Recent Progress in Integer (and Nonlinear) Optimization

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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)

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Combinatorial Optimization  * CONCORDE [TSP Input]
Global Optimization         * ICOS [AMPL Input]
Linear Programming
  * bpmpd [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][ZIMPL 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]
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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 (1/1-10/31)

- BPMPD **6871**
- SCIP **6347**
- FEASPUMP **2524**
- CONCORDE **815**
- SDPA **728**

NEOS solver usage statistic for 2007 (1/1-10/31)

- QSOPT-EX **644**
- SDPT3 **262**
- SEDUMI **216**
- CSDP **198**
- BNBS **167**

NEOS solver usage statistic for 2007 (1/1-10/31)

- PENSDP **141**
- CONDOR **111**
- NSIPS **100**
- SDPLR **95**
- ICOS **49**

NEOS solver usage statistic for 2007 (1/1-10/31)

- PENBMI **23**
- DDSIP **21**
- SDPA-C **20**

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 (10-27-2007)

$ Parallel CPLEX and MOSEK on LP problems (10-31-2007)

COMBINATORIAL OPTIMIZATION

* Concorde-TSP with different LP solvers (10-31-2007)

LINEAR PROGRAMMING

Benchmark of commercial LP solvers (8-7-2007)

Benchmark of free LP solvers (8-7-2007)

$ Large Network-LP Benchmark (commercial vs free) (10-28-2007)

NONLINEAR PROGRAMMING

Benchmark of commercial and other (QC)QP Solvers (8-8-2007)

AMPL-NLP Benchmark, IPOPT, KNITRO, LOQO, PENNLP & SNOPT (8-8-2007)

SEMIDEFINITE/SQL PROGRAMMING

Several SDP-codes on SDP problems with free variables (7-23-2007)

Several SDP codes on problems from SDPLIB (8-10-2007)

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

Newer SDP/SOCP-codes on the 7th DIMACS Challenge problems(8-9-2007)

Several SDP codes on sparse and other SDP problems (8-8-2007)

SOCP (second-order cone programming) Benchmark (10-28-2007)

MIXED INTEGER PROGRAMMING

* MILP Benchmark - free codes (10-29-2007)
* Feasibility Benchmark - FEASPUMP vs CPLEX (10-27-2007)
* MI(Q)QP Benchmark (10-28-2007)

PROBLEMS WITH EQUILIBRIUM CONSTRAINTS

MPEC Benchmark (8-9-2007)

Important features of all our benchmarks

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

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31 Oct 2007 First continuous benchmark

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Parallel CPLEX and MOSEK on LP problems

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H. Mittelmann (mittelmann@asu.edu)

Logiles at http://plato.asu.edu/ftp/cpx_msk_logs/

The barrier methods of CPLEX-11.0 and MOSEK-5.0.60 were run on 1, 2, 4 processors of a 2.667 GHz Intel Core 2 Quad (64-bit, Linux) on large LP problems from here.

Times given are elapsed CPU times in seconds.

Large LPs on 1, 2, and 4 processors of a 2.667GHz Intel Core 2 Quad

problem	CPLEX1	CPLEX2	CPLEX4	MOSEK1	MOSEK2	MOSEK4
nug08-3rd	294	172	105	439	295	209
nug20	755	485	315	678	541	330
nug30	41228	15557	9754	39555	28967	20012
pde_1	768	603	455	1953!	1249!	1184!
pde_2	7098!	8969	2897!	1747	1340	1161
qap_1	1144	486	310	1952	1253	1258
qap_2	664	331	220	935	709	496

! non-optimal

28 oct 2007 Second continuous benchmark

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Large Network-LP Benchmark (commercial vs free)

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H. Mittelmann (mittelmann@asu.edu)

Logfiles of these runs at: http://plato.asu.edu/ftp/net_logs/

This benchmark was run on a 2.4 GHz AMD Opteron (64 bit,Linux,12GB)

The MPS-datafiles are here.

The network resp. dual simplex versions of the following codes were t

- http://www.cplex.com/ ILOG-CPLEX-11.0
- http://www.mosek.com/ MOSEK-5.0.0.60
- https://projects.coin-or.org/Clp/ Clp-1.6
- http://www.isye.gatech.edu/~wcook/qsopt/ QSopt-1.0 (32 bit binary)

Times are user times in secs including input. 3 hour time limit.

problem	nodes	arcs	CPLEX	MOSEK	CLP	QSOPT
16_n14	16381	261873	260	213	79	140
i_n13	8181	739733	172	277	264	211
lo10	23728	383578	96	79	53	123
long15	32767	753676	355	33	38	1894
netlarge1	45774	7238591	858	404	403	t
netlarge2	39893	1158027	251	45	230	t
netlarge3	38502	4489009	514	180	1124	t
netlarge6	8000	15000000	313	448	3230	m
square15	32760	753512	489	31	52	1746
wide15	32767	753676	465	33	48	1217

"m": out of memory, "t": time limit exceeded

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Concorde-TSP Benchmark (excerpt)

problem	Cplex-11.0	QSopt-1.0$	GLPK-4.11	MOSEK-5.0.0.60
d1655	55	100	1360	71
fl1400	415	11368	2518	676
fl3795	3582	>50000		16779
nrw1379	70	126	462	125
pcb3038	19309	33706		31432
rl1304	87	112	>64000	261
rl1889	1406	6710	fail	3412
u1817	32746			
vm1748	247	536	2030	486

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Parallel CPLEX on MIP problems

Logiles at http://plato.asu.edu/ftp/ser_par_logs/

CPLEX-11.0 was run in default mode on a single and on a 2-processor 2.4GHz 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

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

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

"c": problem convex

class	problem	c	Opter-1	Opter-2	Intel-1	Intel-2	Intel-4
MILP	bienst2	y	203	83	154	70	34
	lrn	y	101	51	54	25	26
	mas74	y	467	365	294	131	71
	neos13	y	154	524	67	91	245
	neos5	y	251	207	185	117	40
	seymour1	y	284	204	158	114	71

Parallel CPLEX on MIQP and MIQQP problems

class	problem	c	Opter-1	Opter-2	Intel-1	Intel-2	Intel-4
MIQP	ibienst1		1612	1447	1052	466	313
	inug08	y	7954	4940	2820	1593	1844
	iqap10		1560	467	599	185	180
	isqp	y	5847	3994	1790	1043	1970
MIQQP	ibienst1		331	112	247	105	51
	imisc07		83	46	54	31	22
	imod011	y	9353	>10200	5025	3571	2916
	inug06-3rd	y	8016	>15600	4251	3230	3582
	inug08	y	4281	4021	2598	1473	1068
	iran13x13		40	50	29	13	7

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Feasibility Benchmark - Feaspump vs CPLEX

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

CPLEX-11.0: 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

"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.

Feasibility Benchmark (excerpt)

problem	CPLEX-h	o	CPLEX-f	o	FP-ab	o	FP-bfl	o
atlanta-ip	241	3	837	2	56	1	21	4
core4872-1529	1	3	1	3	497	1	58	2
ds	1	1	1	1	-	-	6531	1
germanrr	26	3	267	2	22	1	5	4
momentum1	1	1	1	1	25	1	16	1
momentum2	4003	2	323	1	67	3	62	4
momentum3	3	2	2	2	516	1	253	2
msc98-ip	353	1	271	2	23	3	22	4
neos16	676	4	557	1	392	3	223	2
neos-506428	-	-	-	-	4470	1	-	-

Feasibility Benchmark (continued)

problem	CPLEX-h	o	CPLEX-f	o	FP-ab	o	FP-bfl	o
neos-595925	3	1	1	2	141	3	83	4
net12	50	2	939	1	14	2	67	2
ns808444	-	-	-	-	56	1	-	-
ns894236	2693	1	2001	1	160	1	88	1
ns894244	4856	1	-	-	543	1	591	1
ns894788	-	-	-	-	47	1	908	1
ns897005	158	1	360	1	175	1	59	1
ns897642	7	1	5	1	504	1	19	1
ns903616	281	1	-	1	154	1	144	1
ns930473	320	1	-	-	1076	2	45	3

Feasibility Benchmark (continued)

problem	CPLEX-h	o	CPLEX-f	o	FP-ab	o	FP-bfl	o
ns930473	320	1	-	-	1076	2	45	3
ns1061051	557	1	1632	2	4	3	4	3
ns1116954	-	-	-	-	2070	1	364	1
ns1208400	681	1	6753	1	2653	1	729	1
ns1219534	34	3	109	1	85	1	97	2
NSR8K	392	2	279	2	6154	1	594	3
protfold	39	3	201	2	145	2	32	1
ramos3	1	3	1	3	383	1	179	2
rd-rplusc-21	180	1	19	1	632	3	1199	2
van	2035	2	1109	2	695	1	458	3

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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-2.0:	https://projects.coin-or.org/Cbc
GLPK-4.22:	http://www.gnu.org/software/glpk/glpk.html
MINTO-3.1:	http://coral.ie.lehigh.edu/~minto/
SCIP-1.0:	http://scip.zib.de/
SYMPHONY-5.1.4:	https://projects.coin-or.org/SYMPHONY
CPLEX-11.0:	(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 2.67GHz Intel Core 2:

   SCIP-CPLEX:     66
   CPLEX:          64
   SCIP-CLP:       60
   SCIP-SOPLEX:    56
   CBC:            51
   MINTO:          30     (with CLP, with CPLEX: 39)
   GLPK:           24
   SYMPHONY:       18
   LP_SOLVE;       13
```

Mixed Integer Linear Programming Benchmark (free codes)

63 cases solved by both CPLEX and SCIP-C

CPLEX faster by 5 or more:	26
SCIP-C faster by 5 or more:	0
SCIP-C faster:	6/63

48 cases solved by both CBC and SCIP-S

CBC faster by 3 or more:	12
SCIP-S faster by 3 or more:	13
SCIP-S faster:	25/48

SCIP-S faster than SCIP-L:	31/56
SCIP-L faster than CBC:	27/51

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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/
also solved as MIQQP with

CPLEX-11.0: 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-OA-C	CPLEX	FilMINT	Bonmin	B-OA-C	CPLEX	FilMINT
ibell3a	48	6	11	t	55	7	6	1600
ibienst1	1466	6163	1616	t	1285	5971	331	t
icap6000	3315	52	10	1961	t	157	9	1065
ilaser0	f	27	2232	f	f	56	24	f
imod011	7954	t	125	8134	t	t	9473	f
inug08	t	t	8075	f	t	t	4299	t
iqiu	389	t	251	1510	1528	t	169	2758
isqp0	(1)f	f	105	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)

	QP				QQP			
problem	Bonmin	B-OA-C	CPLEX	FilMINT	Bonmin	B-OA-C	CPLEX	FilMINT
iair04	3387	1039	317	2188	5475	1560	82	5151
iair05	1812	177	93	f	1628	127	93	1218
ieilD76	845	126	31	3122	1032	111	22	910
imas284	806	12	30	87	845	12	8	562
imisc07	974	3082	328	7627	1054	3260	83	t
iqap10	5591	2123	1597	3691	9086	4949	4863	t
iran13x13	3739	127	48	2515	4971	232	41	2026
iran8x32	257	62	12	3680	546	211	23	5856
iswath2	(3)t	153	287	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

Mixed Integer (Q)QP Benchmark

- 25 MIQ(Q)P cases total
- MIQP cases solved:
  - CPLEX 22, Bonmin 17, FilMINT 10, LaGO 5
- MIQQP cases solved:
  - CPLEX 16, Bonmin 16, FilMINT 9, LaGO 4

Conclusions

- Parallel CPLEX effective most of the time, MOSEK competitive
- FEASPUMP competitive with 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 MIQQP, much slower for MIQP

Thank you for your attention