

# **Benchmark Updates in Integer and Nonlinear Programming**

INFORMS Annual Meeting  
*Washington, DC*  
*12-15 October 2008*

H. D. Mittelmann  
Dept of Math and Stats  
Arizona State University

## 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 (**35 percent of NEOS**)

We maintain the following NEOS solvers (8 categories)

Combinatorial Optimization \* CONCORDE [TSP Input]

Global Optimization \* ICOS [AMPL Input]

Linear Programming

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

Mixed Integer Linear Programming

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

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

\* qsopt\_ex [LP Input][MPS 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-gmp [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 10/1/07-9/30/08

- **SCIP 12990**
- **BPMPD 9405**
- **FEASPUMP 1971**
- **CONCORDE 1136**
- **QSOPT-EX 881**

## NEOS solver usage statistic for 10/1/07-9/30/08

- **SDPT3 391**
- **BNBS 387**
- **SDPA 277**
- **CONDOR 201**
- **CSDP 194**

## NEOS solver usage statistic for 10/1/07-9/30/08

- **PENBMI 189**
- **ICOS 148**
- **SDPLR 137**
- **NSIPS 110**
- **SEDUMI 85**

NEOS solver usage statistic for 10/1/07-9/30/08

- PENS DP **33**
- SDPA-GMP **14**
- DDSIP **6**



# 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(QC)QP Benchmark
- Conclusions

## SERIAL vs PARALLEL OPTIMIZATION

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

\* Parallel CPLEX on MIP problems (6-11-2008)

Parallel CPLEX and MOSEK on LP problems (8-10-2008)

## COMBINATORIAL OPTIMIZATION

\* Concorde-TSP with different LP solvers (8-20-2008)

## LINEAR PROGRAMMING

Benchmark of commercial LP solvers (8-23-2008)

Benchmark of free LP solvers (8-23-2008)

Large Network-LP Benchmark (commercial vs free) (8-21-2008)

## NONLINEAR PROGRAMMING

Benchmark of commercial and other (QC)QP Solvers (8-28-2008)

AMPL-NLP Benchmark, IPOPT, KNITRO, LOQO, PENNLP & SNOPT (8-28-2008)

## SEMIDEFINITE/SQL PROGRAMMING

Several SDP-codes on SDP problems with free variables (4-1-2008)

Several SDP codes on problems from SDPLIB (4-10-2008)

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

Newer SDP/SOCP-codes on the 7th DIMACS Challenge problems(4-7-2008)

Several SDP codes on sparse and other SDP problems (4-4-2008)

SOCP (second-order cone programming) Benchmark (8-15-2008)

## MIXED INTEGER PROGRAMMING

\* MILP Benchmark - free codes (10-4-2008)

\* Feasibility Benchmark - FEASPUMP vs CPLEX and SCIP (9-30-2008)

\* MI(QC)QP Benchmark (10-10-2008)

## PROBLEMS WITH EQUILIBRIUM CONSTRAINTS

MPEC Benchmark (5-2-2008)

## **Important features of all our benchmarks**

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

## Reasons for updates

- New commercial software
  - CPLEX-11.2 (SCIP, Feaspump, Bonmin, Concorde)
  - MOSEK 5.0.0.93, KNITRO-5.2
- New free software
  - CLP-1.8\*, CBC-2.2.\*, GLPK-4.3\*, SCIP-1.1
  - IPOPT-3.5.\*, SeDuMi (64-bit), Boncouenne
- New multicore hardware

## Benchmarks still in need of updates

- MINLP Benchmark, nonconvex/Boncouenne
- MINLP Benchmark, not only MIQCQP
- Benchmarks in new areas
  - Parallelism on Multicores (Matlab)
  - Compressive Sensing, other sparse optimization
  - Derivative free/nonsmooth optimization etc

# 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(QC)QP Benchmark
- Conclusions

20 Aug 2008

=====

Concorde-TSP Benchmark (excerpt)

=====

---

problem	Cplex-11.11	QSopt-1.0\$	GLPK-4.11	MOSEK-5.0.0.93
d1655	54	100	1360	131
f11400	403	11368	2518	1186
f13795	3520	>50000		28460
nrv1379	70	126	462	108
pcb3038	18941	33706		30643
r11304	86	112	>64000	152
r11889	1389	6710	fail	6082
u1817	31933			
vm1748	243	536	2030	799

---



# 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(QC)QP Benchmark
- Conclusions

11 Jun 2008

=====  
Parallel CPLEX on MIP problems  
=====

Logiles at [http://plato.asu.edu/ftp/ser\\_par\\_logs/](http://plato.asu.edu/ftp/ser_par_logs/)

CPLEX-11.1 was run in opportunistic and deterministic parallel modes on 4 and 8 processors of a dual-quad 2.2GHz Opteron (64-bit, Linux), as well as on 1, 2, 4 processors of a 2.667GHz Intel Core 2 Quad (64-bit, Linux) on problems from the benchmarks:

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

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

Times given are elapsed CPU times in seconds.

10 Apr 2008

=====  
Parallel CPLEX on MILP problems  
=====

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

=====

problem    Opt4o   Opt4d   Opt8o   Opt8d   Int1l   Int2o   Int2d   Int4o   Int4d

=====

bienst2	59	119	34	64	156	71	97	40	89
lrn	41	58	39	55	38	27	44	49	39
mas74	120	131	91	109	237	116	182	65	105
neos13	236	290	214	127	72	98	90	126	282
neos5	57	202	40	117	189	64	247	21	150
seymour1	91	123	67	101	166	100	114	65	84

=====

Parallel CPLEX on MIQP and MIQCQP problems ("c" convex)

problem	c	Opt4o	Opt4d	Opt8o	Opt8d	Int11	Int2o	Int2d	Int4o	Int4d
ibienst1		236	421	121	458	1174	453	584	295	298
inug08	y	1989	1852	1483	1695	3113	1632	1570	1732	1652
iqap10		350	480	347	543	664	191	222	179	267
isqp	y	1735	2029	1690	1954	1798	1061	1140	2193	2033
ibienst1		49	317	23	311	253	75	480	34	241
imisc07		40	113	42	57	110	75	236	48	76
imod011	y	3481	7705	3736	8021	5292	3822	5300	3123	5303
inug06-3	y	4301	6284	4211	6483	4317	3280	4371	3130	4280
inug08	y	2520	2007	1035	1559	2762	1576	1941	1068	1357
iran13x13		8	94	7	103	27	12	100	7	64

# 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(QC)QP Benchmark
- Conclusions

3 Oct 2008 =====  
Feasibility Benchmark - Feaspump vs CPLEX/SCIP  
=====

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

CPLEX-11.11: <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)

SCIP-1.1: <http://scip.zib.de/> (uses CPLEX for LP)

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

## Feasibility Benchmark (excerpt)

problem	CPLEX-h	CPLEX-f	FP-ab	FP-bf1	SCIP
atlanta-ip	251	786	22	23	184
core4872-1529	1	1	267	-	341
ds	1	1	-	-	35
germanrr	23	178	15	4	168
momentum1	1	1	17	20	-
momentum2	3488	260	37	-	1353
momentum3	2	2	252	-	-
msc98-ip	201	191	14	16	229
neos16	118	302	281	64	114
neos-506428	-	-	1958	237	1338

### Feasibility Benchmark (continued)

problem	CPLEX-h	CPLEX-f	FP-ab	FP-bf1	SCIP
neos-595925	3	1	991	142	5
net12	47	843	7	5	233
ns808444	515	-	45	2349	3207
ns894236	2585	1719	122	29	-
ns894244	3791	-	433	772	2890
ns894786	-	-	3331	-	-
ns894788	-	1696	93	15	-
ns897005	135	398	117	91	233
ns897642	6	5	399	19	118
ns903616	225	1126	136	76	-
ns930473	299	498	606	25	-



### Feasibility Benchmark (continued)

problem	CPLEX-h	CPLEX-f	FP-ab	FP-bf1	SCIP
ns1061051	540	1162	3	4	-
ns1116954	-	-	1131	188	6191
ns1208400	653	6887	2861	180	473
ns1219534	37	116	81	32	59
ns1405304	697	-	522	31	-
ns1425622	5830	339	43	8	11
ns1456591	3	-	118	-	1256
NSR8K	336	306	4468	643	3193
protfold	40	215	137	139	363
ramos3	1	1	330	271	68
rd-rplusc-21	139	21	595	682	216
van	1347	1216	650	388	486

# 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(QC)QP Benchmark
- Conclusions

4 Oct 2008 =====  
Mixed Integer Linear Programming Benchmark (free codes)  
=====

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-2.2.1: <https://projects.coin-or.org/Cbc>

GLPK-4.31: <http://www.gnu.org/software/glpk/glpk.html>

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

SCIP-1.1: <http://scip.zib.de/>

SYMPHONY-5.1.10: <https://projects.coin-or.org/SYMPHONY>

CPLEX-11.11: (for comparison purposes; mipgap=0, absmipgap=1e-9)

# 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(QC)QP Benchmark**
- Conclusions

10 Oct 2008

=====  
Mixed Integer (QC)QP Benchmark  
=====

MIQP cases from [http://plato.asu.edu/ftp/ampl\\_files/miqp\\_ampl/](http://plato.asu.edu/ftp/ampl_files/miqp_ampl/)  
also solved as MIQCQP with

CPLEX-11.2: <http://www.cplex.com/>

Bonmin-0.1.4: <https://projects.coin-or.org/Bonmin>

(Bonmin: default hybrid algorithm. with Clp)

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

Bonmin-0.100.2: (hybrid and B-OA-C)

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 (QC)QP Benchmark (convex cases)

problem	QP					QCQP			
	Bonmin	B-0A-C	CPLEX	FilMINT		Bonmin	B-0A-C	CPLEX	FilMINT
ibell3a	48	6	25	t	55	6	14	1600	
ibienst1	1466	6237	3988	t	1285	5838	785	t	
icap6000	3315	38	18	1961	t	32	23	1065	
ilaser0	f	4	5480	f	f	14	339	f	
imod011	7954	t	214	8134	t	t	t	f	
inug08	t	t	t	f	t	t	t	t	
iqiu	389	t	498	1510	1528	t	401	2758	
isqp0	(1)f	10	121	f	(2)f	f	t	f	

(1) B-BB solves in 4408 s

(2) B-BB solves in 4485 s

Mixed Integer (QC)QP Benchmark (nonconvex cases)

QP

|

QCQP

```

=====
problem  Bonmin B-OA-C CPLEX FilmINT  Bonmin B-OA-C CPLEX FilmINT
=====
  iair04   3387    992    785    2188   5475    1358    212    5151
  iair05   1812    168    238         f   1628    118    131    1218
  ieild76   845    166     61   3122   1032    150     59    910
  imas284   806      9     48     87    845      9     15    562
  imisc07   974   4541    691   7627   1054   5332    407      t
  iqap10   5591   2163   2609   3691   9086   4638      t      t
  iran13x13 3739     89    148   2515   4971    124     95    2026
  iran8x32   257     45     26   3680    546     68     43    5856
  iswath2   (3)t    396    406      t   (4)t    283     f      t
  ivalues  1396      t     f     t   1658      t     f      t
=====

```

(3) B-QG solves in 3770 s

(4) B-QG solves in 4066 s

=====  
Mixed Integer (QC)QP Benchmark  
=====

- 25 MI(QC)QP cases total
- MIQP cases solved:
  - CPLEX 21, Bonmin 17, Bonmin-0.100.2 6, FiLMINT 10, LaGO 5
- MIQCQP cases solved:
  - CPLEX 12, Bonmin 16, Bonmin-0.100.2 4, FiLMINT 9, LaGO 4



## Conclusions

- Parallel CPLEX effective most of the time, MOSEK competitive
- FEASPUMP competitive with CPLEX and SCIP
- SCIP-CPLEX competitive for MILP with CPLEX except for speed
- SCIP-CLP best free MILP solver, then CBC, SCIP-SOPLEX

- BONMIN-0.1.4 competitive with CPLEX for MIQCQP, much slower for MIQP
- BONMIN-0.100.2 still unstable

**Thank you for your attention**