan. – Combinatorial algorithms for process synthesis. *Computers Chemical Engineering*, 16:313–320, 1992.

[7] S. Gyapay and A. Pataricza. – A Combination of Petri Nets and Process Network Synthesis.In *2003 IEEE International Conference on Systems, Man & Cybernetics"*, pages 1167–1174, Washington, D.C., USA, October 5-8 2003. IEEE Press.

was elaborated enriching the Petri nets paradigm with the capability to optimize the flow in the net. This way a variety of practical applications can be covered by model-based computation analysis and optimization ranging from diagnostics of IT systems to production systems.

In general, the existing paradigm of PNS is able to handle constraints in the term of production capabilities or assets in materials. In the extended paradigm using Petri nets as basic formalism we further added another relevant feature in the form of temporal constraints that are defined in an exact form by means of temporal logic. Such constraints may express the sequence of events happening in the network with a special emphasis on events observable at the outputs. For instance, in the case of a diagnostic problem described by the Petri net this combined approach is able to deliver a maximum likelihood diagnosis for an observed sequence of output events[8]. Here, the individual operations corresponding to the individual operational steps in the IT network are assigned with the probability of the event (including the operations representing fault occurrence) and the observed output temporal sequence of symptoms serve as temporal constraints. An optimal solution fulfilling both the quantitative optimality criterion and the temporal restrictions on the outputs delivered is a solution of the maximum likelihood diagnostic problem.

In order to solve this problem, we combined three different algorithms. The first one is an adapted version of the PNS optimization algorithm, the *Accelerated Branch and Bound algorithm*. As the Petri net extension necessitates some more strict constraints on the operations allowed, an additional phase of elimination of logically infeasible solutions was created. Finally, the temporal observations are verified by the so-called model checking standard approach to check the validity of temporal logic expressions for automatons. The paper reports on the efficiency measures achieved so far.

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Sequential quadratic programming applied to control theory problems

Catherine Buchanan
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We have used hopdm to study sequential quadratic programming techniques applied to small nonlinear programs arising from control theory. To facilitate the use of hopdm we have coded a link to ampl which provides automatic differentiation. Difficulties have been experienced in finding a suitable linesearch method and merit function, especially when dealing with non-convexity. Our experience will be illustrated with some preliminary computational results.

Nonnegative polynomials, linear recurrences and decomposition into rank-one Hankel matrices

François Glineur
UCL/CORE, Louvain-la-Neuve, Belgium

In this talk, we look at what information can be extracted from the optimal solution of this semidefinite program when it claims that the polynomial is not nonnegative: in particular, can we find an abscissa where the polynomial is negative?

It turns out that this question is closely related to the following problem : given a (possibly semidefinite) Hankel matrix (i.e. a matrix with constant anti-diagonals), express it as a sum of rank-one Hankel matrices ; this is an analog for Hankel matrices of the spectral decomposition of symmetric matrices.

We establish a strong link between this problem and the theory of linear recurrences and derive from it an algorithm to find such a decomposition. We also prove some unicity properties and give a necessary and sufficient condition for a polynomial to admit only real roots. Finally, we look at how much of these properties extend to the case of polynomials with several variables.

Systems of quadratic inequalities and the S-lemma

Imre Pólik, Tamás Terlaky
McMaster University, Hamilton, Canada

We review the many facets of the S-lemma, which is a widely used method in control theory but it has important consequences in quadratic and semidefinite optimization, convex geometry and linear algebra as well. These areas were subject to active research, but as there was little or no co-operation between researchers from these areas their results remained mainly isolated. We give a unified analysis of the theory, reveal hidden connections with various areas of mathematics that point to new research directions. Applications from control theory, error estimation and computational geometry are also presented.

The problem of making a digraph k-vertex connected by adding a minimum number of edges

László Végh
Eötvös Loránd University, Hungary

The problem of making a digraph k-vertex connected by adding a minimum number of edges, is a special case of the problem of covering bi-supermodular functions. There is a min-max theorem for the general problem by A. Frank and T. Jordan, which gives rise to a polytime algorithm relying on the ellipsoid method. We give a purely combinatorial algorithm for this problem extending a previous work of A. Frank in the special case when he starting connectivity is $k-1$.

Maximum even factor algorithm

Gyula Pap
Eötvös Loránd University, Hungary

We give a new, algorithmic proof for the maximum even factor formula, which can be converted into a polynomial time combinatorial algorithm to solve the maximum even factor problem. This is the first combinatorial algorithm to solve the problem, it uses contractions of odd cycles similar to Edmonds' matching algorithm. There are some significant differences: here we do not build a structure similar to the alternating forest, the even factor problem does not admit this structure.

An algorithm for source location in directed graphs

Mihály Bárász, Johanna Becker, András Frank
MTA-ELTE and Eötvös Loránd University, Hungary

Ito, Makino, Arata, Honami, Itatsu, and Fujishige [9] provided a theoretical answer to a source location problem by proving that the minimum cardinality of a subset R of nodes in a directed graph $D = (V, A)$ for which there are k edge-disjoint paths from R to every node $v \in V - R$ and there are l edge-disjoint paths from every node $v \in V - R$ to R is equal to the maximum number of pairwise disjoint deficient sets where a nonempty subset of nodes is deficient if its in-degree is less than k or its out-degree is less than l. They also showed how this theorem gave rise to a polynomial time algorithm to compute the optima in question in case the demands k and l are fixed, and posed as an open problem of developing an algorithm that is polynomial not only in the size of the digraph but in k and l, as well. To describe such an algorithm is the main goal of the present work. The algorithm is strongly polynomial even in the edge-capacitated extension of the problem.

[9] Hiro Ito, Kazuhisa Makino, Kouji Arata, Shoji Honami, Yuichiro Itatsu, and Satoru Fujishige, Source location problem with flow requirements in directed networks, Optimization Methods and Software, Vol. 18, No. 4, August 2003, pp. 427-435.

Level decomposition for two-stage stochastic programming problems

Csaba Fábián, Zoltán Szõke
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The Level Decomposition Method uses a bundle-type convex programming algorithm suited for constrained optimization, which unifies the treatment of optimality and feasibility issues. Moreover, the underlying convex programming algorithm works with inexact data, which enables coordination of different computational efforts: computation of recourse function data on the one hand, and optimization on the other hand. As the optimum is gradually approached, more and more accurate data are computed. Recourse function data of appropriate accuracy are computed through a stochastic approximation scheme closely integrated with the inexact convex optimizer. This framework enables effective application of interior-point methods for the approximate solution of the recourse problems.

The Level Decomposition Method effectively solved two-stage stochastic programming problems with several million scenarios. (Transforming our largest stochastic test problem into a deterministic linear programming problem results more than 300 million constraints and 800 million variables.) The talk gives a brief account of the method, its implementation, and its empirical behavior.

Estimation of rare event probabilities in stochastic networks with exponential and beta distributions

Ashraf A. Gouda, Tamás Szántai
Budapest University of Technology and Economics, Hungary

The lecture is dealing with estimation of rare event probabilities in stochastic networks. The well known variance reduction technique, called Importance Sampling (IS) is an effective tool for doing this. The main idea of IS is to simulate the random system under a modified set of parameters, so as to make the occurrence of the rare event more likely. The major problem of the IS technique is that the optimal modified parameters, called reference parameters to be used in IS are usually very difficult to obtain. Rubinstein (1997) developed the Cross Entropy (CE) method for the solution of this problem of IS technique and then he and his collaborators applied this for estimation of rare event probabilities in stochastic networks with exponential distribution (see De Boer, Kroese, Mannor and Rubinstein (2002)). In this lecture we test this simulation technique for medium and large sized stochastic networks and compare its effectiveness to the simple crude Monte Carlo (CMC) simulation.

The effectiveness of a variance reduction simulation algorithm is measured in the following way. We calculate the product of the necessary CPU time and the estimated variance of the estimation. This product is compared to the same for the simple Crude Monte Carlo simulation. This was originally used for comparison of different variance reduction techniques by Hammersley and Handscombe (1967). The main result of the lecture is the extension of CE method for estimation of rare event probabilities in stochastic networks with beta distributions. In this case the calculation of reference parameters of the importance sampling distribution requires numerical solution of a nonlinear equation system. This is done by applying a Newton–Raphson iteration scheme. In this case the CPU time spent for calculation of the reference parameter values can not be neglected. Numerical results will also be presented.

Recent developments concerning the modeling system SLP-IOR

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The purpose of the lecture is twofold. On the one hand, we give an overview on recent developments regarding SLP-IOR, our model management system for stochastic linear programming. The scope of the system has been extended by implementing several additional model classes, including multistage recourse problems, integrated chance constraints and CVaR constraints. On the other hand, for illustrating the computational capabilities of SLP-IOR, we present computational results for two-stage recourse problems. From the algorithmic point of view, the presentation will be concentrated on successive discrete approximation methods. These will be discussed from the numerical point of view, the main ideas concerning their implementation will be discussed, and computational results will be presented with several test problem batteries.

New criss-cross type algorithms for linear complementarity

Zsolt Csizmadia, Tibor Illés
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We generalize new criss-cross type algorithms for linear complementarity problems (LCPs) given with sufficient matrices. Most LCP solvers require apriori information about the input matrix. The sufficiency of a matrix is hard to be checked (no polynomial time method is known). Our algorithm is similar to Zhang's linear programming, and Akkeleş-Balogh-Illés's criss-cross type algorithm for LCP-QP problems. We modify our basic algorithm in such a way that can start with any matrix M, without having information about the property of the matrix (sufficiency, bisymmetricity, positive definitness, etc) in advance. Even in this case our algorithm terminates with one of the following cases in finite number of steps: it solves the LCP problem, solves its dual problem, or gives a certificate that the input matrix is not sufficient, so cycling can occur. Although our algorithm is more general than that of Akkeleş and Illés's, the finiteness proof has benn simplified. Furhermore, the finiteness proof of our algorithm gives a new, constructive proof to Fukuda and Terlaky's LCP duality theorem as well.

Remarks on submodular functions and related set function classes

Stephan Foldes
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Submodular set functions arise naturally both in mathematical and application contexts, and their efficient optimization is of theoretical and practical interest. Polynomial time combinatorial optimization algorithms are available for submodular functions (Schrijver 2000 and Iwata, Fleischer, Fujishige 2001). It has been observed that these algorithms work correctly only if the input function is known to be submodular, in contrast to certain class-specific algorithms on graphs or other types of input, which compute efficiently on members of the class an otherwise difficult parameter, yet require no class membership recognition before being applied to the input. This dependency on recognition is inherent in any class-specific polynomial-time algorithm on not only the submodular class, but on any class of set functions satisfying a very mild hypothesis. The form of representation of the input function plays a crucial role, and while representation by a value-giving oracle may be natural in some contexts, algebraic representations are relevant in the structural theory of special set function classes such as submodular, supermodular and monotone functions. Selected results of recent research on the algebra of such function classes and possible algorithmic implications will be discussed.

This presentation is partly based on joint work with Peter L. Hammer and Miguel Couceiro.

Exploiting symmetry in graph to efficiently compute Lovasz type bounds

Igor Djukanovic
University of Maribor, Slovenia

Franz Rendl
University of Klagenfurt, Austria

Semidefinite programming formulation of the Lovász theta number does not give only one of the best polynomial simultaneous bounds on the chromatic number and the clique number of a graph, but also leads to heuristics for graph coloring and extracting large cliques (or equivalently stable sets). This semidefinite programming formulation can be tightened toward either number by adding several types of cutting planes. The strengthened bounds are particularly strong on graphs with a lot of symmetry. The number of variables in these semidefinite programming models can for a graph with a rich automorphism group be significantly decreased resulting in algorithms with orders of convergence lower by up to 3.

Particle swarm method as a new tool for single and multiobjective optimization

Károly Jármai
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A new and promising optimization technique is introduced, the particle swarm optimization (PSO). In this evolutionary technique the social behaviour of birds is mimicked. The technique is modified in order to be efficient in technical applications. It can calculate discrete optima, uses dynamic inertia reduction and craziness at some particles. The efficiency of the technique is shown on the optimum design of a stringer-stiffened shell under bending and compression. The PSO is built into an interactive program system, where several optimization techniques are employed. The program system includes multiobjective optimization techniques as well. Results show that PSO is a reliable and robust technique to find optima with highly non-linear constraints. At the cost calculation 2D and 3D curve fitting is employed to determine the production time.

Criticality in resource constrained projects

György Csébfalvi
University of Pécs, Hungary
Roni Levi
S & E Engineering and Project Management, Israel

The concept of float and criticality plays a central role in project management. However, the recent literature does not offer a general and useful measure for criticality (flexibility) in resource constrained projects. This paper presents a new measure to solve this problem. The presented resource constrained total project float measure (RCTPF) is defined as the sum of the resource constrained total activity floats, where the resource constrained total activity float can be interpreted as the maximal resource feasible delay that can occur in the performance of an activity. In the proposed approach, a resource-constrained project is characterized by its "best" schedule, where best means a resource constrained schedule for which the RCTPF measure is maximal. Theoretically the optimal schedule searching process is formulated as a mixed integer linear programming (MILP) problem with big-M constraints, which can be solved for small-scale projects in reasonable time. To solve the problems a state-of-the-art MILP solver (CPLEX) was used. The implicit enumeration algorithm for the RCTPF measure is formulated as a tree-search problem with three effective pruning rules. The first pruning rule is a special consistency check, which can help to visibilize the "invisible" inconsistencies. The second pruning rule eliminates schedules from explicit enumeration that are known to be unnecessary. The third pruning rule is based on the relaxation of a MILP model, which is a tighter reformulation of the traditional zero-one resource constrained project scheduling model. To solve the relaxed problems a fast state-of-the-art interior point solver (BPMPD) was used. According to the NP-hard nature of the problem, the proposed implicit enumeration algorithm provides exact solutions for small to medium size problems in reasonable time. Large-scale problems can be managed by introducing an optimality tolerance. In order to illustrate the essence and viability of the proposed new algorithm, we present detailed computational results for a subset from the popular Patterson's set.

An exact penalty method for smooth equality constrained optimization

Tamás Rapcsák, W. Bergsma

Computer and Automation Research Institute, Hungarian Academy of Sciences, Hungary

A new exact penalty function is presented which turns a smooth constrained nonlinear optimization problem into an unconstrained one. The advantage of the proposed penalty method is that arbitrary positive penalty parameters ensure local optimality, avoiding this way the possible ill-conditioning of the problem.

Use of empirical likelihood in optimal pre-control plans

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Universidad Politécnica de Valencia, Spain

The problem of designing an automatic system to select the performance parameters of some quality control tools can be modelled as a Mixed Integer Non-linear Programming (MINLP) problem. Particularly, we focus on the case of Pre-control. This model depends on certain probabilities which we are able to obtain under some assumptions on the distribution of the process. In this work, we propose the use of empirical likelihood when the distribution of the process is unknown, and we present some numerical results.

LEMON — a Software **L**ibrary for **E**fficient **M**odeling and **O**ptimization in **N**etworks

Alpár Jüttner
Eötvös Loránd University, Hungary

We present LEMON, a new open source library written in C++ language. It provides a set of easy-to-use, generic and extendable implementation of common data structures and algorithms in the area of optimization. It is a particularly usable toolkit to implement optimization algorithms for network design problems. Being LEMON an open source project, the full implementation is transparent for the users. This fact and its generic design make it possible to easily and efficiently adapt the the implemented algorithms for any special demand. In the presentation we show the basic design aspects of the library and compare it with the most important similar commercial and free packages.

On the scheduling problem in the combinatorial model of the PNS problem

Csanád Imreh
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In the problem of designing a process network, we have to find a suitable network of operating units which produces the desired products from the given raw materials. If we consider this process network design problem from a structural point of view, then we obtain a combinatorial optimization problem called the Process Network Synthesis or (PNS) problem. In this combinatorial model each operating unit has a cost and the goal is to find a feasible network with the minimal cost (the cost of the network is the sum of the costs of the operating units contained in it). If we also assign processing time to the operating units then a further question is to find a system which has the minimal maximum finishing time. We present some models where both types of objective functions are taken into account, we present some algorithms and some complexity results concerning the models introduced.

Dénes König, the father of the "hungarian method"

Zsuzsanna Libor
College of Szolnok, Hungary

I fulfil a long-overdue obligation when I retrace the life of the well-known Hungarian mathematician Dénes König and recognize his achievements. Two anniversaries make this particularly timely: the anniversary of his 120th birthday and the 60th anniversary of his tragic death.

His famous theorem which now bears König's name is one of the most quoted in graph theory. Using this the american matematician H. W. Kuhn constructed a solution algorithm to the so-called assignment problem in matematical economics. Kuhn called the process the "Hungarian method" - about König and Egerváry - and it has become known by that name.

I would like to show König's life and scientific work to know him and his impression to the other mathematicians better.

Continuous vs discrete-time approaches in batch chemical process scheduling - application to heat integration

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This paper presents a concise comparison of the application of continuous and discrete-time mathematical modelling techniques in addressing scheduling of batch chemical processes. The discrete-time approaches have a tendency of leading to very large problems, particularly in terms of binary variables. On the other hand, in comparison to their discrete counterparts, continuous-time approaches result in much smaller problems. Moreover, the accuracy of discrete-time approaches is highly dependent on the time interval lengths within the time horizon, which is not encountered in continuous-time techniques. It is mainly for this reason that recent developments in batch process scheduling have focused on continuous rather than discrete-time approaches. However, there have been a number of continuous-time approaches developed by various researchers in this field. Most of these approaches are ideal for short-term scheduling, as they tend to suffer the same drawbacks as their discrete counterparts for lengthy time horizons or/and more complicated problems. The comparison on this paper is based on the performance of a formulation that is based on a state sequence network representation versus a formulation based on a state task network representation as applied in heat integration of multipurpose batch plants. The results will be based on a literature example and a case study from an agrochemical facility.

Optimising the general purpose Controller network architecture (GPCNA)

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General Purpose Controller Network Architecture (GPCNA) is an experimental network architecture designed for interconnecting nodes in distributed embedded applications. GPCNA provides deterministic access to the network medium to support distributed hard real-time application components.

GPCNA uses a token bus to transfer fixed sized frames. Token monitor issues an explicit token that contains the schedule using which the nodes are allotted medium access. The 37 byte frame structure includes a 5 byte header and a 32 byte payload. Payload within the token carries single byte addresses of the nodes on the network sorted in the order they are granted access to the medium. Only the node in possession of the token is granted medium access, and this node subsequently transmits the token to the node scheduled next in the token payload. Thus, the original GPCNA allows only up to 32 nodes to be present on the network.

This paper suggests three optimizations to the original GPCNA concept. Primarily, the use of virtual tokens reduces the token overhead. Nodes can dynamically request bandwidth allocation to transmit a periodic or sporadic message. Finally, categorization of nodes as talkers and listeners and use of different schedules for successive transmission cycles increases the number of nodes on the GPCNA bus.

Sparse simplex methods applied to quadratic programs and quadratic mixed integer programs

Frank E.F.D. Ellison, M. Guertler, Guatam Mitra
Brunel University, UK

Sparse Simplex is the method of choice in most situations where the solution of multiple sub-problems demands an effective restart using the optimum solution to a previous sub-problem. The method is outlined and the power of ability to restart is demonstrated by examples in the field of portfolio analysis with cardinality constraint, also in Stochastic Programming using regularisation of the master problem.

Recent achievements in interior point technology

Csaba Mészáros

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Interior point methods (IPMs) are efficient tools for solving wide classes of large-scale optimization problems. Our talk gives a survey about the achievements made in the past years in the implementation technology of IPMs for linear and quadratic problems. Our survey covers symbolic and numeric issues and efficient implementation techniques. We demonstrate that the state of the art methodology of IPMs is capable of solving problems with a couple of millions of variables/constraints in reasonable time on widely available desktop computers.

Algorithmic and implementation aspects of parametric and sensitivity analysis in convex quadratic optimization

Oleksandr Romanko, Tamás Terlaky
McMaster University, Canada

Alireza Ghaffari Hadigheh
University of Tabriz, Iran

We present an Interior Point Method and optimal partition based technique, and provide a polynomial time algorithm for conducting sensitivity and parametric analysis of Convex Quadratic Optimization problems. A general case of simultaneous perturbation in the coefficient vector of the linear term of the objective function and in the right-hand side vector of the constraints is considered. We will discuss the implementation issues for the outlined algorithm. The results on simultaneous perturbation analysis are numerically illustrated. We also provide an engineering application of parametric quadratic optimization where simultaneous parametrization comes from the nature of the problem.

Current state of the dual simplex method

István Maros
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Real world linear programming problems include all types of variables and constraints. To handle them efficiently, new versions of the dual simplex are required. The talk will present a general dual phase-1 and phase-2 algorithms that together make the dual a fully competitive alternative of the primal simplex. The algorithms make multiple use of the expensively computed transformed pivot row and make the largest improvement in the objective ,(phase-1 or phase-2) that can be achieved with a selected outgoing variable. The two algorithms, though are different, have some advantageous common features, like: (i) in one iteration they can make progress equivalent to many traditional dual iterations, (ii) using proper data structures they can be implemented very efficiently so that an iteration requires hardly more work than the traditional pivot method, (iii) they have inherently better numerical stability because they can create a large flexibility in finding a pivot element, (iv) they excel at coping with degeneracy as they can bypass dual degenerate vertices more easily than the traditional pivot procedures. One significant difference is that while the dual phase-1 procedure is more efficient if the variables are little restricted (many non-negative and free variables are present), the phase-2 procedure is more efficient if there are many bounded variables in the model. The power of the methods is demonstrated by some computational experience on real world problems.

Engine assignment problem under some operation policy for railway transportation

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Eötvös Loránd University, Hungary

A railway network is given. We assume that on this network one company controls (and operates) all trains. The important information about the trains are described in the timetable. The trains can be passenger- or freight trains. There are slightly different operating policy for passenger- and freight trains. Passenger trains should be operated according to the announced timetable independently from the number of passengers would like to use it. In contrary, freight trains will be operated only in the case when there are enough goods need to be transported or if there is need to rearrange some equipments (coaches, engines etc.) of the railway company.

One of the key issues in organizing the railway transportation is how to assign engines to trains that will be operated. The solution of this important practical question contains several steps and some well described operating policy should be taken into consideration. The engine assignment problem at a railway company has to be solved after each modification of the timetable (regularly once a year). This is the planning stage of the solution of the engine assignment problem. Currently we are modelling this part of the whole process. Due to technical (some engines have broken down) or organizing problems (some freight trains are not operated on some coming days), transportation engineers who are daily operating the railway transportation should modify the planed engine assignment or use some engines that are reserved for such occasions. Both at planning stage and during daily operations of the railway transportation one of the main question is how many engines are necessary to operate all trains.We have build up a 0-1 programming model for engine assignment problem. This model contains constraints related to the timetable and those which are related to the operating policy, too. Constraints coming from the operating policy makes the problem NP-hard.We have identified the hard constraints and built up a relaxed model that does not contains these. The relaxed model is closely related to a maximal bipartite matching problem that can be solved efficiently. The solution of the relaxed

model can be used as an initial solution for the 0-1 programming model.

Preliminary computational results using data from the Hungarian State Railway Company will be presented.

Assessing store performance equitably

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In this paper, we set up Benchmarking of Supermarket Chains Model (BSCM). Our model contains benchmarking of supermarket chains, which compete on mature target market with dense network of transportation and well established census data collection follow market share-maximizing objective. Our first advancement from the corresponding literature is that our model has three-fold benchmarking: It benchmarks sales performance of stores of several competing chains, supporting decisions on store managers' evaluation. It benchmarks market share of stores in different regions of target market, supporting decisions on allocation of limited DM promotion budget geographically. It benchmarks intensity of competition in different regions of target market, supporting decisions on future store locations. Our second advancement from the literature is that the model additionally can provide: Estimates about attractiveness of different store features for customers, supporting decisions on store improvement Estimates about competitive force of chains, supporting development of competitive strategies

Our third advancement from the literature is that we are using an improved version of Huff-type market force functions of stores: In his original paper (Huff, 1965), these are infinite functions, monotonic decreasing with geographic distance. The infinite stretching of market force is not realistic, so many researcher tried to solve this problem introducing finite radiuses within competitive effects of the stores can take place. But correct estimation of that radiuses mean further problem. In our approach, we use infinite market force functions, but infinite stretching will be blocked by introducing the term Force of Local Competition (FLC) in the formulation. This is the market force of small local family stores, from where we do not have detailed store-level data. We assume that FLC is proportional with the economic attractiveness of different regions of target market, so we estimate it using regional socio-demographic data from census.

A new resource leveling milp model for multi-mode projects based on global measure

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In many project in the practice, certain activities may be carried out in different execution modes, which differ in resource requirements and durations. We present a multi-mode MILP model based on a new global measure to balance the fluctuation of resource usage. On the analogy of production scheduling we choose the idle time to the "global" measure. The proposed new measure is based on the idle resource units. According to the shape-oriented approach, to characterize the global efficiency of the resource usage profile we introduce an objective function system, which minimize the idle resource units and maximize the resource usage.

In the case of small-scale projects the model, as a mixed integer linear programming problem (MILP), can be solved directly. According to the NP-hard nature of resource leveling problem, special methods have been developed for medium-size projects such as the tree-search implicit enumeration algorithms. For large-scale projects we can apply heuristics to constrain the size of the searching trees.

New exact and heuristic solution procedures for the setup cost oriented resource leveling problem

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University of Pécs, Hungary

This paper presents the setup cost oriented resource leveling measure (SU) for the single resource case. The measure models the costs that incur when the utilised resource units are installed - or, in the case of human resources engaged, at the time they enter the project - and, after interruption of operating or employment, are re-installed or re-engaged. The measure may also be considered modification of the traditional class of Fluctuation Between Periods (FB) measures.

The model is formulated as a mixed integer LP problem which may be solved directly in the case of small-size problem instances. In the case of medium-size projects, the algorithms of the proposed models may be formulated as tree-search problems based on effective pruning rules. According to the NP-hard nature of the problem, the proposed implicit enumeration algorithms provide exact solutions for small to medium size problems. For large-scale problems a simple "beam-search" heuristic may be developed by constraining the size of the searching tree

The speedup of the cluster-based approach in divide and conquer paradigm

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It is computationally intractable to obtain an optimal solution to instances of NP-hard optimization problems with real-world input size. Thus, the implementation of most commercial tools for solving such instances are required to balance between the runtime and the solution quality. In this article, we analyze the runtime efficiency of the implementations that are designed based on the divide and conquer paradigm in combination with clustering techniques, and produce very satisfactory solutions in a good scalability and a short runtime when the instances of such problems have real-world size. Under some fairly weak conditions, we show theoretical lower and upper bounds of the speedup of any clustered implementation relative to its counterpart (non-clustered implementation) on sequential machines. As seen in this article, the speedup depends only on the number of independent subproblems and the conceptual running time of algorithms which are used to find solutions to those problems.

An efficient algorithm to determine the core of cooperative games

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The objective of any cooperative Game is to find out the core of the game .So far it is solved by series of linear programs(atmost n-1 wher n is the no of players).The core of the game is to be achieved by maximising the profit(either additive or multiplicative).The linear program does not reach the global core due to degeneracy.In this paper the authors proposing an efficient method which needs only one iteration and overcome the the difficulties of linear program approach

The authors are able to prove that this method offers global solution by simulation. A simulation study for 3,4,5 and 10 players is carried out and both linear programs and proposed method is compared .The results are proving the effective ness of the proposed method.

A method for solving fuzzy number linear programming problems based on multiobjective linear programming technique

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In the real-world optimization problms, it is usually taken place that coeficients of the objective function are not known precisely and should be interpreted as fuzzy numbers. In this paper we define the concepts of optimal solutions for fuzzy number linear programming (FNLP) Problem. Then by using the concept of comparison of fuzzy numbers we trasform FNLP problem into multiobjective linear programming problem. To this end we propose several thorems, which are used to obtain optimal solutions of FNLP. Finally, we give some examples for illustrating the method.

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Notes