

# 10A1 Lecture

## Summary and Final Remarks

**Martin Grötschel**

**Beijing Block Course**

**“Combinatorial Optimization at Work”**

**September 25 – October 6, 2006**



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# CO Problems & Applications

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## General problems:

- Linear programming
- Integer, mixed integer, and 0/1-programming

## Algorithmic issues:

- Polynomial time solvability
- NP-hardness

## Solution techniques:

- Polyhedral combinatorics
- Cutting plane algorithms
- Branch&cut&price
- Column generation
- Heuristics
- Lagrangean relaxation



# CO Problems & Applications

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Prototypical CO problems:

- Travelling salesman problem
- Set partitioning
- Network flow problems
- Shortest path problem
- Spanning tree problem
- ...



# 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
- 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

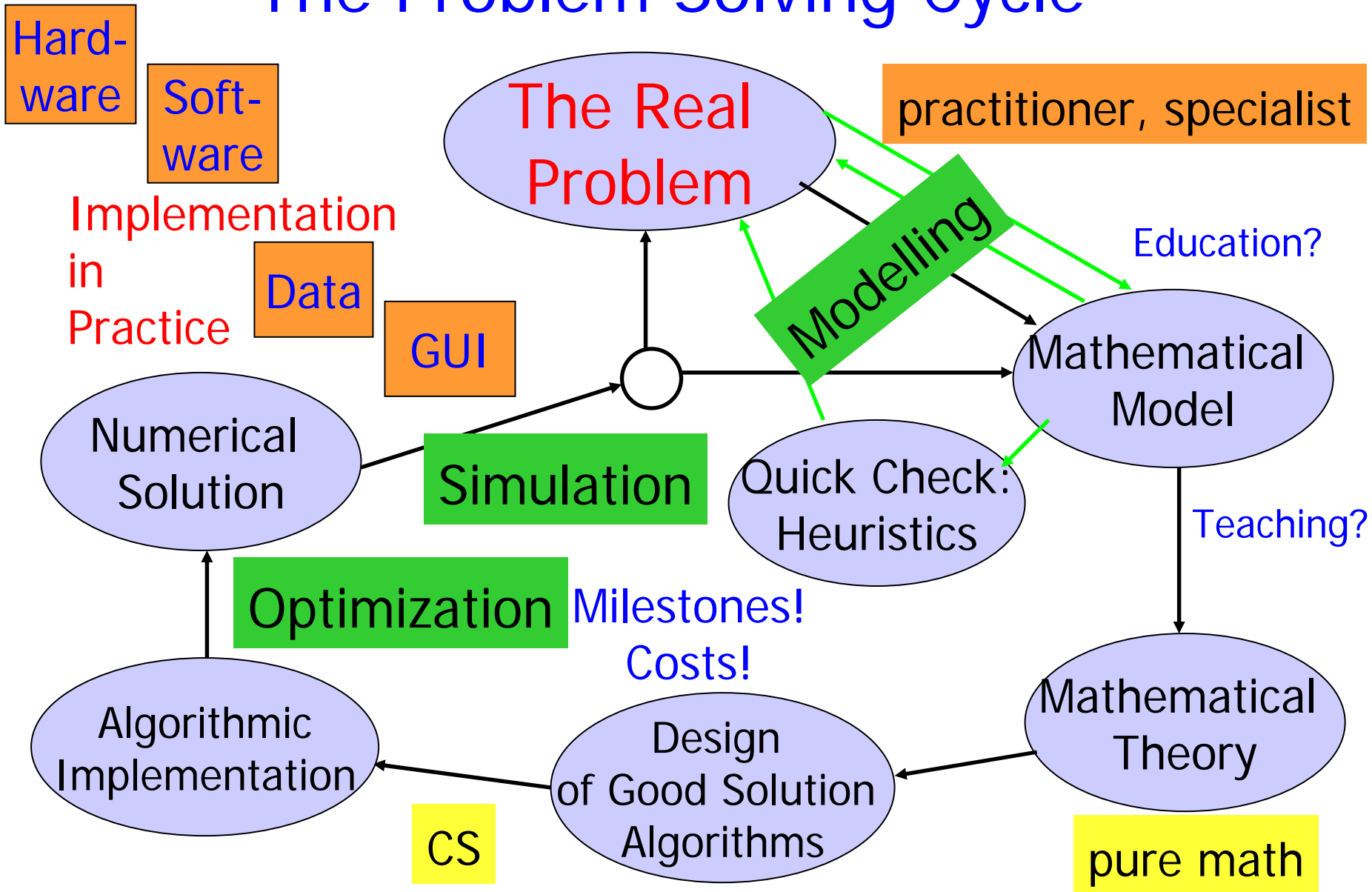
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## Applications:

- 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”



# 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/USB-Stick

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



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**Thanks for your  
participation**



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