

# 10A1 Lecture

## Summary and Final Remarks

**Martin Grötschel**

**Block Course at TU Berlin**

**"Combinatorial Optimization at Work"**

**October 4 – 15, 2005**



Martin Grötschel

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# COatWork: The Program

## Tuesday, Oct. 4

01M0: 09:00-09:30	MG	Welcome and Introduction
01M1: 09:30-10:30	MG	Linear and Integer Programming: an Introduction
01M2: 11:00-12:30	MG	Basics of Polyhedral Theory
01A1: 13:30-15:00	TK	Using ZIMPL and LP / IP Solvers
01A2: 15:30-17:00	TK	Exercises

## Wednesday, Oct. 5

06:45-19:03		Excursion to Volkswagen, Wolfsburg Visit of "VW Konzernlogistik" and more
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For those who stayed in Berlin:

00M1: 09:00-10:30	TA	Chip Verification 1
00M2: 11:00-12:30	TA	Chip Verification 2
00A1: 13:30-15:00	MP	Introduction to PORTA and Polymake & Exercises
00A2: 15:30-17:00	MP	Exercises

## Thursday, Oct. 6

02M1: 09:00-10:30	MG	The Travelling Salesman Problem and some Applications
02M2: 11:00-12:30	MG	Scheduling Stacker Cranes & Some Aspects of Logistics
02A1: 13:30-15:00	MG	Sequencing Welding Robots
02A2: 15:30-17:00	TK	Exercises



# COatWork: The Program

## Friday, Oct. 7

03M1: 09:00-10:30	MG	Chip Design
03M2: 11:00-12:30	MG	Printed Circuit Board Production: Some Issues
03A1: 13:30-15:00	BB	From Planning to Operations: The Ever-Shrinking Optimization Time Horizon (Beef Cutting, Dispatching of Concrete Trucks, Production-line Scheduling of Wafer Fabs)
03A2: 15:30-17:00	TK	Exercises

## Saturday, Oct. 8

04M1: 09:00-10:30	BB	Simplex Algorithms: The Legacy of George Dantzig (Algorithmic framework for the primal and dual, ratio test, degeneracy, pricing, solving large-scale problems)
04M2: 11:00-12:30	BB	MIP: Then and Now
04A1: 13:30-15:00	BB	Exercises
04A2: 15:30-17:00	TK	Exercises

## Monday, Oct. 10

05M1: 09:00-10:30	MG	Combinatorial Optimization and Telecommunication
05M2: 11:00-12:30	MG	Telecommunication Network Design
05A1: 13:30-15:00	AB	Internet Routing & Exercises
05A2: 15:30-17:00	TK	Exercises

## Tuesday, Oct. 11

06M1: 09:00-10:30	MG	Frequency Assignment for GSM Mobile Phone Systems
06M2: 11:00-12:30	HG	Capacity and Coverage Planning for the UMTS Radio Interface
06A1: 13:30-15:00	TK	Site Selection in UMTS
06A2: 15:30-17:00	TK	Exercises



# COatWork: The Program

## Wednesday, Oct. 12

07M1: 09:00-10:30	MG	Online Optimization
07M2: 11:00-12:30	MG	Service Vehicle Scheduling (“Yellow Angels” of ADAC)
07A1: 13:30-15:00	TK	Exercises
07A2: 15:30-17:00	TK	Exercises
07A3: 17:00-18:00	ED	Special Lecture, Eran Davidson: Entrepreneurship: From University to Start-up Company

## Thursday, Oct. 13

08M1: 09:00-10:30	MG	Combinatorial Optimization and Transportation, Telebus
08M2: 11:00-12:30	RB	Crew Scheduling Problems
08A1: 13:30-15:00	TK	Exercises
08A2: 15:30-17:00	TK	Exercises

## Friday, Oct. 14

09M1: 09:00-10:30	RB	Vehicle Scheduling Problems
09M2: 11:00-12:30	RB	Combinatorial Auctions and Rail Track Scheduling
09A1: 13:30-15:00	TS&RB	Combinatorial Auctions & Exercises
09A2: 15:30-17:00	TK	Exercises

## Saturday, Oct. 15

10M1: 09:00-10:30	MG&TK	Optimizing Container Terminals
10M2: 11:00-12:30	MG&TK	and Related Topics
10A1: 13:00-15:00	MG	Summary and Final Remarks



# CO Problems & Applications

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# CO Problems & Applications

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## General problems:

- Linear programming (Oct 4, 8)
- Integer, mixed integer, and 0/1-programming (Oct 4, 8)

## Algorithmic issues:

- Polynomial time solvability (Oct 4)
- NP-hardness (Oct 4)

## Solution techniques:

- Polyhedral combinatorics (Oct 4 and in applications)
- Cutting plane algorithms (Oct 4, 8)
- Branch&cut&price (Oct 4, 8)
- Column generation (Oct 13, crew scheduling etc.)
- Heuristics (Oct 6 (TSP), Oct 12 (Online))
- Lagrangean relaxation (Oct 13, 14 crew & vehicle sched.)



# CO Problems & Applications

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Prototypical CO problems:

- Travelling salesman problem (Oct 6)
- Set partitioning (Oct 13)
- Network flow problems (Oct 14)
- Shortest path problem (Oct 7, 14, routing and col gen)
- Spanning tree problem (Oct 6, 7, TSP, chip design)
- ...



# CO Problems & Applications

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Applications:

Several aspects of chip verification

Chip design:

- Global placement
- Local placement
- Global (homotopic) routing
- Local routing
- Layer assignment & via minimization
- Compactification





# CO Problems & Applications

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Applications:

Printed circuit board production

- Task partitioning
- Component placement
- Wire routing
- Layer assignment (via minimization)
- Hole drilling (modelling the objective)



# CO Problems & Applications

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## Applications:

- Garbage collection (Chinese postman)
- Grave sequencing in archeology
- Wafer fabrication (Bixby)
- Concrete delivery (Bixby)
- Beef cutting (Bixby)



# CO Problems & Applications

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Applications:

Telecommunication:

- Frequency Assignment in GSM
- The UMTS Radio Interface
- Locating the Nodes of a Network
- Balancing the Load of Signaling Transfer Points
- Integrated Topology, Capacity, and Routing Optimization as well as Survivability Planning
- Planning IP Networks
- IP Routing
- Optical Networks



# CO Problems & Applications

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Applications:

Online optimization:

- Yellow angels
- Stacker crane scheduling
- Elevator control
- Greeting cards commissioning
- (Bin packing)
- (Ski rental)
- Online TSP and online DARP



# CO Problems & Applications

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## Applications:

### Transportation & Logistics:

- Factory logistics (AGVs, conveyors, etc.)
- Harbour optimization issues
- Telebus: Transporting disabled persons
- Network Planning
- Line Planning
- Price and Frequency Planning
- Vehicle Scheduling
- Duty Scheduling
- Integrated Vehicle and Duty Scheduling
- Track Auctioning



# CO Problems & Applications

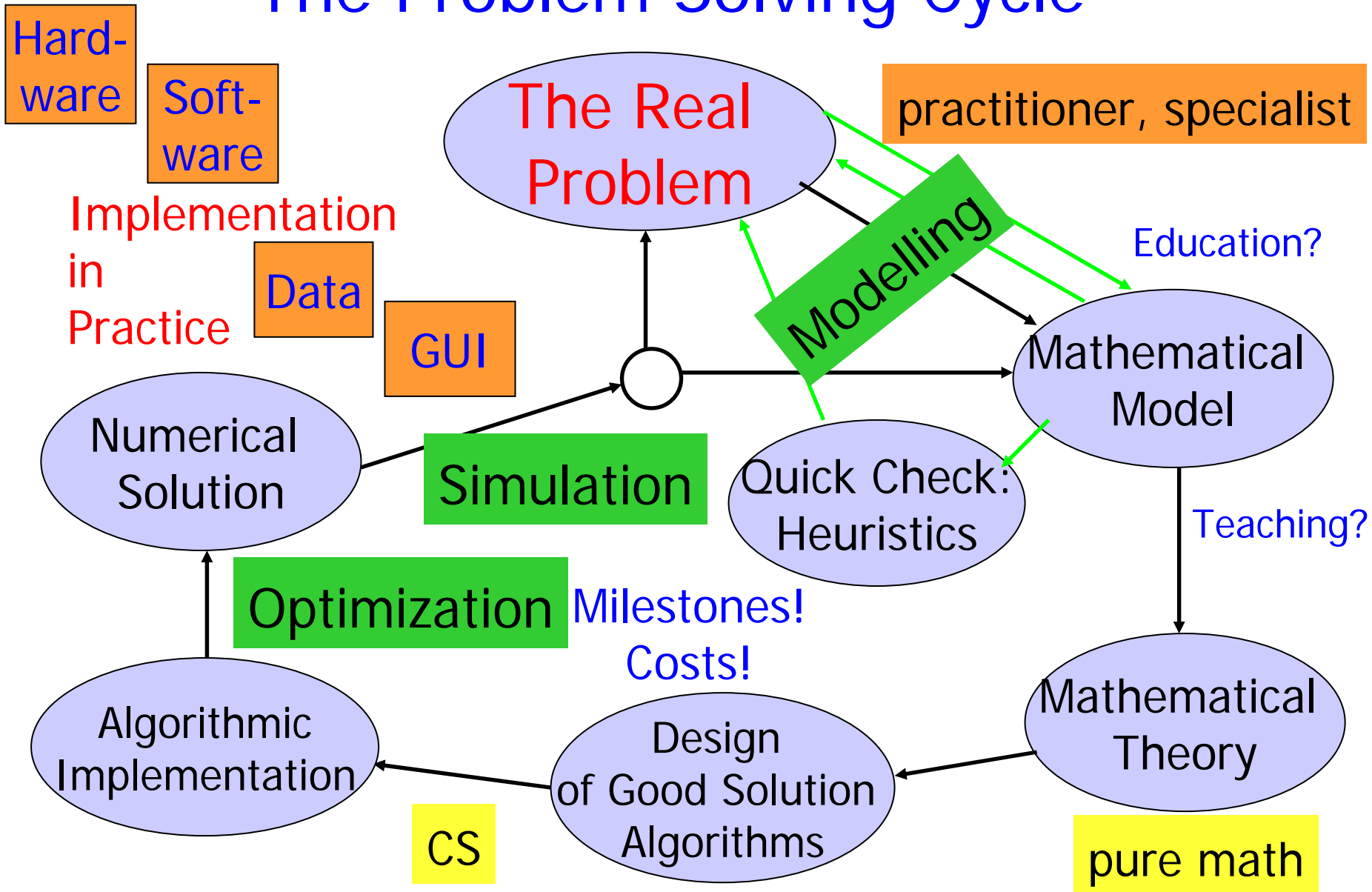
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## Applications:

- We have introduced in some detail about 40 real-world problems to which methods of combinatorial optimization can be applied.
- And we have mentioned additional interesting applications in passing.
- We have outlined
  - what could be achieved in practice and
  - what the obstacles to implementation have been.
- And we have provided a realistic picture of the “solution environments”.



# The Problem Solving Cycle



In Modern Applied Mathematics

# CO Problems & Applications

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We hope that you know now more about

“mathematics and the real world”





# Contacts in the recent days

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- E-Mails deleted



# Questionnaire

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- Was it worth spending two full weeks on such a course?
- What did you like?
- What did you not like?



# Questionnaire

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- Was there too much teaching (in a very short time period)?
- Is a block course an adequate format for such a lecture series?
- What could be a more suitable format?
- Were the classes too long?
- Was the level of teaching “right”?
- Should there be more details about
  - the problems and their data
  - the theory behind the problem
  - the algorithms designed and used
  - the solution and implementation in practice?
- Should more theory be taught?
- Should one concentrate only on “little” problems that can be explained easily?
- Does it make sense to give broad overviews?



# Questionnaire

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- Should there be more exercises?
- Did you like the exercises?
- Should the exercises be in a different form?
- Was it a good idea to make software and data available on the Web?
- Is it a good idea to use laptops in the exercises?
- What else would you like to see in the Power Point presentations?
- Was it worth visiting Volkswagen?
- Should one try to include such an excursion if the course is repeated?



# Questionnaire

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- What would you like to see written?
- This concerns depth, length and detail of the articles to be written.
- Should there be only articles on individual applications?
- Should there be overview articles?
- Should there also be some theory surveys or should these be integrated into the application articles?



# The CO at Work Project

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The final product of this “Combinatorial Optimization at Work” project (if we succeed finishing it) will consist of several items.

- There will be a printed book that contains the articles.
- The book will be available for download (for free) from the Web.
- All articles will be offered on the Web.
- There will be updates from time to time, including new articles.
- Data of real problem instances will be made available.
- Some software for the solution of the problems addressed will be made available for free on the Web.



# CD-ROM

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- All Power Point presentations are on the CD
- The films shown
- The final program
- Some photos



# 10A1 Lecture

## Summary and Final Remarks

**Thank for your  
participation**



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