Proceedings of the Twenty-Sixth RAMP Symposium
Hosei University, Tokyo, October 16-17, 2014

Future perspectives of optimization: My view

Martin Grötschel[1*]

Abstract When thinking about the future of optimization one has to take a broad perspective; disciplines such as operations research (OR), computer science, applied mathematics, and scientific computing need to be taken into account as well as emerging fields such as data science and MSO (which is an abbreviation of modelling, simulation and optimization).

Optimization (and its close relatives mentioned before) are, in a sense, difficult disciplines since they are becoming more and more interdisciplinary. And moreover, in the academic world, they are heterogeneous as they may be located in departments or faculties of mathematics, management science, economics, computer science, industrial or other types of engineering. In industry, the positioning of OR and optimization specialists is similarly fuzzy. There is almost no situation where OR or optimization form the core of some organization. All this makes it somewhat difficult to pursue "clean" OR/optimization careers in industry or academia.

What makes it worse is that the names used for denoting the activities are unstable. They are changing over time and from country to country. Even worse, the various names are not well understood — some not at all by the general public, some have different interpretations — depending on the user community.

It is interesting to observe that all this is a weakness of the field, but it is also a strength, as I will point out. In this talk I will elaborate on my view of the past and future of optimization and its relatives and my conclusion is that it is very bright, if appropriately "positioned and managed".

Keywords optimization, operations research, mathematical programming, future perspectives

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Future perspectives of optimization: My view

26th RAMP Symposium
Tokyo, Japan, October 17, 2014
Martin Grötschel
Zuse Institute, Technische Universität and MATHEON
Berlin

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My abstract

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- operations research (OR),
- computer science,
- applied mathematics, and
- scientific computing

need to be taken into account as well as emerging fields such as

- data science and
- MSO (an abbreviation of modelling, simulation and optimization).

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- And moreover, in the academic world, they are heterogeneous as they may be located in departments or faculties of mathematics, management science, economics, computer science, industrial or other types of engineering.
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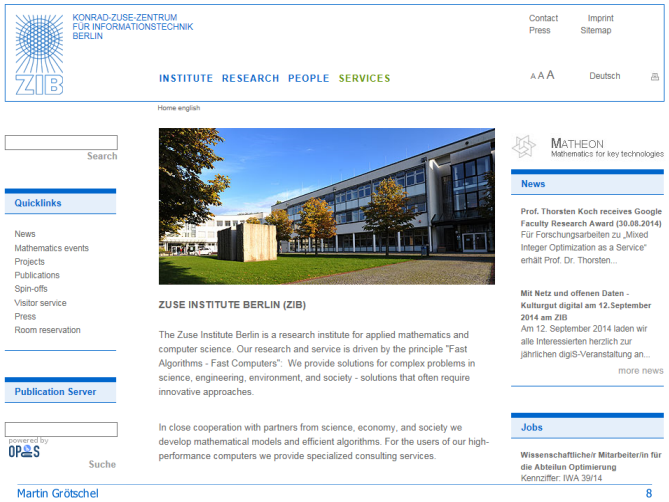
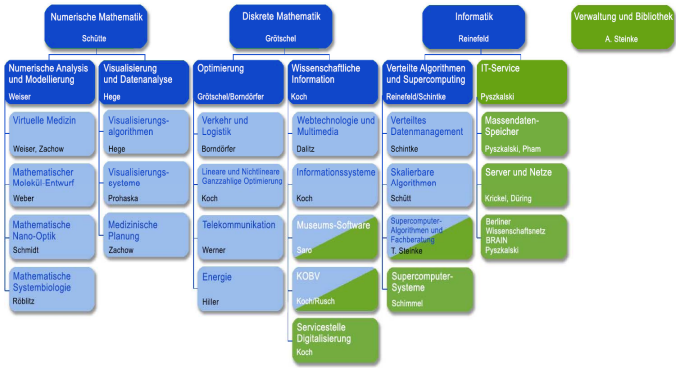


Current Structure of ZIB

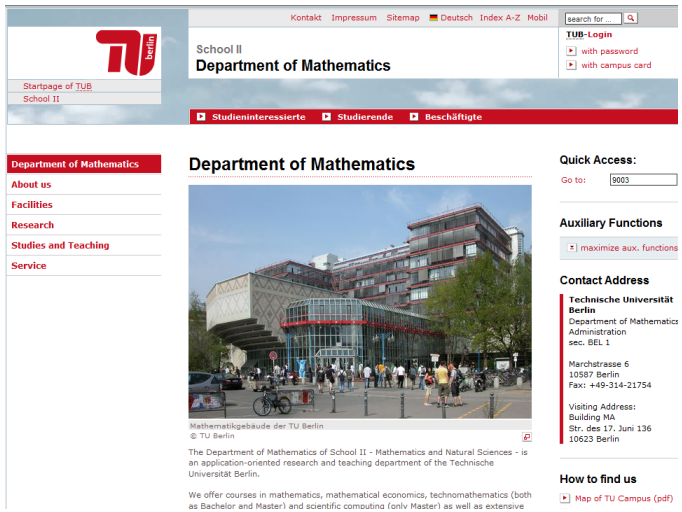


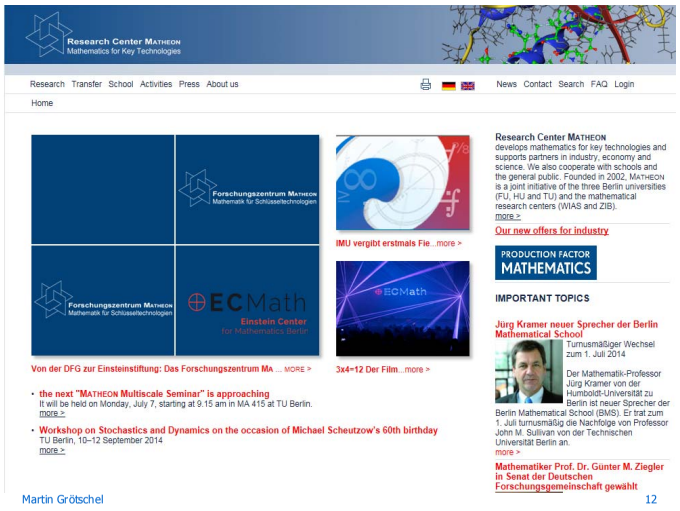
ZIB

Evaluation of ZIB on November 24-25, 2014

Zukunftskonzept des ZIB

Das ZIB als interdisziplinäres Kompetenzzentrum für Computing und Data Science





MATHEON

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Optimization etc.

The initial name was

- Programming or
- Mathematical programming

Root of the name? (see George Dantzig's explanation)

In German:

- Optimierung

But then programming was highjacked by computer scientists and the name changed to

- Optimization or
- Optimisation
- Mathematical optimiz(s)ation

Just look at MOS

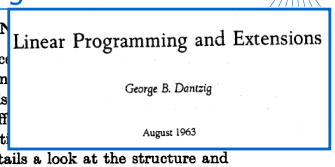
MOS/MPS

Mathematical Optimization Society

Welcome to the website of the Mathematical Optimization Society

The Mathematical Optimization Society (MOS), founded in 1973, is an international organization dedicated to the promotion and the maintenance of high professional standards in the subject of mathematical optimization. Up to 2010 its name was "Mathematical Programming Society (MPS)".

Where does programming come from?



1-2. THE PROGRAMMIN

Industrial production, the flow of resourc
of military effort in a war theater—all are com
activities. Differences may exist in the goals
processes involved, and the magnitude of eff
to abstract the underlying essential similarit
seemingly disparate systems. To do this entails a look at the structure and state of the system, and at the objective to be fulfilled, in order to *construct a statement of the actions to be performed, their timing, and their quantity (called a "program" or "schedule"), which will permit the system to move from a given status toward the defined objective.*

If the system exhibits a structure which can be represented by a mathematical equivalent, called a mathematical model, and if the objective can also be so quantified, then some computational method may be evolved for choosing the best schedule of actions among alternatives. Such use of mathematical models is termed mathematical programming. The observation that a number of military, economic, and industrial problems can be expressed (or reasonably approximated) by mathematical systems of linear inequalities and equations[1] has helped give rise to the development of linear programming.

What names do we know for OR?

English:

Operations Research (North America and most other countries)
Operational Research (United Kingdom)
OR: The science of better (INFORMS)
INFORMS recently coined Analytics

German:

Unternehmensforschung (West Germany)
Unternehmungsforschung (West Germany)
Operationsforschung (East Germany)
now mostly Operations Research
and many more names elsewhere

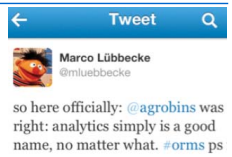
ORMS-Today: August 2013, vol. 40, No. 4

PRESIDENT'S DESK

A rose by any other name

INFORMS President

Anne Robinson



How does "analytics" translate into other languages? Does it have the same impact in other cultures as is being witnessed in North America? In Italian, the literal translation is "analytica," a lovely, lyrical Italian word, that has little relevance or meaning in the context in which we describe it.
The German O.R. Society has adopted the business analytics term, as evidence by their forthcoming conference "Business Analytics and Operations Research." Marco Lübbecke, chair of operations research at RWTH Aachen University in Aachen, Germany, went as far as tweeting that "analytics simply is a good name, no matter what." (see Figure 1.)
My Verizon colleague and INFORMS Past President Rina Schneur mentioned that a lecture she recently gave on a trip to the Technion in Israel triggered a similar conversation on this topic. The conclusion was that analytics was a difficult concept to translate.

EURO Gold Medal winners on Operational Research

- S. Vajda, (article on EURO Gold Medal Ceremony)
  "The three ages of Operational Research",
  European Journal of Operational Research 45(1990)131-134
  "I believe that the term fits awkwardly those activities which OR comprises now, but it is too late to change."
- R. L. Ackoff, "The future of Operational Research is past"
  Journal of the Operational Society 30(1979)93-104
- J. Krarup, "EURO Gold Medal 1986: A parable on two-level parallelism",
  European Journal of Operational Research 38(1989)274-276
  "...an interdisciplinary bastard like operational research..."

EURO Gold Medal winners on Operational Research (positive guys)

- P. Hansen, "A short discussion of the OR crisis"
  European Journal of Operational Research 38(1989)277-281
  "No general agreement seems to have been reached about its methodology, and the directions in which it should evolve. …
  There are many ways to live a life of OR, to discover new results and apply them, and thus to enjoy OR's truth and beauty."
- R. Burkard, "OR Utopia"
  European Journal of Operational Research 119(1999)224-234
  "The borders of OR Utopia have yet another quality: people can come and go, without passport. There is no quota for foreigners…
  OR Utopia…is a peaceful border between OR, mathematics, and computer science, …management science, economy, logistics, … "

Name consultants are needed

Example:

DFG-Forschungszentrums (FZT 86) Mathematik für Schlüsseltechnologien: Modellierung, Simulation und Optimierung realer Prozesse

DFG Research Center (FZT 86) Mathematics for key technologies: Modelling, simulation, and optimization of real-world processes

became

MATHEON

The issue is not just good science but good science marketing.

MATHEON application in 2001

Mathematics for key technologies: Modelling, simulation, and optimization of real-world processes

MATHEON

Initiatorengruppe:

Prof. Dr. M. Grötschel* (TU Berlin und ZIB, design. Sprecher)

Prof. Dr. P. Deuflhard (FU Berlin und ZIB)

Prof. Dr. V. Mehrmann (TU Berlin)

Prof. Dr. J. Sprekels (HU Berlin und WIAS)

Terminology (for this lecture)

Moreover, it has become clear that all three of the following scientific activities

- modeling
- simulation
- optimization

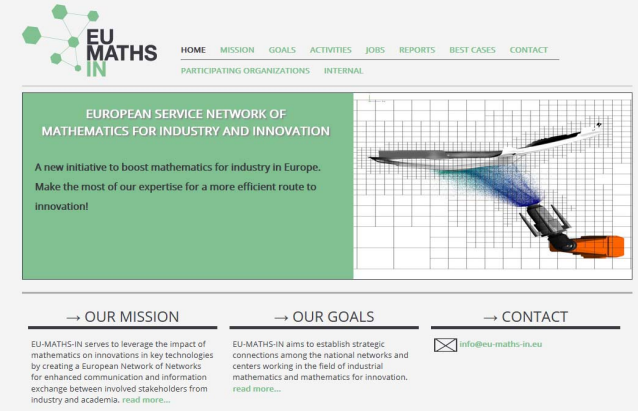
are necessary for the solution of real-world problems and that they should be considered jointly in all solution approaches. Very recently, it has become fashionable to abbreviate the combined efforts by

- MSO

I will follow this trend (partly) in my lecture.

In fact, Matheon, as I will explain later was one of the trendsetters in this direction, as the next slide shows:

New Developments



MSO as a Key EnablingTechnology (KET)

EU MATHS IN European Service Network of Mathematics for Industry and Innovation

Position paper on establishing Modelling, Simulation and Optimization as KET

Where is mathematical modelling, simulation and optimisation?
A call for reason to capitalize on European Mathematical Expertise for industrial innovation and European competitiveness

It has become widely recognized that the approach of modelling, simulation and optimisation (MSO) builds the third pillar for scientific progress and innovation, besides experiments and theory building. In the various Working Programs of Horizon 2020 of the European Commission, however, the use of mathematics/mathematical modelling simulation and optimisation is mentioned fewer than a handful of times (one positive exception is the FET paper). While in the current version of the Work Programs the terms modelling and simulation are used in a somewhat inflationary way, the connection to a sound mathematical basis is rarely made. But, in our experience and expertise, future challenges for innovations in industry and society exhibit increasing complexity and at the same time have to obey ever-shorter innovation cycles. For this it takes more than just trying out all possible parameter variations on a computer. The real-world challenges to be dealt with on our way towards innovations in industry and society exhibit properties that make MSO a far more non-trivial task. In fact, many of the current (and future) problems require the development of mathematical methodologies, such as the areas of:

MSO as a Future and Emerging Technology (FET)

EU MATHS IN European Service Network of Mathematics for Industry and Innovation

Draft on establishing MSO as FET area:

Value creation through mathematical modelling, simulation and optimization: A proposal for new Research Infrastructures and dedicated FET topics

Future challenges for innovation in industry and society exhibit increasing complexity and at the same time have to obey to ever-shorter innovation cycles. One of the key technologies in this permanent fight is the use of computers at peak performance in an appropriate way, i.e. in the integrated modelling, simulation and optimization (MSO) frame. In the competitive industry and in the top scientific research projects a full holistic approach is to be applied (e.g. to use MSO on a complete vehicle, a full digital factory, the human heart or the complete vascular system). To develop such a holistic approach one needs a mathematical model that allows to simulate and optimize the real product on virtual product via the use of high performance computing (HPC) tools.

Names

Our field is under naming pressure!

New concepts/abbreviations/names are invented that are in competition with optimization and operations research, additionally contributing to the confusion.

Contents

1. Outline
2. Where do I come from?
3. Naming business — Opinions and Facts
4. What are OR and optimization? — Opinions and Facts
5. Success stories
6. Failures?
7. What should OR/optimization do?
8. Conclusions

Operations Research/Optimization: approached as a subject

As a topic in mathematics
- optimization
- mathematical programming

As a topic in management science / business administration
- operations management
- management engineering

As a topic in engineering
- industrial engineering
- supply chain management/flexible manufacturing

As a topic in computer science

As a topic in psychology/sociology

Systems Theory/Cybernetics

Decision Sciences, Decision Aid

...

de Werra's sweep

D. de Werra: "What is my objective function?"
European Journal of Operational Research 99(1997)207-219

2. OR is a pure science.
3. OR is an open science.
4. OR relies on basic sciences and on life sciences.
5. OR is a natural science.
6. OR is an art.
7. OR does miracles.

Dominique forgot: OR is an applied science.

Academic OR/Opt in Berlin (one typical example)

Technische Universität Berlin
- Fakultät IV - Elektrotechnik und Informatik
  - Institut für Wirtschaftsinformatik und Quantitative Methoden
    - Operations Research (OR)
- Fakultät VIII Wirtschaft und Management
  - Fachgebiet Produktionsmanagement
- Fakultät II Mathematik und Naturwissenschaften
  - Institut für Mathematik
    - Arbeitsgruppe Algorithmische und Diskrete Mathematik

very little interaction

Freie Universität Berlin
- Fachbereich Wirtschaftswissenschaft
  - Institut für Produktion, Wirtschaftsinformatik und OR

Humboldt Universität Berlin
- Wirtschaftswissenschaftliche Fakultät
  - Institut für Operations Research

Plus several working groups in the mathematical institutes in various branches of maths.

Contents

Typical optimization problems

$$\max f(x) \ \ or \ \ \min f(x)$$
$$g_i(x) = 0, \quad i = 1,2,\ldots,k$$
$$h_j(x) \le 0, \quad j = 1,2,\ldots,m$$
$$x \in \mathbb{R}^n \ (and \ \ x \in S)$$

„general“ (nonlinear) program NLP

$$\min c^T x$$
$$Ax = a$$
$$Bx \le b$$
$$x \ge 0$$
$$(x \in \mathbb{Q}^n)$$

linear program LP

$$\min c^T x$$
$$Ax = a$$
$$Bx \le b$$
$$x \ge 0$$
$$x_i \in \mathbb{Z} \ \ for\ some\ i$$
$$(x_i \in \{0,1\} \ \ for\ some\ i)$$

(linear) (mixed-) integer program IP, MIP

program = optimization problem

Special „simple“ combinatorial optimization problems

- Finding a
- minimum spanning tree
- shortest path
- maximum matching
- maximal flow through a network
- cost-minimal flow
- …

solvable in polynomial time (and very fast in practice)

Special „hard“ combinatorial optimization problems

- travelling salesman problem
- location und routing
- set-packing, partitioning, -covering
- max-cut
- linear ordering
- scheduling (with a few easy exceptions)
- node and edge colouring
- …
- NP-hard (in the sense of complexity theory)

The most successful solution techniques employ linear programming as a bounding procedure.

Progress in LP: 1988—2004

Operations Research,
Jan 2002, pp. 3—15, updated in 2004)

Courtesy Bob Bixby

Algorithms (*machine independent*):

Primal *versus* best of Primal/Dual/Barrier 3,300x

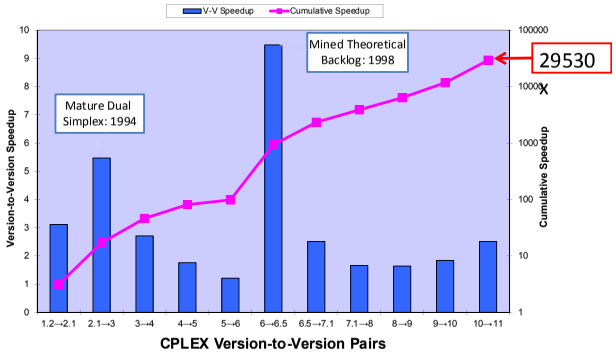
Machines (workstations →PCs): 1,600x

NET: Algorithm × Machine 5,300,000x

(2 months/5300000 ~= 1 second)

Mixed Integer Speedups 1991-2008

Courtesy Bob Bixby



Commercial optimization software

- CPLEX
- Gurobi
- XPRESS
- MOSEK
- ...

Bixby plenary talk ICIAM 2015 in Beijing

The SCIP Optimization Suite of ZIB

The SCIP Optimization Suite is a toolbox for generating and solving mixed integer programs. It consists of the following parts:

SCIP: a mixed integer programming solver and constraint programming framework

SoPlex: a linear programming solver

ZIMPL: a mixed integer programming modeling language

GCG: a generic branch-cut-and-price solver

UG: a parallel framework for solving mixed integer (linear and nonlinear) programs

The user can easily generate linear programs and mixed integer programs with the modeling language ZIMPL. The resulting model can directly be loaded into SCIP and solved. In the solution process SCIP may use SoPlex as underlying LP solver.

Since all five components are available in source code and free for academic use, they are an ideal tool for academic research purposes and for teaching mixed integer programming.

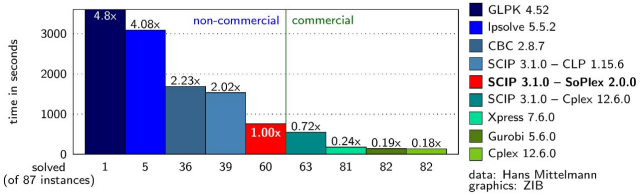
SCIP

Solving Constraint Integer Programs

http://scip.zib.de/

About

SCIP is currently one of the fastest non-commercial solvers for mixed integer programming (MIP) and mixed integer nonlinear programming (MINLP). It is also a framework for constraint integer programming and branch-cut-and-price. It allows for total control of the solution process and the access of detailed information down to the guts of the solver.

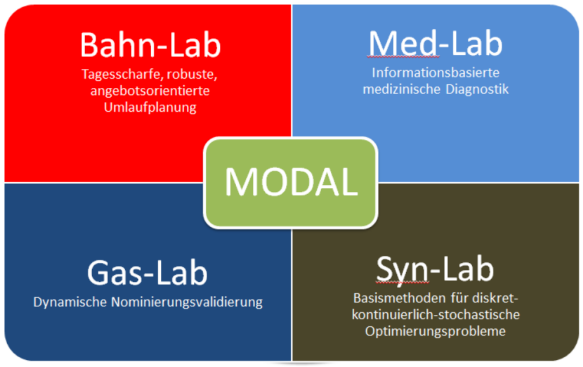


MIP solver benchmark (1 thread): Shifted geometric mean of results taken from the homepage of Hans Mittelmann (23/Mar/2014). Unsolved or failed instances are accounted for with the time limit of 1 hour.

History of the SCIP Optimization Suite

1996 SoPlex – Sequential obj. simPlex (R. Wunderling [now IBM])
1998 SIP – Solving Integer Programs (A. Martin [now U Erlangen])
10/2002 Beginning of SCIP development (T. Achterberg [now Gurobi])
08/2003 Chipdesign verification ⇨ Constraint Programming
10/2004 ZIMPL – Zuse Inst. Math. Programming Language (T. Koch)
09/2005 First public version 0.8 of SCIP
09/2007 SCIP 1.0 release, ZIB Optimization Suite (Soplex, SCIP, ZIMPL)
11/2008 Development of GCG started (G. Gamrath)
01/2009 Gas transport optimization ⇨ nonlinear
03/2009 Beginning of UG development (Y. Shinano)
09/2009 Beale-Orchard-Hays Prize (T. Achterberg)
04/2010 Supply-Chain management) extremely large LPs/MIPs
12/2010 Google Research Award 2011
08/2012 Version 3.0.0, first releases of GCG and UG
SCIP Optimization Suite (Soplex, SCIP, ZIMPL, GCG, UG)

BMBF-Forschungscampus Modal



SoPlex Sequential object-oriented simplex

SoPlex is an implementation of the revised simplex algorithm. It features primal and dual solving routines for linear programs and is implemented as a C++ class library that can be used with other programs.

Roland Wunderling,
Paralleler und Objektorientierter Simplex-Algorithmus,
Dissertation, TU Berlin,1997

now employed by IBM, developing CPLEX's LP technology

Zimpl

Zimpl is a little language to translate the mathematical model of a problem into a linear or (mixed-) integer mathematical program expressed in .lp or .mps file format which can be read and (hopefully) solved by a LP or MIP solver.

Thorsten Koch, *Rapid Mathematical Programming*, Berlin 2004
(awarded with the Dissertation Prize 2005 of the Gesellschaft für Operations Research)

SCIP http://scip.zib.de/

Tobias Achterberg, Tobias, *Constraint Integer Programming*, Dissertation, TU Berlin, 2007

Dissertation Prize 2008 of the Gesellschaft für Operations Research (GOR)

George B. Dantzig Dissertation Award 2008 of the Institute of Operations Research and the Management Sciences (INFORMS), 2nd prize)

Beale-Orchard-Hays Prize 2009 of the Mathematical Optimization Society for the paper: Tobias Achterberg, "SCIP: Solving constraint integer programs", Mathematical Programming Computation, 1 (2009), pp. 1-41.

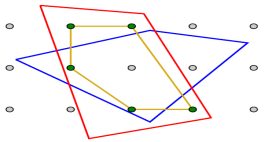
Now employed by IBM, developing CPLEX's MIP technology

GCG Generic Column Generation

GCG extends the branch-cut-and-price framework SCIP to a generic branch-cut-and-price solver.

- performs Dantzig-Wolfe decomposition for detected or provided structure
- Solves reformulation with branch-and-price approach
- pricing problems solved as MIPs
- generic branching rules for branch-and-price

Provides easy access to another state-of-the-art MIP solving technology.



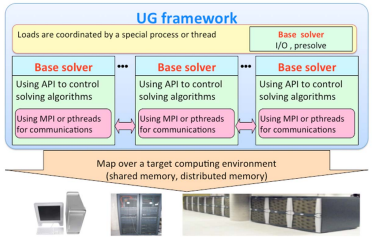
Gerald Gamrath, *Generic Branch-Cut-and-Price*, Diploma Thesis, TU Berlin, 2010

Currently developed in cooperation with RWTH Aachen, also funded by SPP 1307

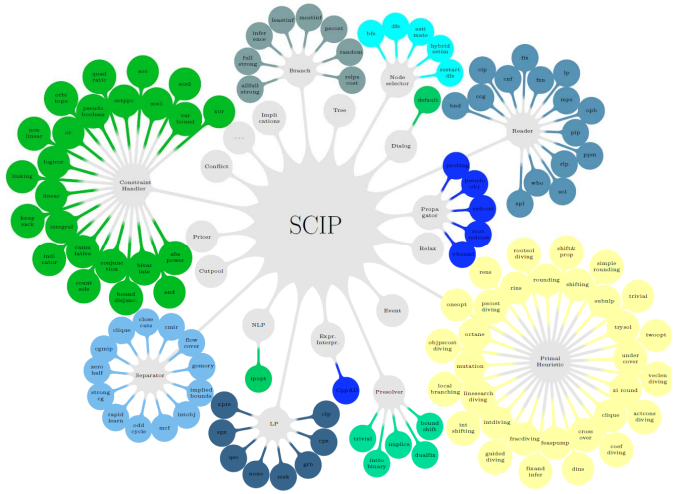
UG Ubiquity Generator Framework

UG is a generic framework to parallelize branch-and-bound based solvers (e.g., MIP, MINLP, ExactIP) in a distributed or shared memory computing environment.

- Exploits powerful performance of state-of-the-art "base solvers", such as SCIP, CPLEX, etc.
- Without the need for base solver parallelization

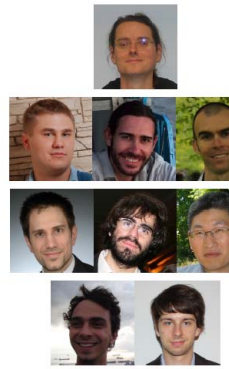


Yuji Shinano, *A Generalized Utility for Parallel Branch-and-Bound Algorithmus*, Dissertation, Tokyo University of Science,1997



Current ZIB LP/MIP/SCIP Group

- Thorsten Koch
- Gerald Gamrath
- Ambros Gleixner
- Stephen Maher
- Matthias Miltenberger
- Felipe Serrano
- Yuji Shinano
- Gregor Hendel
- Benjamin Müller



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Former ZIB LP/MIP/SCIP Group

- Tobias Achterberg
- Thorsten Koch
- Marc Pfetsch

- Timo Berthold
- Gerald Gamrath
- Ambros Gleixner
- Stefan Heinz
- Matthias Miltenberger
- Yuji Shinano
- Stefan Vigerske
- Kati Wolter

- Gregor Hendel
- Alexandra Kraft
- Michael Winkler

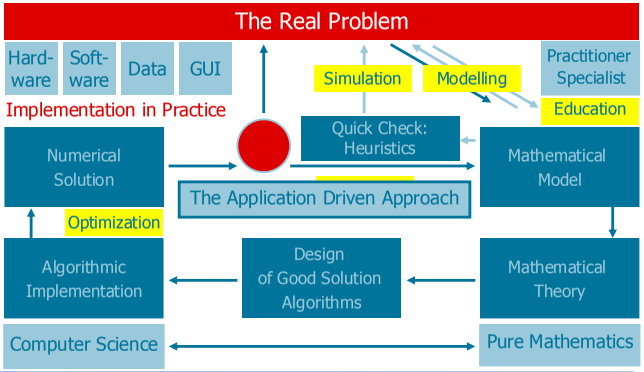
51

The big triple

- Modelling
- Simulation
- Optimization

- MSO (new buzz word/abbreviation, in particular used in applied mathematics)

The problem solving cycle



Mathematical Modelling: What is that?

Beginning with observations

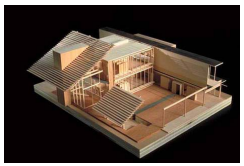
- of our environment
- a problem in practice of particular interest or
- a physical, chemical, or biological phenomenon

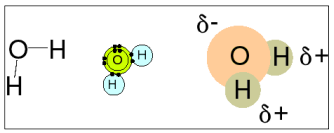
and with guiding/tailored experiments:

the attempt of a formal representation via „mathematical concepts" (variables, equations, inequalities, objective functions , etc.), aiming at the utilization of mathematical theories and tools.

Confusion: There are many other ways of modelling

- computer models
- business model
- architectural models
- chemical models
- medical models
- ...





Simulation

Simulation, Simulator or simulate are derived from the latin words ***simulare*** and ***similis*** .

They mean: pretend to be or the same sort.

Simulation

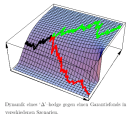
„Computation" of several (close to reality) variants of a mathematical modell aimimg at:

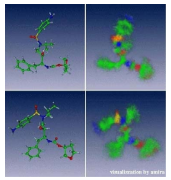
- „validation"of the correctness of a model
- investigation of typical instances in the model framework, e.g., to avoid experiments or to test some functionality (crash-test)
- good predictions (weather)
- computation of reasonable solutions for the control of a system in practice (control of transport and logistics-systems)

Simulation

Computation of instances varying several parameters

Parameters of a car crash test, e.g.:
speed, material stiffness, various angles





3D-reconstruction of a scull from a magneto-resonance tomografic investigation

Kalyanmoy Deb: The great confusion

From his book: „Multi-objective optimization using evolutionary algorithms" (Wiley, 2001)

Preface
Optimization is a procedure of finding and comparing feasible solutions until no better solution can be found. (Really?)

Classical optimization methods can at best find one solution in one simulation run, thereby making those methods inconvenient to solve multi-objective optimization problems. (???)

Evolutionary algorithms (EAs), on the other hand, can find multiple optimal solutions in one single simulation run due to their population-approach. (True?) Thus, EAs are ideal candidates for solving multi-objective optimization problems. (Very convincing!)

Kalyanmoy Deb: The great confusion

From his book: „Multi-objective optimization using evolutionary algorithms" (Wiley, 2001)

Constraints are inevitable in any real-world optimization problem. (A deep observation)

In order to widen the applicability of an optimization algorithm in various different problem domains, natural and physical principles are mimicked to develop *robust* optimization algorithms. Evolutionary algorithms and simulated annealing are two examples of such algorithms. (Juggling words)

But I have learned about marketing: „powerful".

Examples

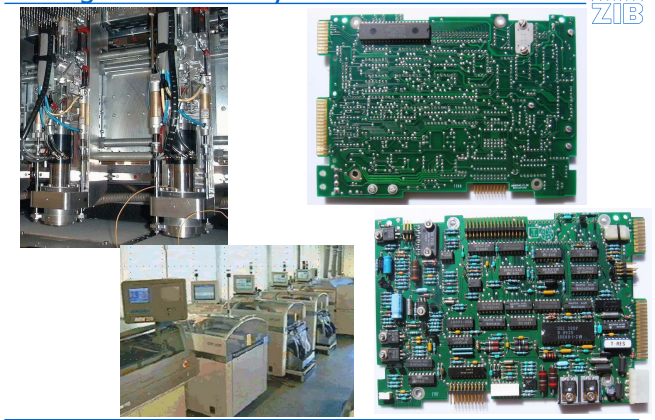
Almost all from ZIB projects

Herlitz at Falkensee (Berlin)

Optimization and control of transport devices (such as elevators, stacker cranes) in factories

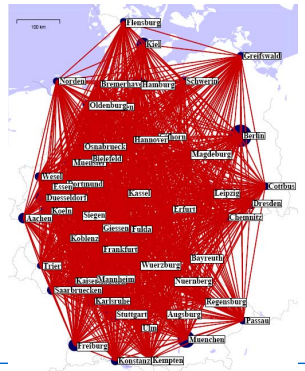
Herlitz, Falkensee

Printed Circuit Board: Drilling and Assembly Machines

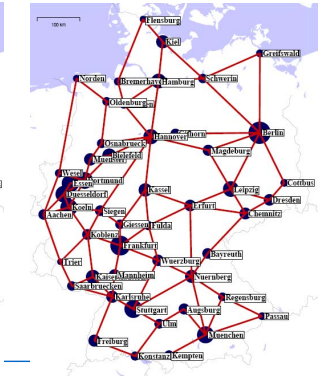


Telecommunication network design
MATHEON B3

Logical connections

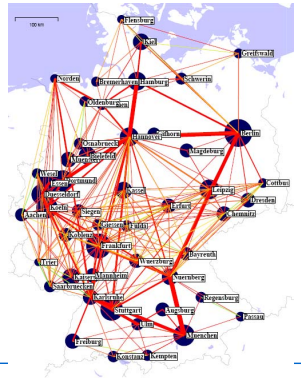


Physical connections



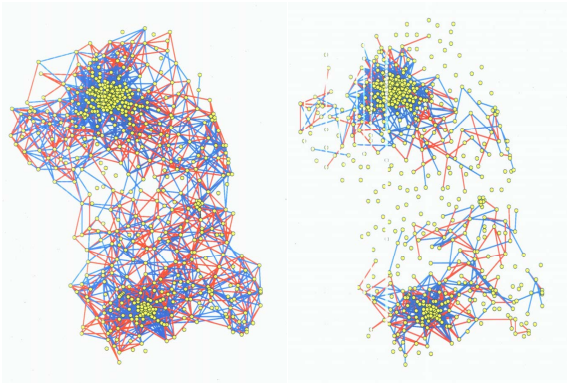
Network design
MATHEON B3

Logical connections: solution



Physical connections: solution

Region Berlin - Dresden



2877 carriers

50 channels

Interference reduction: 83.6%

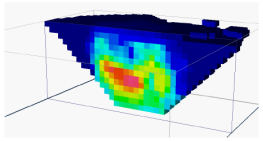
A Project with BHP Billiton

Production scheduling for an open pit mine with a stockpile

Goal Maximize net present value

Decisions
- Which block is mined when?
- What material is processed immediately?
- What material is stockpiled?
- What fraction of stockpile is processed when?

Constraints
- Block mining order
- Mining and processing capacities
- ***Mixing of material in stockpile***



Block model of an open pit mine
blue = low grade ore, red = high grade ore

Stockpiles at Yandi mine, Australia.

Cooperation

The University of Melbourne

University of New South Wales

BHP Billiton

Some TSP World Records

	year	authors	# cities	# variables
2006 pla 85,900 solved 3,646,412,050 variables	1954	DFJ	42/49	820/1146
	1977	G	120	7140
	1987	PR	532	141,246
number of cities 2000x increase	1988	GH	666	221,445
4,000,000 times problem size increase	1991	PR	2,392	2,859,636
	1992	ABCC	3,038	4,613,203
	1994	ABCC	7,397	27,354,106
	1998	ABCC	13,509	91,239,786
in ~60 years	2001	ABCC	15,112	114,178,716
	2004	ABCC	24,978	311,937,753
2005 W. Cook, D. Epsinoza, M. Goycoolea			33,810	571,541,145

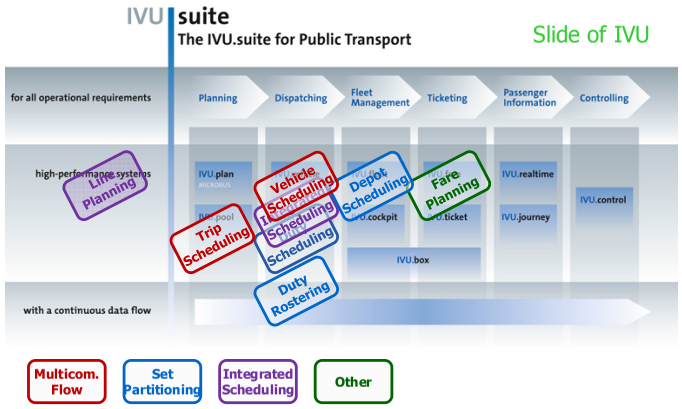
Telecommunication topics: Hardware and logistics (ZIB and MATHEON)

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

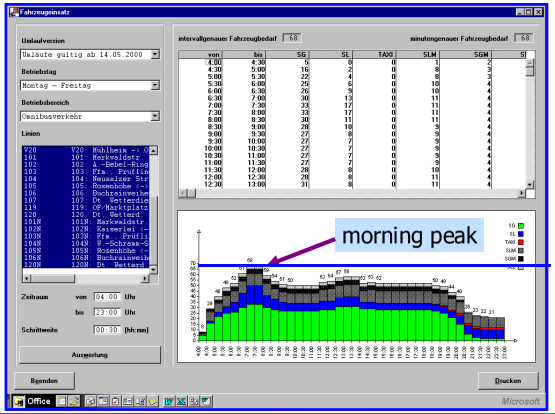
Producing Mobile Phones
- Production facility layout
- Control of CNC machines
- Control of robots
- Cutting and welding
- Printed Circuit Boards
  - Via minimization
  - Component Placement
  - Mounting Devices
  - Routing
- Lot sizing
- Scheduling
- Logistics

Marketing and Distribution of Mobile Phones

Optimization in Public Transit



Vehicle scheduling in public transport



Martin Grötschel 72

Public Transport Projects (ZIB and Matheon)

Busses (Berlin and elsewhere)
- Telebus (Transportation of disabled persons)
- Bus Circulation
- Bus driver Scheduling
- Integrated Vehicle and Driver Scheduling
- Timetable Exchange

Subways and Light Railways
- Subway Time Tabling
- Vehicle Scheduling

Infrastructure Planning
- Line Planing
- Network Planning (Potsdam)
- Fare Planing

Airlines
- Airline Crew Scheduling
- Tail Assignment: Robustness

Railways
- Railway Track Allocation
- ICE Circulation

Spin-Offs : LBW, Intranetz

Applications (general topics)

Areas with significant optimization demand:
- Industrial production (control of CNC machines, assembly line optimization, robot control,…)
- Mining (Scheduling, rock damage and fracture models, …)
- Health care & medicine (support for operations, drug design,…)
- Energy (optimization of energy production and mix, unit commitment,…)
- Resource planning (environmental issues,…)
- Financial mathematics (modelling of risk,…)
- Infrastructure planning (public transport, water, street, gas,… networks, harbor design)
- Agriculture (no personal experience, but …)
- Telecommunication
- Logistics & Traffic and Transport

I can go on forever

Is there more than optimization?

- Data (collecting data, making them correct, updating,…)
- Data security, privacy and long term archiving
- Today: Big data in all media
- Test problems
- Modeling Languages
- Decision Making: Decision Heuristics
- Psychology/Sociology
- Game Theory and Bounded Rationality
- Mechanism Design
- Safety

- Integration of different views

Contents

Failures of OR/Optimization

1. Inability to come up with a "good" name.
2. Inability to make the subject a trademark.
3. OR/Optimization remains "fuzzy" to the outsider.
4. OR virtually unknown in the public media.
5. Optimization has (at least in Germany) unwanted connotations (labor unions).
6. Promises of OR/Optimization made in the sixties and seventies could not be fulfilled. This led to the shut-down of many OR departments in industry and academia.
7. Too mathematically oriented optimizers (ignoring, e.g., data handling and psychology of the work force) still do not deliver.
8. Academic focus on publishable but practically irrelevant results (e.g. worst-case or average-case performance of heuristics).

Contents

1. Outline
2. Where do I come from?
3. Naming business — Opinions and Facts
4. What are OR and optimization? — Opinions and Facts
5. Success stories
6. Failures?
7. What should OR/optimization do?
8. Conclusions

Simple answers

Theory and algorithms

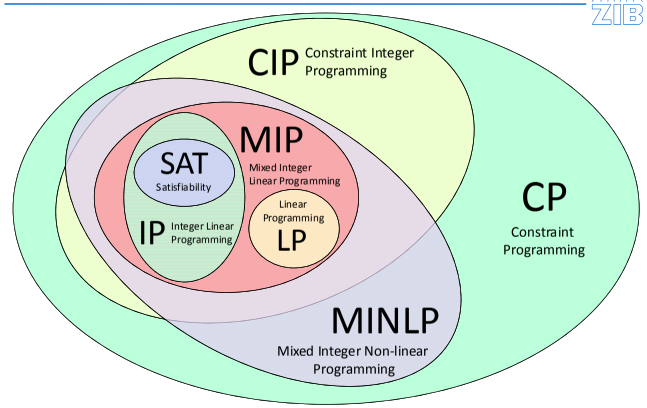
- Continue developing the mathematical solution technology. Integrate solution technologies, e.g.,
  - linear
  - nonlinear
  - combinatorial
  - integer
  - mixed-integer
  - stochastic
  - robust
  - online
  - real-time
  - multi-objective
  - uncertain and not necessarily reliable data
  - ...

Simple answers

Practice

- Focus on real and not on artificial problems.
- The world is full of exciting new unsolved questions.
- Cooperate with other disciplines: They all need us!
- All grand challenges have optimization aspects such as making best use of scarce resources. Participate in their solution!

Problem classes



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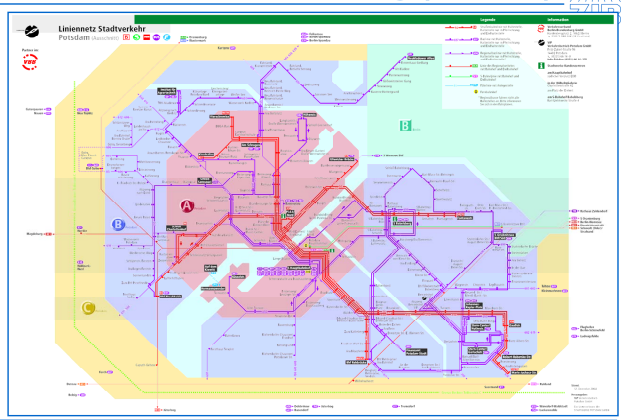
Network, Line and Fare Planning (Potsdam)



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Modelling Aspects of Gas Transportation

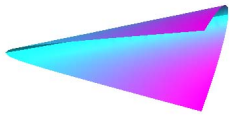
Nonlinear Nonconvex:

- Loss of pressure over pipes:

$$p_u^2 - p_v^2 = c q_{uv}^2$$

- Power of compressor:

$$f_{uv} = \gamma \left(\left(\frac{p_v}{p_u} \right)^{\frac{\kappa-1}{\kappa}} - 1 \right) q_{uv} \leq f_{uv}^{\max}$$



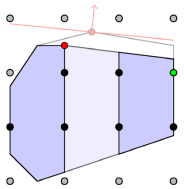
Mixed-Integer:

- Flow direction

$$s_{uv} = 0 \vee s_{vu} = 0$$

- Coupling constraints

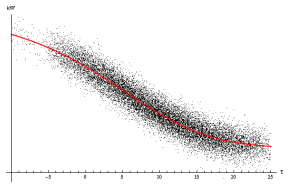
$$\begin{aligned} q_{uv} &\leq q_{uv}^{\max} s_{uv} \\ p_u - p_v &\leq M r_e + \overline{d_e} s_{uv} - \underline{d_e} s_{vu} \end{aligned}$$



Modelling Aspects of Gas Transportation

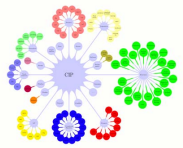
Uncertainty:

- Stochastic nomination at exits
- Unknown nomination at entries



Constraint Integer Programming:

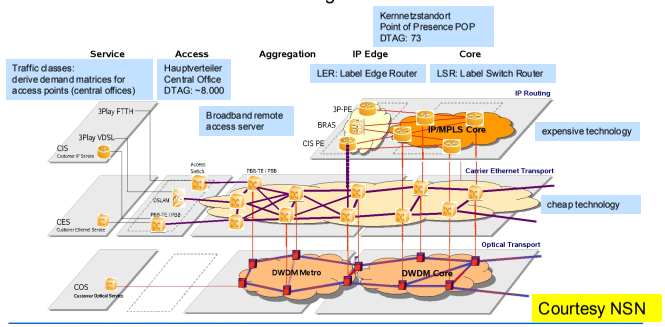
- combines SAT, MIP, and CP
  - ➢ strong modeling capability
  - ➢ full power of MIP solving techniques



Multi-layer multi-level Planning

Goal: Integration of multi-layer backbone and regional networks

- Future networks: IP/Ethernet layer over shared optical fiber layer
- Huge networks (900 nodes), combine different services/technologies
- More structure: hierarchical routing



Contributions to answering some HARD questions

What do I mean?

We should start addressing politically relevant "global questions" seriously.

High Quality Public Transportation:
Mathematical, Social, Political, and Business Aspects

What is a "good" public transportation system?

Can such a system result from deregulation?
How does one regulate/deregulate, e.g., the railway system of a country, properly?

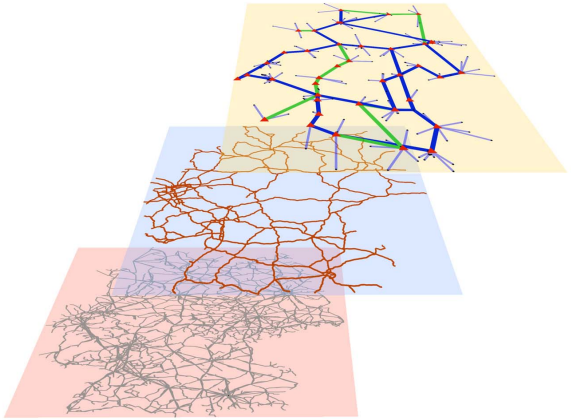
We are currently investigating such and related issues which are highly relevant for everybody's everyday life. There are more questions than answers.

Similar questions in

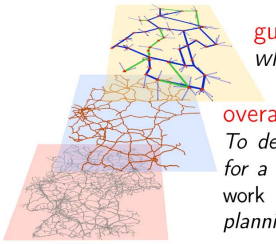
- Electricity production and distribution
- Gas transport
- In general: Energy
- Financial markets
- Political decision making (German voting system)
- Life sciences and health care

...

Networks



Networks: A MATHEON Vision



guiding question:
what constitutes a good network?

overall goal:
To develop theory, algorithms, and software for a new, advanced level of integrated network optimization *that addresses network planning problems as a whole.*

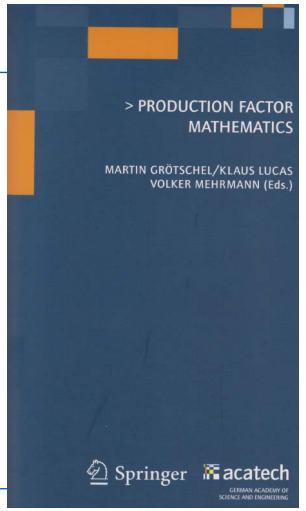
examples:

- line planning and timetabling in public transport
- fiber and UMTS telecommunication network design
- harbor and factory logistics

Networks: Industry Partners

OneSpin Solutions
DB
ViP Verkehrsbetrieb Potsdam GmbH
ILOG
Nokia Siemens Networks
PSI
HHLA
Lufthansa
atesio
Kollmorgen Steuerungstechnik
DFN Deutsches Forschungsnetz
IBM
T.A. Cook
PTV traffic mobility logistics.
e·on Gastransport

acatech German National Academy of Engineering 2010



Some big "OR stuff" that is not optimization

- Integration of approaches to modeling of problems and problem solving (engineering, management science, computer science, law,...)
- Big Data: "Data Science" is a new keyword that may cut significantly into the domain of OR
- Decision Making: Decision Heuristics/Mechanisms in Sociology Psychology and the Neuro Sciences

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PRESIDENT'S DESK

A rose by any other name

INFORMS President

Anne Robinson

Regardless, the universal appreciation and recognition of the power of applying our analytical toolbox for better decision-making is pervasive. The interest in mathematical modeling and creative applications of data (especially when the word "big" is used) is global. This invigorated interest is helping drive more students to learn our field, as well as greater leverage and application of operations research theory and practice. In the words of William Shakespeare, "A rose by any other name would smell as sweet."

Contents

Directions

I am myself a person preferring to address questions

- that can be quantified precisely
- that have clean data and
- that have clear objectives and
- that can be modeled nicely.

However, I think we should start addressing problems more seriously

- that can't be quantified precisely
- that don't have clean data and
- that don't have clear objectives and
- that can't be modeled nicely.

but that are of high political and social relevance.

OR/Opt has the potential for doing that and has begun to contribute to such issues!

Science in the View of the Public

I am concerned since I see downfalls of scientific fields such as nuclear technology that has made many promises and brought fear.

The same is presently happening to biotechnology (many people are simply afraid of the progress announced).

Similar tendencies are currently coming up in nano technology.

I see a beginning of a reduction of "trust in science".

OR/Optimization in the View of the Public

OR has to watch out that it keeps the right balance and people do not start getting afraid of OR and optimization.

I see tendencies in public talks of company bosses, politicians, journalists, and union leaders that optimization means nothing but eliminating jobs, cutting down services, etc.

My advice

- Don't care too much about definitions of OR and optimization and all the variations.
- Be flexible.
- Enjoy the stuff that you do.
- Position yourself depending on your own needs, goals, and wishes and that of your company or academic institution.
- And talk about what you are doing and how it impacts society and industry positively, not only to academic and industry people but also to the general public.

The OR/Optimization miracle

In my opinion, it is a miracle that OR/Optimization has survived so well through the last 60 years, having undergone many battles, splits, (re-)unifications and name changes. This is good sign for robust health and indicator for longevity of the field – independent of the name mutations.