SCIP

Solving Constraint Integer Programs

Timo Berthold

Zuse Institute Berlin

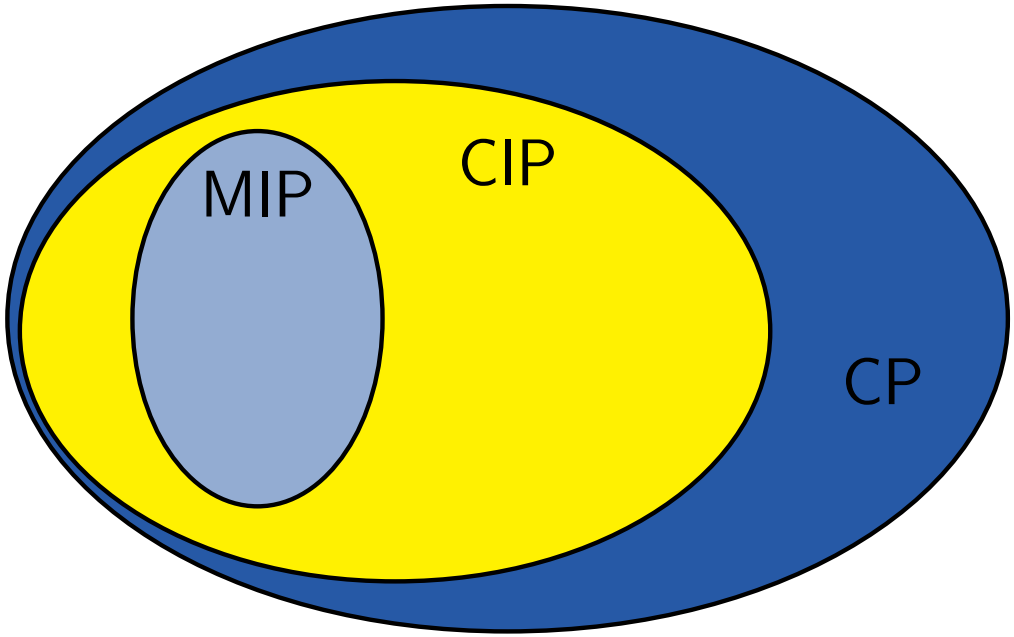
DFG Research Center MATHEON
Mathematics for key technologies

ZIB

Sino-German Workshop, ZIB, 19/Aug/2011

Constraint Integer Programming

- Mixed Integer Programming
- Constraint Integer Programming
- Constraint Programming

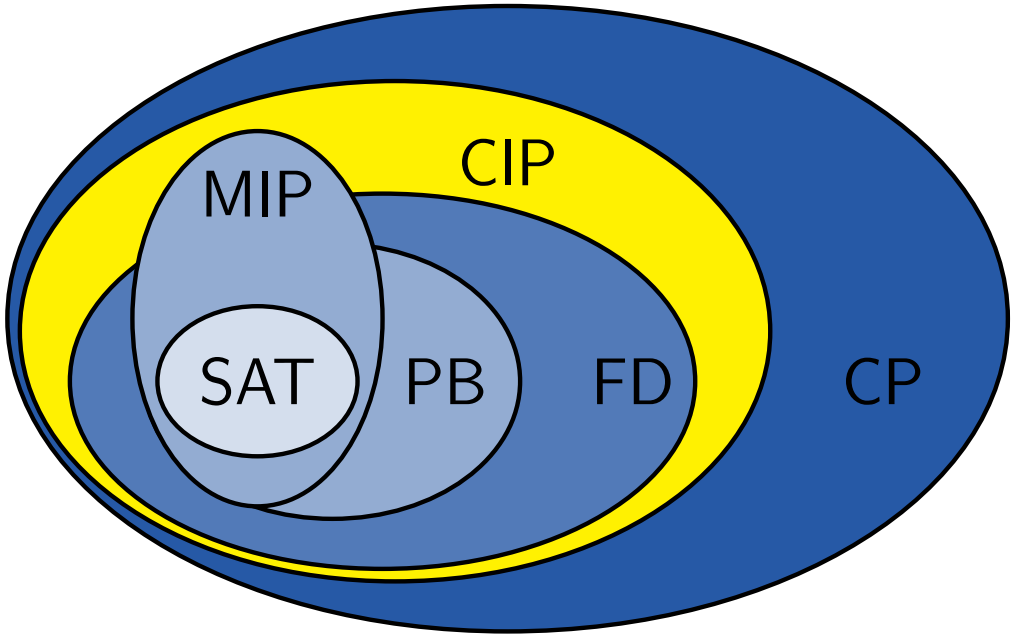


$$\begin{aligned} \min \quad & c^T x \\ s.t. \quad & x \in F \\ & (x_I, x_C) \in \mathbb{Z}^I \times \mathbb{R}^C \end{aligned}$$

- linear objective
- "general" constraints
- integer or real variables

Constraint Integer Programming

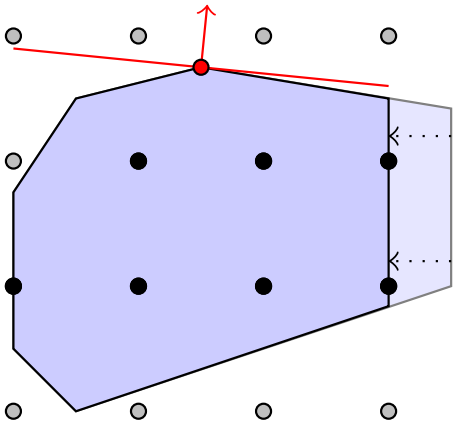
- Mixed Integer Programming
- Constraint Integer Programming
- Constraint Programming
- SATisfiability Testing
- Pseudo-Boolean Optimization
- Finite Domain



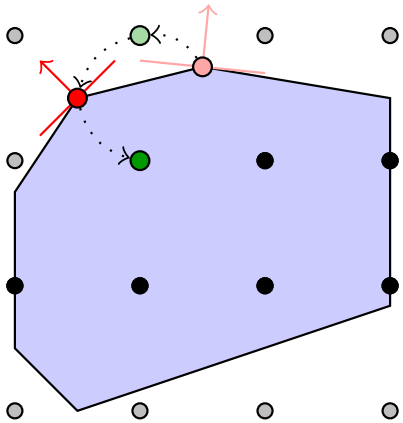
$$\begin{aligned} \min \quad & c^T x \\ s.t. \quad & x \in F \\ & (x_I, x_C) \in \mathbb{Z}^I \times \mathbb{R}^C \end{aligned}$$

- linear objective
- "general" constraints
- integer or real variables

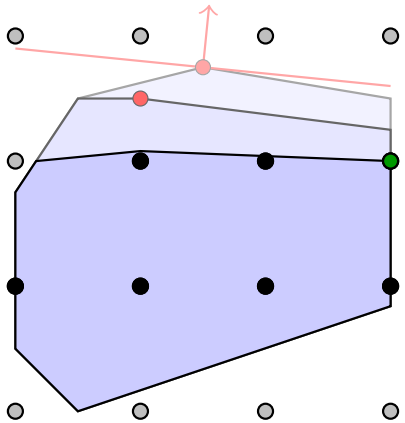
Presolving



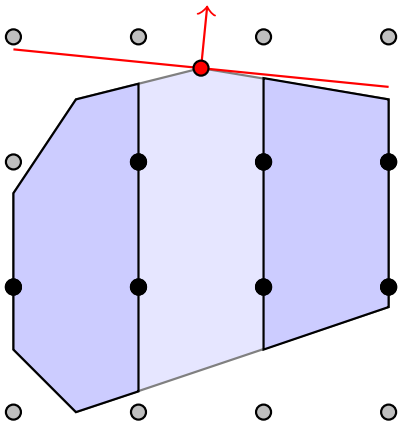
Primal heuristics



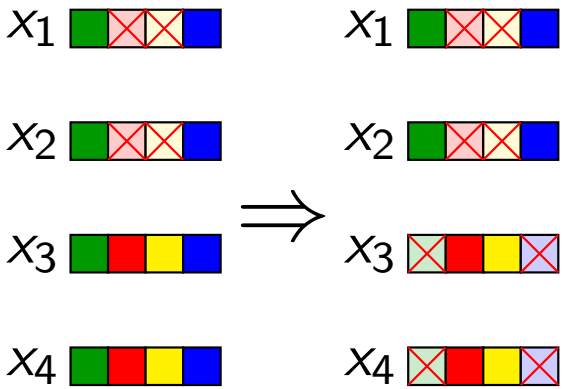
Cutting planes



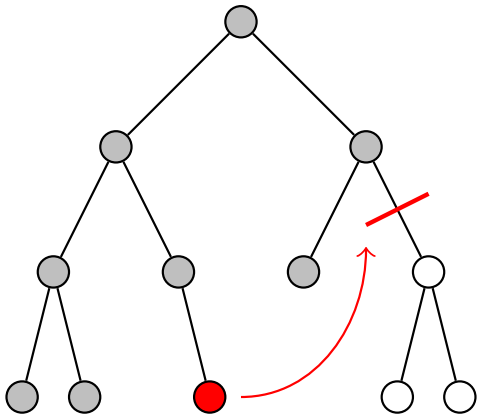
Branch & Bound



Domain propagation



Conflict analysis



How do we solve CIPs?

MIP

- LP relaxation
- cutting planes

CP

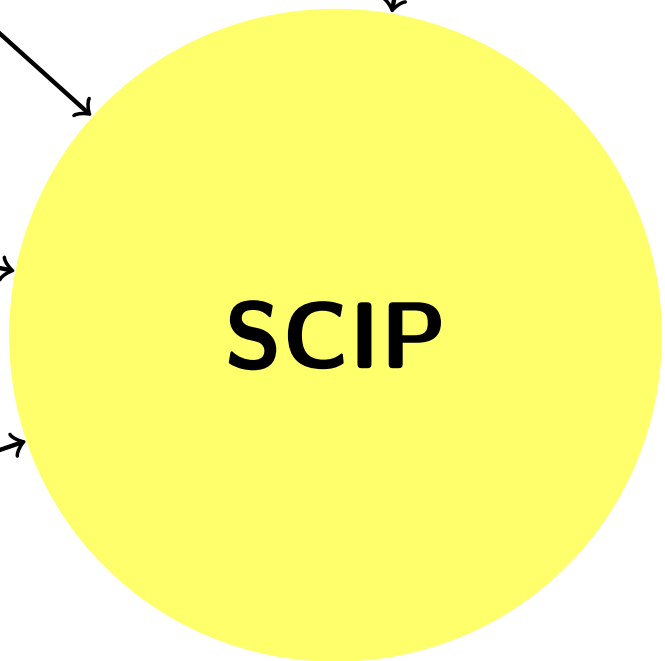
- domain propagation

SAT

- conflict analysis
- periodic restarts

MIP, CP, and SAT

- tree search algorithms



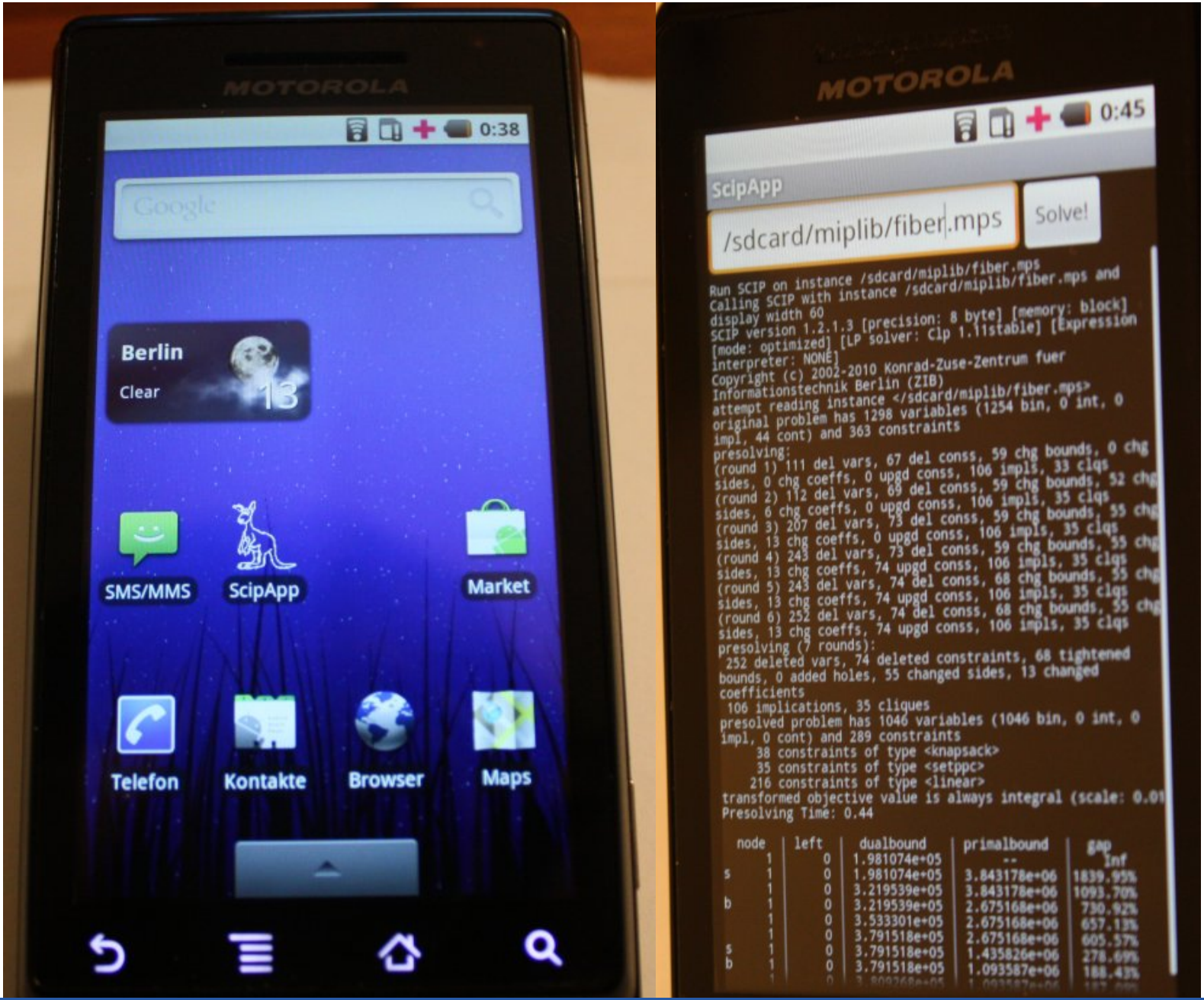
SCIP Facts

- more than 300 000 lines of C code
  → 18% documentation, 20% assertions
- 7 examples illustrating the use of SCIP
- HowTos: each plugin type, debugging, automatic testing, ...
- C++ wrapper classes, python interface (beta), Java

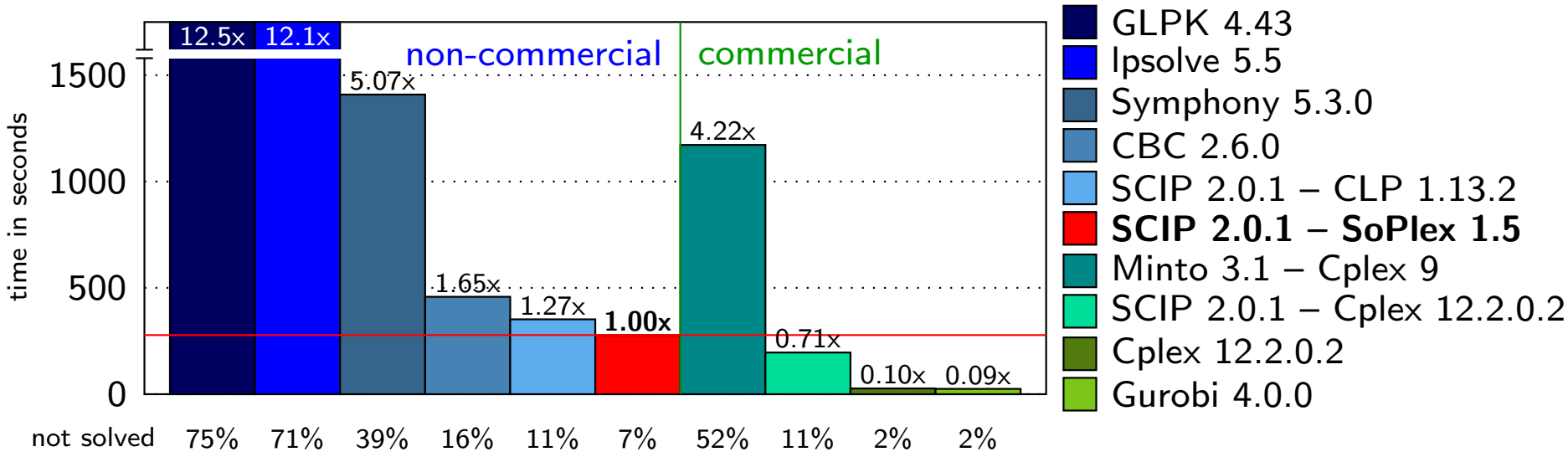
- supports 10 different input formats
- 7 interfaces to external LP solvers
- more than 1000 parameters, 15 "emphasis" settings
- active mailing list (180 members)
- 5000 downloads per year

- free for academics, available in source code: http://scip.zib.de
- runs on Linux, Windows, Mac (Darwin+PPC), SunOS, ...

New: SCIP to go



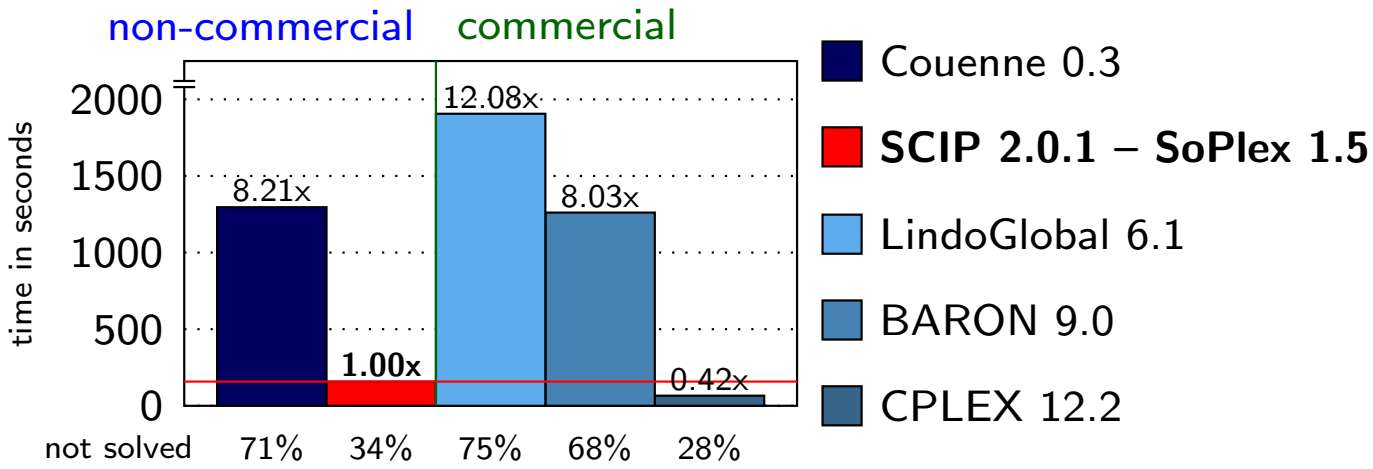
- fastest non-commercial MIP solver



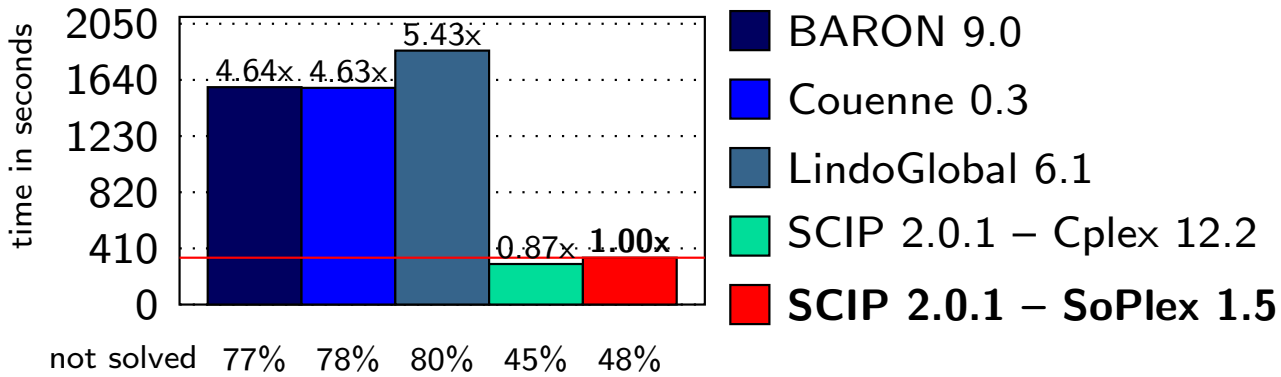
results by H. Mittelmann (16.1.2011)

- winner of "Pseudo-Boolean Competition" 2009, 2010, and 2011

▷ fastest noncommercial solver for convex MIQCPs



▷ fastest MIQCP solver (non-convex)



ZIB Optimization Suite = SCIP + SoPlex + ZIMPL

Toolbox for generating and solving constraint integer programs

ZIMPL

- a mixed integer programming modeling language
- easily generating LPs, MIPs, and MIQCPs

SCIP

- a MIP and CP solver, branch-cut-and-price framework
- ZIMPL models can directly be loaded into SCIP and solved

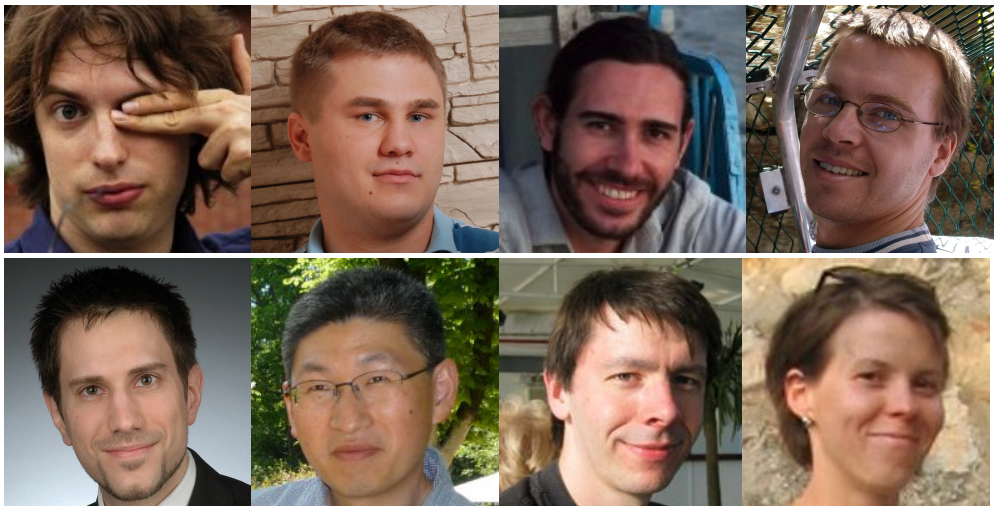
SoPlex

- a linear programming solver
- SCIP uses SoPlex as underlying LP solver

LP/IP team

- Tobias Achterberg (IBM)
- Thorsten Koch
- Marc Pfetsch (TU Braun.)

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



- Gregor Hendel
- Alexandra Kraft
- Michael Winkler

History of SCIP

1996 SoPlex – Sequential obj. simPlex (R. Wunderling [now IBM])

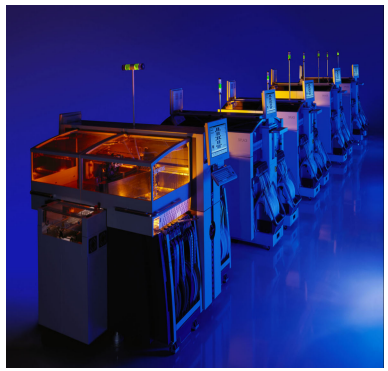
1998 SIP – Solving Integer Programs (A. Martin [now U Erlangen])

Longstanding Cooperation with department
Modeling, Simulation, Optimization

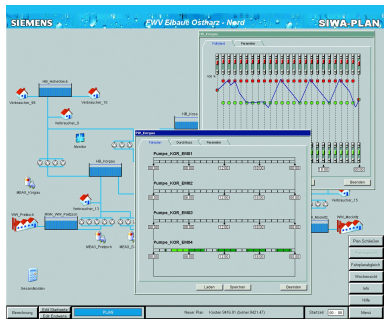
SIEMENS

- first licensee (1996) of SoPlex
- steady use in various optimization modules

placement robots in
circuit board production



optimal planning of
water networks



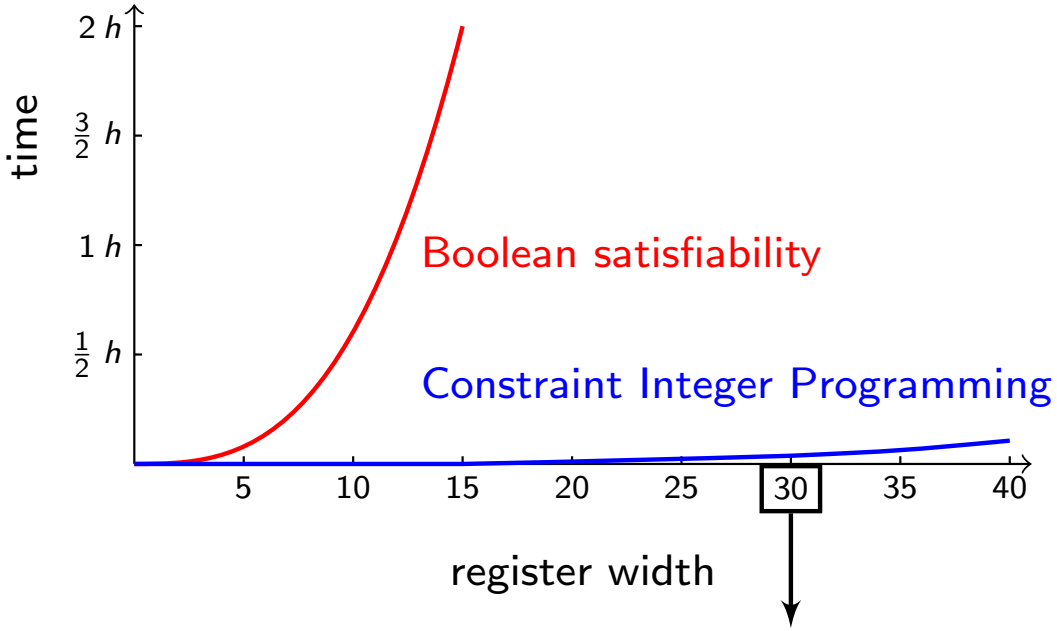
History of SCIP

1996	SoPlex – Sequential obj. simPlex (R. Wunderling [now IBM])
1998	SIP – Solving Integer Programs (A. Martin [now U Erlangen])
10/2002	Start of SCIP development (T. Achterberg [now IBM])
08/2003	Chipdesign verification $\Rightarrow$ Constraint Programming

Goal: (computer-)proof, that a design is free of errors

Method: property checking using CIPs

Result:



constraints	422	152026
variables	3714	50756

Infineon technologies

OneSpin SOLUTIONS

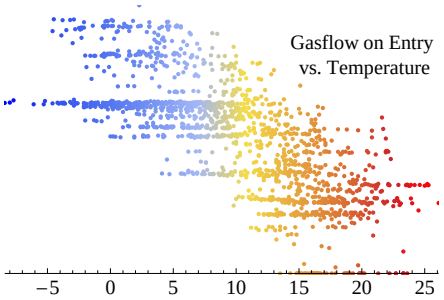
Duration: 2003-2008

History of SCIP

1996	SoPlex – Sequential obj. simPlex (R. Wunderling [now IBM])
1998	SIP – Solving Integer Programs (A. Martin [now U Erlangen])
10/2002	Start of SCIP development (T. Achterberg [now IBM])
08/2003	Chipdesign verification $\Rightarrow$ Constraint Programming
09/2005	First public version 0.80
09/2007	Version 1.00, ZIB Optimization Suite
01/2009	Gas transport optimization $\Rightarrow$ nonlinear

Optimization of gastransport

Stochastic Mixed-Integer Nonlinear Constraint Program



over a **large** network.

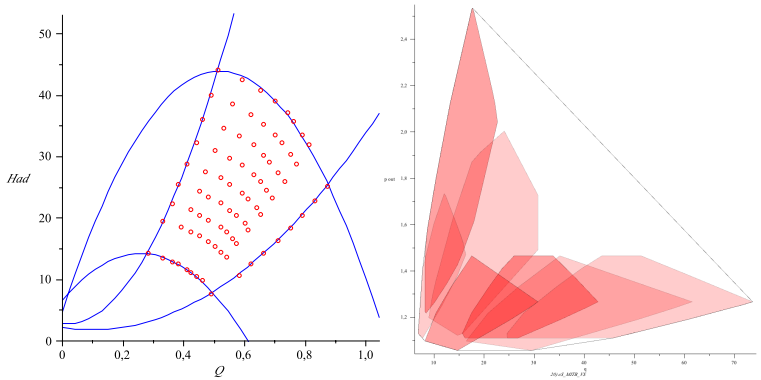
Start: 01/2009

Goal:

- develop algorithms to solve such problems to "global optimality"!

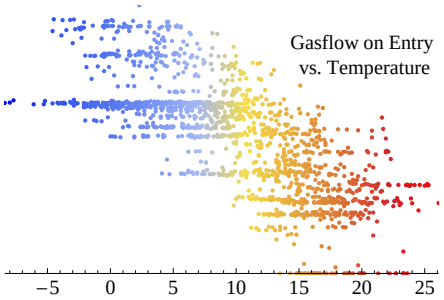
Industry partner:

Open Grid Europe
The Gas Wheel



Optimization of gastransport

Stochastic Mixed-Integer Nonlinear Constraint Program



over a **large** network.

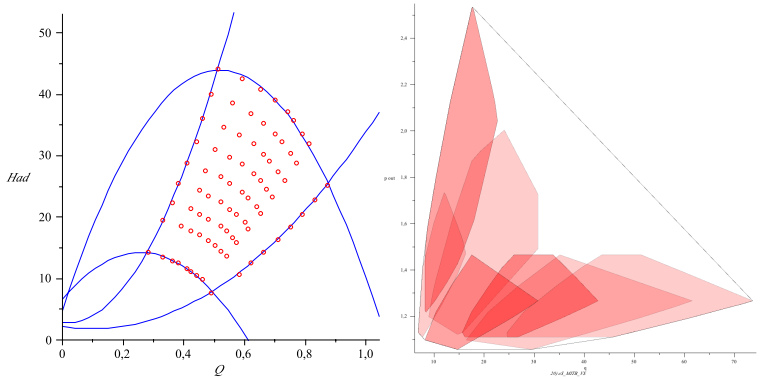
Start: 01/2009

Goal:

- develop algorithms to solve such problems to "global optimality"!
- rather: attempt to integrate as many aspects as possible

Industry partner:

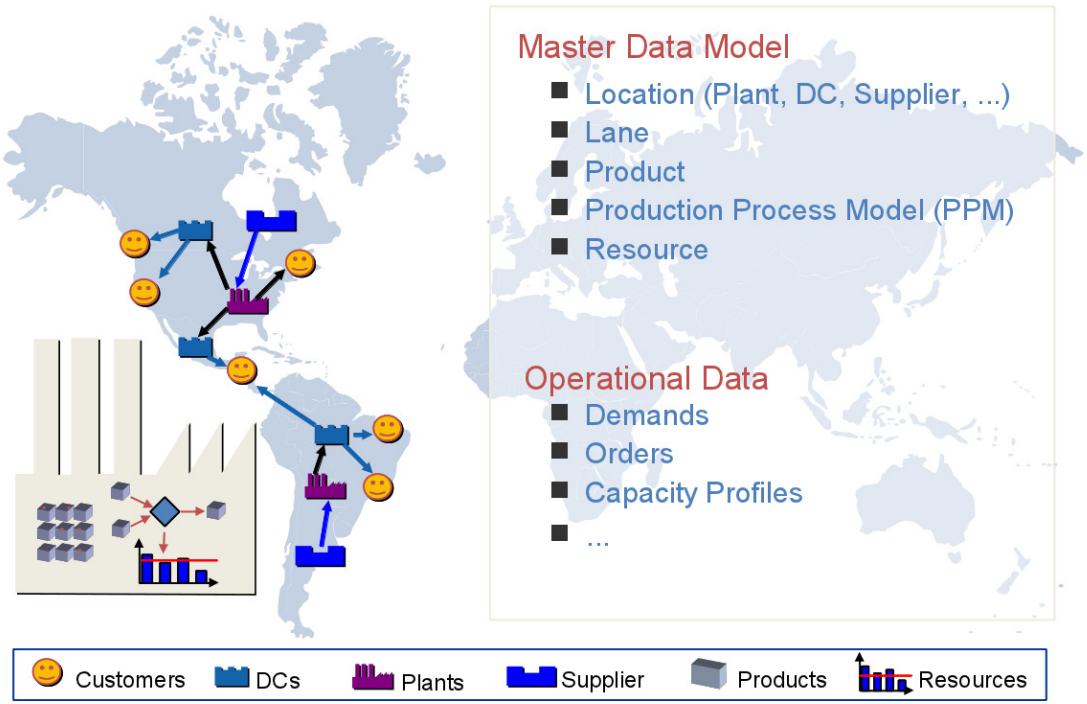
Open Grid Europe
The Gas Wheel



History of SCIP

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 IBM])
08/2003	Chipdesign verification $\Rightarrow$ Constraint Programming
09/2005	First public version 0.80
09/2007	Version 1.00, ZIB Optimization Suite
01/2009	Gas transport optimization $\Rightarrow$ nonlinear
09/2009	Beale-Orchard-Hays Prize (T. Achterberg)
07/2010	Supply-Chain-Management $\Rightarrow$ extrem große LPs/MIPs

Huge, numerically challenging problems



Start: 07/2010

Topics:

- LP solver
- presolving
- numerical stability
- multi-level objective

Industry partner:

History of SCIP

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 IBM])
08/2003	Chipdesign verification $\Rightarrow$ Constraint Programming
09/2005	First public version 0.80
09/2007	Version 1.00, ZIB Optimization Suite
01/2009	Gas transport optimization $\Rightarrow$ nonlinear
09/2009	Beale-Orchard-Hays Prize (T. Achterberg)
07/2010	Supply-Chain management $\Rightarrow$ extremely large LPs/MIPs
12/2010	Google Research Award 2011
01/2011	Version 2.0.1

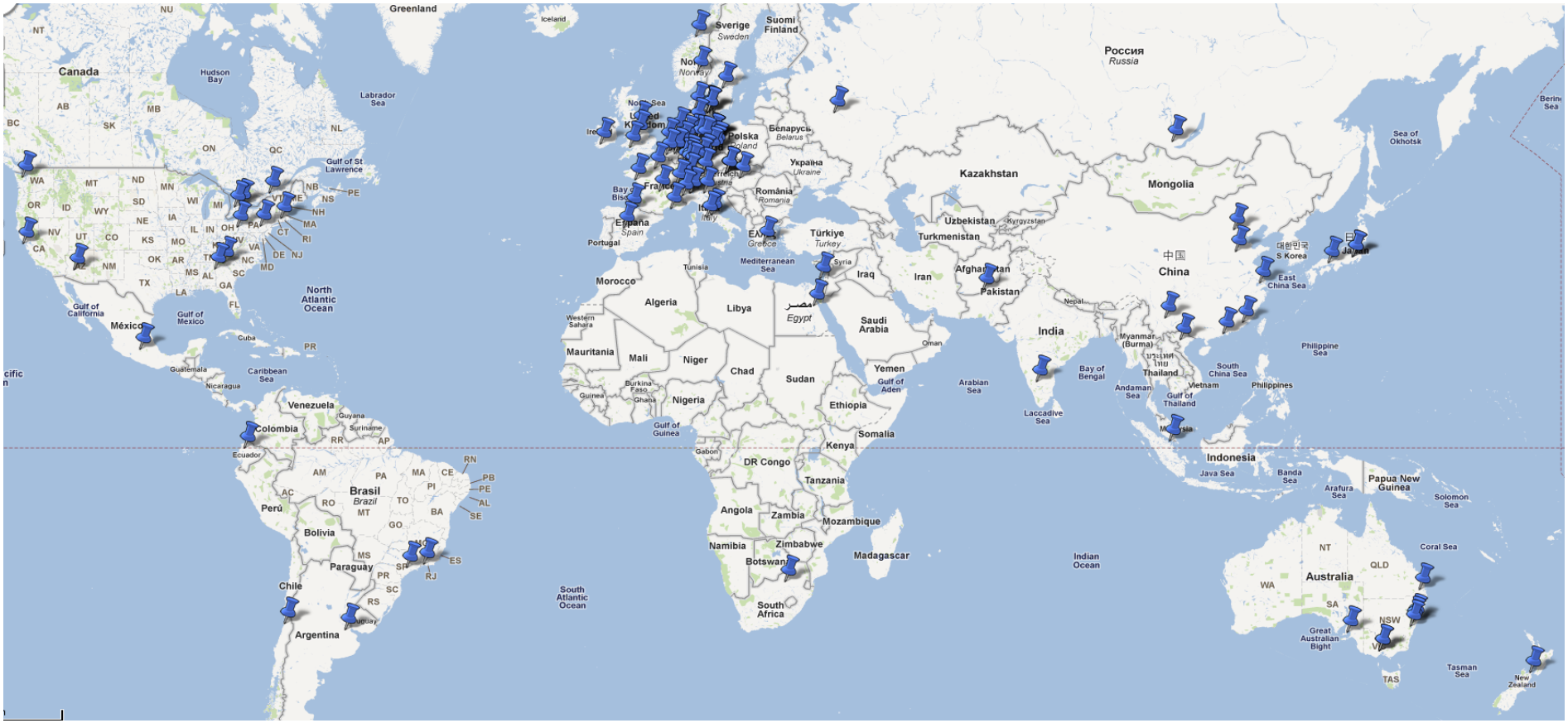
History of SCIP

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 IBM])
08/2003	Chipdesign verification $\Rightarrow$ Constraint Programming
09/2005	First public version 0.80
09/2007	Version 1.00, ZIB Optimization Suite
01/2009	Gas transport optimization $\Rightarrow$ nonlinear
09/2009	Beale-Orchard-Hays Prize (T. Achterberg)
07/2010	Supply-Chain management $\Rightarrow$ extremely large LPs/MIPs
12/2010	Google Research Award 2011
01/2011	Version 2.0.1
10/2011	Version 2.1.0

Outreach

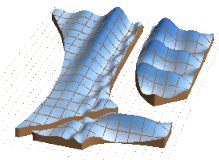
- RWTH Aachen
- Universität Bayreuth
- FU Berlin
- TU Berlin
- HU Berlin
- WIAS Berlin
- TU Braunschweig
- TU Chemnitz
- TU Darmstadt
- TU Dortmund
- TU Dresden
- Universität Erlangen-Nürnberg
- Leibniz Universität Hannover
- Universität Heidelberg
- Fraunhofer ITWM Kaiserslautern
- Universität Karlsruhe
- Christian-Albrechts-Universität zu Kiel
- Hochschule Lausitz
- OvGU Magdeburg
- TU München
- Universität Osnabrück
- Universität Stuttgart
- Aarhus Universitet
- The University of Adelaide
- Università dell'Aquila
- Arizona State University
- University of Assiut
- National Technical University of Athens
- Georgia Institute of Technology
- Indian Institute of Science
- Tsinghua University
- UC Berkeley
- Lehigh University
- University of Bristol
- Eötvös Loránd Tudományegyetem
- Universidad de Buenos Aires
- Institut Français de Mécanique Avancée
- Chuo University
- Clemson University
- University College Cork
- Danmarks Tekniske Universitet
- Syddansk Universitet
- Fuzhou University
- Jinan University
- Rijksuniversiteit Groningen
- Hanoi Institute of Mathematics
- The Hong Kong Polytechnic University
- University of Hyogo
- The Irkutsk Scientific Center
- University of the Witwatersrand
- Københavens Universitet
- Kunming Botany Institute
- École Poly. Fédérale de Lausanne
- Linköpings universitet
- Université catholique de Louvain
- Universidad Rey Juan Carlos
- Université de la Mediterranée Aix-Marseille
- University of Melbourne
- UNAM
- Politecnico di Milano
- Università degli Studi di Milano
- Monash University
- Ikerlan
- Université de Montréal
- NIISI RAS
- Université de Nantes
- The University of Newcastle
- University of Nottingham
- Universitetet i Oslo
- Università degli Studi di Padova
- L'Université Sud de Paris
- Brown University
- The University of Queensland
- IASI CNR
- Erasmus Universiteit Rotterdam
- Carnegie Mellon University
- Universidad Diego Portales
- University of Balochistan
- Universidad San Francisco de Quito
- Universidade Federal do Rio de Janeiro
- Universidade de São Paulo
- Fudan University
- University of New South Wales
- Tel Aviv University
- The University of Tokyo
- Politecnico di Torino
- University of Toronto
- NTNU i Trondheim
- The University of York
- University of Washington
- University of Waterloo
- Massey University
- Austrian Institute of Technology
- TU Wien
- Universität Wien
- Wirtschaftsuniversität Wien
- ETH Zürich

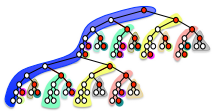
Some universities and institutes using SCIP:



Current Topics:

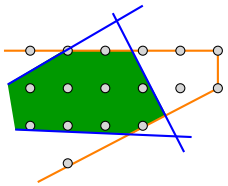
- non-convex constraints
- massive parallelization ($\rightarrow$ HLRN)
- improvements in column generation
- development of a new LP solver

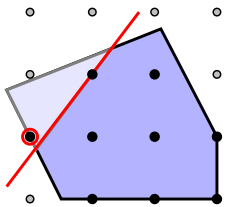


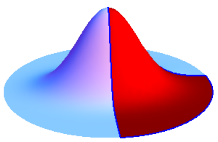


Research projects:

- exact integer programming
  (DFG priority program "Algorithm Engineering")
- mixed-integer nonlinear programming
  (MATHEON project B20)
- solver technologies for supply chain management







SCIP

Solving Constraint Integer Programs

Timo Berthold

Zuse Institute Berlin

DFG Research Center MATHEON
Mathematics for key technologies

ZIB

Sino-German Workshop, ZIB, 19/Aug/2011