Summary

Future Perspectives

Closing

CO@W Berlin

Martin Grötschel

9. 10. 2009
11:30 - 13:00
## Today’s program

<table>
<thead>
<tr>
<th>Fr 09.10.</th>
<th>Finish</th>
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<tbody>
<tr>
<td>09:00-10:00</td>
<td>TK</td>
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<tr>
<td>10:00-11:00</td>
<td>Real world data again</td>
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<td>11:00-11:00</td>
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<td>11:30-13:00</td>
<td>Results of examination</td>
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<td>11:30-13:00</td>
<td>MG</td>
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<tr>
<td>11:30-13:00</td>
<td>Summary, future perspectives and closing</td>
</tr>
</tbody>
</table>
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   - Theory
   - Software
   - Modeling and models
   - Applications

2. Future perspectives
   - Theory
   - Software
   - Applications

3. What happens internationally?
   - IMU - International Mathematical Union (CDC, ICMI, CEIC)
   - Formation of centers

4. Questions, remarks, critique?

5. Thanks
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5. Thanks
What have we done?

Mathematical problems touched

- Linear and mixed integer programming
- Constraint Programming
- Polyhedral theory
- Polyhedral combinatorics (facets, cutting planes, etc.)
- Nonlinear integer programming
- Complexity theory
- Online optimization
- Worst case analysis
- Auction theory
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What have we done?
Mathematical algorithms/ software touched

- Linear and mixed integer programming
  - Solving LPs and MIPs in practice
  - Dual and primal simplex, interior point methods
  - CPLEX in ~1200 cities
  - Branch and Bound
  - Cutting planes
  - Presolving

- Constraint Programming

- Nonlinear integer programming

- Online optimization

- Special combinatorial optimization problems
  - Various flow problems
  - Shortest paths with additional restrictions
  - TSP and variants
  - etc.
What have we done?

Software

- **Academic Software**
  - Zimpl
  - Soplex
  - SCIP
  - PORTA
  - Polymake
  - COIN-OR

- **Commercial Software**
  - CPLEX
  - Gurobi
  - XPRESS
  - MOSEK
  - etc.

Some participants complained that there was too much programming and software usage training.

Well, if you want to solve real-world problems there is no way around that.

I do hope that you have learned to employ the tools that were presented and test the academic and commercial software made available to you.
What have we done?

Software

- Don’t forget: software needs data (Thorsten Koch)
- Don’t forget: software needs testing and comparisons (Hans Mittelmann)

Test run of CPLEX, SCIP, GUROBI yesterday

0 Oct 2009
Feasibility Benchmark - Feaspump, CPLEX, SCIP, GUROBI

H. Mittelmann (mittelmann@asu.edu)

Logfiles for these runs are at: http://plato.asu.edu/ftp/feas_bench_logs/

MILP problems from the following sources were solved for a feasible point
http://mplb.zib.de/
http://coral.ie.lehigh.edu/mip-instances/
http://plato.asu.edu/ftp/mip/
http://plato.asu.edu/ftp/unibo/
http://plato.asu.edu/ftp/b_sub/

The following codes were run on one CPU of a 2.67GHz Intel Core2 under Linux:

CPLEX-12.1: http://www.ilog.com/cplex/ (single thread)
FEASPUMP: http://www.or.deis.unibo.it/research_pages/ORcodes/FP-gen.html
"ab"/"bfl": Achterberg-Berthold/Bertacco-Fischetti-Lodi variants
as implemented for interactive use at NEOS: http://neos.mcs.anl.gov/ (utilizes CPLEX)
SCIP-1.2: http://scip.zib.de/ (uses CPLEX for LP)
GUROBI-2.0.0: http://gurobi.com/ (single thread)

Times given are user times in seconds. A time limit of 2 hrs was imposed.

<table>
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<tr>
<th>problem</th>
<th>CPLEX</th>
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<th>SCIP</th>
<th>GUROBI</th>
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5. Thanks
Modellierung: What is that?

„Art is a lie that makes us realize truth“

Olga Koklowa
Picasso’s first wife

The model of the mathematician

The model of the artist

A mathematical model is a lie that helps us see the truth.
Picasso and his women: Abstraction

Which is the most valuable picture?
The problem solving cycle in modern applied mathematics

The Real Problem

Hardware  Software  Data  GUI

Implementation in Practice

Numerical Solution
Optimization
Algorithmic Implementation
Computer Science

The Application Driven Approach

Simulation  Modelling
Quick Check: Heuristics

Practitioner Specialist
Education

Mathematical Model
Mathematical Theory
Pure Mathematics

Design of Good Solution Algorithms
Modeling

- Modeling is an art or craft but unfortunately not a science.
- Modeling is experience based.
- There is no “modeling theory”.

Martin Grötschel
Mathematical models treated

- travelling salesman problem (the prototype problem)
- routing
- location
- set-packing, -partitioning, -covering
- cut problems (max and min)
- scheduling
- node and edge colouring
- shortest paths with resource constraints
- various flow problems
- general IPs and MIPs
- etc.
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What have we done?

Applications

- Real auctions (single items, combinatorial: real life)
- Control of CNC machines, stacker cranes
- Logistics
- Transportation
- School bussing
- Track allocation
- Public transport
- Vehicle & elevator scheduling
- Telecommunication
- Mining
- Health care
- Gas transport
- ADAC yellow angels
- Open pit mining

Combinatorial Optimization at Work
What have we done?

Applications

- Printed Circuit Board Production
- Wafer Fab (ILOG, Bixby), the semiconductor supply chain
- Real-time dispatching of concrete trucks
- Beef disaggregation
- Supply chain scheduling
- Unit commitment in the electric power industry
- Water Supply Network Planning
- Luggage transport at airports
- Placement machines
- Stacker cranes, elevators, AGVs and the like
- Greeting cards commissioning and assembly lines
- Harbour optimization
- Delivery
- Yellow angels
What have we done?

Applications

- Line planning in public transport
- Crew Scheduling Models
  - Freight Train Scheduling
  - Duty Scheduling in Public Transit
  - Airline Crew Scheduling
  - Telebus
- Online Dial-a-Ride Problems
  - Dispatching the service vehicles of ADAC
  - Controlling cargo elevators in a distribution center
  - Controlling passenger elevators in high-rise buildings
- Integrated Coordination of School Starting Times and Public Transport
What have we done?

Applications

- Single Depot Vehicle Scheduling
- Multiple Depot Vehicle Scheduling
- Integrated Vehicle and Duty Scheduling
- Trip Scheduling
- Railway Track Allocation
- Stacker cranes, elevators, AGVs and the like
- Greeting cards commissioning and assembly lines
- Harbour optimization
- Sheet Metal Design
- Recovered Paper Production
- Free Flight Airplane Routes
Telecommunication

- GSM Frequency/Channel Assignment
- Optimizing the UMTS Radio Interface
- Locating the Nodes of a Network Optimally
- Clustering Base Transceiver Stations
- Balancing the Load of Signaling Transfer Points
- Integrated Topology, Capacity, and Routing Optimization as well as Survivability Planning
- Planning IP Networks
- Optical Network Design
- Traffic Engineering
Telecommunication: mentioned in passing

- Designing mobile phones
  - Task partitioning
  - Chip design (VLSI)
  - Component design

- Producing Mobile Phones
  - Production facility layout
  - Control of CNC machines
  - Control of robots
  - Cutting and welding
  - Printed Circuit Boards
    - Via minimization
    - Component Placement
    - Mounting Devices
    - Routing
  - Lot sizing
  - Scheduling
  - Logistics

- Marketing and Distributing Mobiles
Health Care (Martin Puterman)

- Surgeon Scheduling
- Priority Scheduling
- Radiotherapy or Chemotherapy Scheduling
- Workforce Planning
- Facility Location
- Radiotherapy Beam Direction Optimization
- Shift Scheduling
- Surgical Path Control
What have we done?

Data

- Data game
What have we done?
Visiting companies, entrepreneurship

- Siemens
- Schering
- HHLA
- ViP

Combinatorial Optimization at Work

- Founding a company
- CPLEX/Gurobi
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5. Thanks
Possible research directions

- Combinations of the following aspects
  - linear
  - mixed-integer
  - nonlinear
  - stochastic

- Multiobjective optimization theory (realistic approaches)

- Theory of online and real time optimization

- Better understanding of semi-algebraic geometry

- Further progress on many special models using the whole available machinery (example: symmetric TSP)
Possible research directions

- Understanding heuristics
  - worst-case behavior
  - average-case behavior (realistic stochastic models)
  - predicting the practical quality of a heuristic
  - (usable) polynomial time approximation schemes

- Stochastic analysis of models

- Hirsch conjecture ?

- P=NP ?
Possible research directions

- Mathematical auction theory, mechanism design, algorithmic economics
- Mathematics of regulation and deregulation
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Software research and development

- More use of NLP-techniques in LP and IP (bundle method)
- Stochastic programming codes
- Global optimization codes
- Multiobjective optimization codes
- Research in linear programming
  - almost no progress since 2004
  - simplex
  - interior point methods
- Integration of techniques (CP and MIP, Tobias Achterberg)
- Large scale
- Parallelization
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5. Thanks
New applications

- I simply see no end.
- Wherever you look, optimization is needed; and discrete optimization is becoming more and more important since most decisions made are discrete.
- Whether you want to
  - maximize profit
  - minimize cost
  - make best use of resources

optimization is required.
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Martin Grötschel
International Mathematical Union (IMU)

IMU Awards and Prizes
Extended Deadline for Contributions to the ICMI/ICIAM Study

The International Programme Committee of the joint ICMI/ICIAM Study (ICMI Study 20) on *Educational Interfaces between Mathematics and Industry* (EIMI) announces that the deadline for submitting contributions to the Study has been extended from September 15 until OCTOBER 15, 2009.

Instructions on submission of contributions and general information on the Study, organised jointly by the International Commission on Mathematical Instruction (ICMI) and the International Council for Industrial and Applied Mathematics (ICIAM), can be found on the Study website.

The EIMI Study Conference will be held in Lisbon on April 19-23, 2010.
Committee on Electronic Information and Communication (CEIC)

CEIC Announcements

Spanish Digitization Project

The Spanish Digital Mathematics Library is ready to expand to Latin America, June 2007.

Presentation to the General Assembly in Santiago, August 19, 2006

Read the PDF presentation made to the IMU describing the CEIC's activities from 2003-2006.

Recommendations on Digital Mathematics Library

With the ultimate goal of creating an enduring network of digital mathematical literature", the General Assembly of the International Mathematical Union on August 20, 2006 at its meeting at Santiago de Compostela formally endorsed the CEIC statement Digital Mathematical Library: a vision for the Future and adopted the CEIC recommendation Some Best Practices for Retrodigitisation.

Recommendations on Information and Communication

Citation Statistics

Open Access   Berlin Declaration
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Formation of Centers

- MATHEON and BMS in Berlin
- Hausdorff Center in Bonn
- MITACS in Canada
- MASCOS in Australia
- CMM in Santiago de Chile
- ICM in Poland

Collaborative research is getting of increasing importance.
Big questions need big effort.
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Questions

- Your evaluation
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5. Thanks
Thanks to all lecturers, helpers,...

TK  Thorsten Koch  TS  Thomas Schlechte  BE  Berkan Erol
CR  Christian Raack  BH  Benjamin Hiller  MR  Markus Reuter
AW  Axel Werner  AF  Armin Fügenschuh  OH  Olga Heismann
TB  Timo Berthold  MN  Marika Neumann  ID  Ivan Dovica
KW  Kati Wolter  CC  Carlos Cardonha  RD  Rene Dammer
SH  Stefan Heinz  AE  Andreas Eisenblätter  ES  Elmar Swarat
RB  Ralf Borndörfer  MM  Maren Martens  RM  Robert Meirich
DH  Dung Hoang  TO  Thorsten Klug  NP  Nils Paetsch
BB  Bob Bixby  TUGS  Gründungsservice  UK  Urs Kramer
CB  Christina Burt  MP  Martin Puterman  NF  Niklas Forck
YB  Yao Ban  NW  Nadia Wisniewski  GG  Gerald Gamrath
AB  Andreas Bley  SV  Stefan Vigerske  RW  Robert Waniek
AG  Ambros Gleixner  IPG  TB,KW,SH,AG,TK  MW  Michael Winkler
HM  Hans Mittelmann  PTG  RB,HN,TS,CC, ID  WH  Wie Huang
TA  Tobias Achterberg  HPC  Hinnerk Stüben&Co  JS  Jonas Schweiger
OB  Oliver Bastert  VIS  Olaf Paetsch  SI  Siarhei Makarevich
EA  Erling Anderson  
TR  Ted Ralphs  
MH  Michael Hofmeister  

and participants

SM  Sybille Mattrisch
UP  Uwe Pöhle
BK  Bettina Kasse
WD  Wolfgang Dalitz
SR  Susanne Richter
WN  Winfried Neun
JL  Jian Li
MH  Mathias Hecht
AVG  WD,SR,WN
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The End