

# **MIP: The State of the Art**

## **Recent Benchmarks of Optimization Software**

Presenting Author: Hans D. Mittelmann

## **What do the numbers mean? Issues in Benchmarking**

Presenting Author: Tobias Achterberg

## **Solving Hard Mixed-Integer Programming Problems**

Presenting Author: Alkis Vazacopoulos

## **Performance of COIN-OR Solvers for the Solution of MINLPs using GAMS**

Presenting Author: Stefan Vigerske

# Recent Benchmarks of Optimization Software

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## Services we provide

- Guide to Software: "**Decision Tree**"
- <http://plato.asu.edu/guide.html>
- Software Archive
- Software Evaluation: "**Benchmarks**"
- Archive of Testproblems
- Web-based Solvers (**40 percent of NEOS**)

We maintain the following NEOS solvers (8 categories)

Combinatorial Optimization \* CONCORDE [TSP Input]

Global Optimization \* ICOS [AMPL Input]

Linear Programming

\* bpmpd [AMPL Input][LP Input][MPS Input][QPS Input]

\* qsopt\_ex [LP Input][MPS Input]

Mixed Integer Linear Programming

\* FEASPUMP [AMPL Input][CPLEX Input][MPS Input]

\* SCIP [AMPL Input][CPLEX Input][MPS Input][ZIMPL Input]

Nondifferentiable Optimization \* condor [AMPL Input]

Semi-infinite Optimization \* nsips [AMPL Input]

Stochastic Linear Programming \* bnbs [SMPS Input]

\* DDSIP [LP Input][MPS Input]

We maintain the following NEOS solvers (cont.)

### Semidefinite (and SOCP) Programming

- \* csdp [MATLAB\_BINARY Input] [SPARSE\_SDPA Input]
- \* penbmi [MATLAB Input] [MATLAB\_BINARY Input]
- \* pensdp [MATLAB\_BINARY Input] [SPARSE\_SDPA Input]
- \* sdpa [MATLAB\_BINARY Input] [SPARSE\_SDPA Input]
- \* sdpa-c [MATLAB\_BINARY Input] [SPARSE\_SDPA Input]
- \* sdplr [MATLAB\_BINARY Input] [SDPLR Input] [SPARSE\_SDPA Input]
- \* sdpt3 [MATLAB\_BINARY Input] [SPARSE\_SDPA Input]
- \* sedumi [MATLAB\_BINARY Input] [SPARSE\_SDPA Input]

## NEOS solver usage statistic for 2007 (1/1-5/31)

- **BPMPD 5359**
- **SCIP 3842**
- **FEASPUMP 1504**
- **QSOPT-EX 487**
- **CONCORDE 472**

## NEOS solver usage statistic for 2007 (1/1-5/31)

- **SDPT3 252**
- **BNBS 103**
- **SEDUMI 92**
- **SDPA 90**
- **NSIPS 83**

## NEOS solver usage statistic for 2007 (1/1-5/31)

- **CSDP 69**
- **SDPLR 45**
- **CONDOR 27**
- **ICOS 27**
- **SDPA-C 19**

# Overview of Talk

- **Current and the Discrete Benchmarks**
  - Concorde-TSP with different LP solvers
  - Parallel CPLEX on MIP problems
  - Feasibility Benchmark
  - MILP benchmark (free codes)
  - MI(Q)QP Benchmark
- Conclusions

## SERIAL vs PARALLEL OPTIMIZATION

Parallel CSDP on SDP problems (8-22-2006)

\* Parallel CPLEX on MIP problems (5-20-2007)

Parallel CPLEX and MOSEK on LP problems (5-24-2007)

## COMBINATORIAL OPTIMIZATION

\* Concorde-TSP with different LP solvers (6-4-2007)

## LINEAR PROGRAMMING

Benchmark of commercial LP solvers (7-12-2006)

Benchmark of free LP solvers (8-3-2006)

## NONLINEAR PROGRAMMING

Benchmark of commercial and other (QC)QP Solvers (1-5-2007)

AMPL-NLP Benchmark, IPOPT, KNITRO, LOQO, PENNLP & SNOPT (5-3-2007)

## SEMIDEFINITE/SQL PROGRAMMING

Several SDP-codes on SDP problems with free variables (10-17-2006)

Several SDP codes on problems from SDPLIB (7-19-2006)

SQL problems from the 7th DIMACS Challenge (8-8-2002)

Newer SDP/SOCP-codes on the 7th DIMACS Challenge problems(1-11-2007)

Several SDP codes on sparse and other SDP problems (7-19-2006)

SOCP (second-order cone programming) Benchmark (1-9-2007)

## MIXED INTEGER LINEAR PROGRAMMING

\* MILP Benchmark - free codes (6-11-2007)

\* Feasibility Benchmark - FEASPUMP vs CPLEX (6-4-2007)

## MIXED INTEGER NONLINEAR PROGRAMMING

\* MI(Q)QP Benchmark (5-18-2007)

## PROBLEMS WITH EQUILIBRIUM CONSTRAINTS

MPEC Benchmark (1-4-2007)

## Important features of all our benchmarks

- Links to codes given
- Links to test problems given
- Links to full logfiles given

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4 Jun 2007

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Concorde-TSP Benchmark (excerpt)

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problem	Cplex-10.2	QSopt-1.0\$	GLPK-4.11	MOSEK-4.0.0.32
d1655	82	100	1360	98
f11400	1679	11368	2518	440
f13795	9335	>50000		5320
nrv1379	78	126	462	144
pcb3038	14876	33706		32000
r11304	63	112	>64000	185
r11889	2788	6710	fail	8842
r15934	93320	>750000		
vm1748	344	536	2030	1001

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20 May 2007

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Parallel CPLEX on MIP problems  
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Logiles at [http://plato.asu.edu/ftp/ser\\_par\\_logs/](http://plato.asu.edu/ftp/ser_par_logs/)

CPLEX-10.1 was run in default mode on a single and on a two-processor 2.4GHz Opteron (64-bit, Linux), on a 2.2GHz dual-core Opteron, as well as on 1, 2, 4 processors of a 2.667GHz Intel Core 2 Quad (64-bit, Linux) on problems from

<http://plato.asu.edu/ftp/milpf.html>

<http://plato.asu.edu/ftp/miqp.html>

Times given are elapsed CPU times in seconds.

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Parallel CPLEX on MILP problems  
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elapsed CPU sec on AMD Opteron resp Intel Core2 (64-bit, Linux)

"c": problem convex

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problem c Opter-1 Opter-2 0-dual Intel-1 Intel-2 Intel-4  
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bienst2	y	2529	608	762	2576	500	259
lrn	y	114	85	356	88	78	29
mas74	y	897	441	483	709	325	176
neos13	y	2073	1694	2266	1181	894	897
neos5	y	1169	>40000		1014	17145	21169
seymour1	y	669	449	526	409	227	184

Parallel CPLEX on MIQP and MIQP problems

problem	c	Opter-1	Opter-2	0-dual	Intel-1	Intel-2	Intel-4
ibienst1		2742	1330	1105	1863	579	374
inug08	y	7973	4761	10209	3185	1856	2133
iqap10		1679	457	687	693	233	211
isqp	y	4755	2824	8827	1467	965	2059
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ibienst1		3132	1878	2644	3221	579	257
imisc07		6460	3255	3445	4739	2374	1188
imod011	y	7348	9463	10014	4536	4552	4540
inug06-3rd	y	6588	6890	7833	3589	3521	3348
inug08	y	4221	2336	2768	2377	1319	872
iran13x13		8756	3876	4278	6941	3070	1459
CLay0304M	y	1278	630	1329	970	488	247
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10 Jun 2007           =====

                          Feasibility Benchmark - Feaspump vs CPLEX

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

CPLEX-10.2: <http://www.ilog.com/cplex/>

  "h"/"f": emphasis on hidden feasible solutions/feasibility

FEASPUMP: [www.or.deis.unibo.it/research\\_pages/ORcodes/FP-gen.html](http://www.or.deis.unibo.it/research_pages/ORcodes/FP-gen.html)

  "ab"/"bfl": Achterberg-Berthold/Bertacco-Fischetti-Lodi variants

  free use at NEOS: <http://neos.mcs.anl.gov/> (utilizes CPLEX)

Times given are user times in seconds. Time limit of 2 hrs.

Column "o" indicates the ranking wrt quality of the objective.

Cases for which at least one code needed more than 300 seconds.

## Feasibility Benchmark

problem	CPLEX-h	o	CPLEX-f	o	FP-ab	o	FP-bf1	o
atlanta-ip	3279	1	429	2	35	3	78	4
core4284-1064	54	2	58	2	344	1	109	4
core4872-1529	68	2	57	2	671	1	99	4
ds	12	1	15	1	-	-	-	-
germanrr	1368	2	107	3	118	1	6	4
momentum1	13	1	-	-	185	2	222	2
momentum2	-	-	-	-	12	1	3527	2
momentum3	-	-	-	-	2156	1	215	2
msc98-ip	3341	1	500	2	31	3	55	4
nag	6	2	6	1	378	4	530	4

### Feasibility Benchmark (continued)

problem	CPLEX-h	o	CPLEX-f	o	FP-ab	o	FP-bf1	o
neos16	676	4	557	1	392	3	223	2
neos19	43	1	268	2	133	3	56	4
neos-565672	62	1	73	1	168	3	173	4
neos-595904	-	-	-	-	5365	1	16	2
neos-595925	-	-	-	-	647	2	734	1
net12	4749	1	-	-	15	2	11	2
ns894236	-	-	738	1	289	1	144	1
ns894244	-	-	-	-	568	1	433	1
ns894324	34	1	33	1	364	1	1121	1
ns894786	-	-	-	-	3149	1	582	1

### Feasibility Benchmark (continued)

problem	CPLEX-h	o	CPLEX-f	o	FP-ab	o	FP-bf1	o
ns894788	-	-	-	-	2088	1	2877	1
ns897005	153	1	714	1	80	1	111	1
ns897642	6	2	7	2	571	1	18	2
ns903346	-	-	-	-	382	1	-	-
ns903616	3156	1	1240	1	365	1	452	1
NSR8K	340	1	434	1	-	-	988	2
protfold	19	1	331	2	67	4	97	2
ramos3	158	4	132	4	581	1	298	2
rd-rplusc-21	-	-	713	1	-	-	-	-
van	4116	3	-	-	285	2	47	1

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11 Jun 2007 =====  
Mixed Integer Linear Programming Benchmark (free codes)  
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The MPS-datafiles for all testcases are in one of

<http://miplib.zib.de/>

<http://plato.asu.edu/ftp/fctp/>

<http://coral.ie.lehigh.edu/mip-instances/>

<http://plato.asu.edu/ftp/milp/>

<http://www.ps.uni-sb.de/~walser/acc/acc.html>

<http://www.ieor.berkeley.edu/~atamturk/data/>

CBC-1.01: <https://projects.coin-or.org/Cbc>

GLPK-4.15: <http://www.gnu.org/software/glpk/glpk.html>

MINTO-3.1: <http://coral.ie.lehigh.edu/~minto/>

SCIP-0.90k/1.0: <http://scip.zib.de/>

SYMPHONY-5.1.3: <https://projects.coin-or.org/SYMPHONY>

CPLEX-10.2: (for comparison purposes; mipgap=0, absmipgap=1e-9)

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Mixed Integer Linear Programming Benchmark (free codes)  
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Solved of 67 total cases in 2 hrs on 3.2GHz P4:

SCIP-CPLEX:	66	
CPLEX:	64	
SCIP-SOPLEX:	56	
SCIP-CLP:	56	
CBC:	40	
MINTO:	30	(with CLP, with CPLEX: 39)
GLPK:	22	
SYMPHONY:	18	
LP_SOLVE;	13	

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Mixed Integer Linear Programming Benchmark (free codes)  
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63 cases solved by both CPLEX and SCIP-C  
 CPLEX faster by 5 or more: 20  
 SCIP-C faster by 5 or more: 4  
 SCIP-C faster: 10

39 cases solved by both CBC and SCIP-S  
 CBC faster by 3 or more: 9  
 SCIP-S faster by 3 or more: 14  
 SCIP-S faster: 25

CBC faster than MINTO: 17/20

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6 Jun 2007

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Mixed Integer (Q)QP Benchmark  
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MIQP cases from [http://plato.asu.edu/ftp/ampl\\_files/miqp\\_ampl/](http://plato.asu.edu/ftp/ampl_files/miqp_ampl/)  
also solved as MIQQP with

CPLEX-10.2: <http://www.cplex.com/>

Bonmin-0.1.2: <https://projects.coin-or.org/Bonmin>

(Bonmin: default hybrid algorithm. with Clp)

(B-OA-C: outer approx. with CPLEX)

FilMINT: currently only at NEOS

LaGO-0.3: <https://projects.coin-or.org/LaGO>

on a 2.4GHz Opteron (Linux). "t" > 3 hrs, "f" fail

Mixed Integer (Q)QP Benchmark (convex cases)

	QP				QQP			
problem	Bonmin	B-0A-C	CPLEX	FilMINT	Bonmin	B-0A-C	CPLEX	FilMINT
ibell3a	48	6	9	t	55	7	610	1600
ibienst1	1466	6163	2685	t	1285	5971	4146	t
icap6000	3315	52	14	1961	t	157	t	1065
ilaser0	f	27	753	f	f	56	t	f
imod011	7954	t	f	8134	t	t	8629	f
inug08	t	t	8514	f	t	t	4129	t
iqiu	389	t	421	1510	1528	t	t	2758
isqp0	(1)f	f	101	f	(2)f	f	t	f

(1) B-BB solves in 4408 s      (2) B-BB solves in 4485 s

Mixed Integer (Q)QP Benchmark (nonconvex cases)

problem	QP				QQP			
	Bonmin	B-OA-C	CPLEX		FilMINT	Bonmin	B-OA-C	CPLEX
iair04	3387	1039	182	2188	5475	1560	t	5151
iair05	1812	177	194	f	1628	127	t	1218
ieilD76	845	126	27	3122	1032	111	f	910
imas284	806	12	22	87	845	12	t	562
imisc07	974	3082	163	7627	1054	3260	6451	t
iqap10	5591	2123	1579	3691	9086	4949	f	t
iran13x13	3739	127	55	2515	4971	232	9140	2026
iran8x32	257	62	18	3680	546	211	t	5856
iswath2	(3)t	153	245	t	(4)t	141	f	t
ivalues	1396	t	f	t	1658	t	f	t

(3) B-QG solves in 3770 s

(4) B-OA solves in 4066 s

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Mixed Integer (Q)QP Benchmark
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- 25 MIQ(Q)P cases total
- MIQP cases solved:
  - CPLEX 21, Bonmin 17, FilmINT 10, LaGO 5
- MIQQP cases solved:
  - CPLEX 7, Bonmin 16, FilmINT 9, LaGO 4

## Conclusions

- Parallel CPLEX effective most of the time
- FEASPUMP stronger than CPLEX
- SCIP-CPLEX competitive for MILP with CPLEX except for speed
- SCIP-SOPLEX/CLP best free MILP solver, then CBC, MINTO
- BONMIN competitive with CPLEX for MIQP, stronger for MIQQP

**Thank you for your attention**