Performance of Optimization Software - an Update

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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 **(1/3 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][LP Input][MPS Input]
  * SCIP [AMPL Input][LP Input][MPS Input] [ZIMPL Input][OSIL Input]
*** also in global category and mixed-int nonlin constrained cat.***
  * qsopt_ex [LP Input][MPS Input] [AMPL Input]
Nondifferentiable Optimization   * condor [AMPL Input]
Semi-infinite Optimization       * nsips [AMPL Input]
Stochastic Linear Programming    * bnbs [SMPS Input]
                                 * DDSIP [LP Input][MPS Input]
                                 * SD [SMPS 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]
* sdplr [MATLAB_BINARY Input][SDPLR Input][SPARSE_SDPA Input]
* sdpt3 [MATLAB_BINARY Input][SPARSE_SDPA Input]
* sedumi [MATLAB_BINARY Input][SPARSE_SDPA Input]

Overview of Talk

- **Current and Selected(*) Benchmarks**
  - Parallel LP/QP/SOCP benchmarks
  - MILP benchmark (MIPLIB2010)
  - Feasibility/Infeasibility Detection benchmarks (MIPLIB2010)
  - slightly pathological MILP cases
  - MIQ(C)P benchmark
- Conclusions

COMBINATORIAL OPTIMIZATION

Concorde-TSP with different LP solvers (3-6-2013)

LINEAR PROGRAMMING

Benchmark of serial LP solvers (6-27-2013)
* Benchmark of parallel LP solvers (5-24-2013)
* Parallel Barrier Solvers on Large LP/QP problems (5-26-2013)
Large Network-LP Benchmark (commercial vs free) (6-12-2013)

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 (6-22-2011)
* MISOCP and large SOCP Benchmark (6-18-2013)

MIXED INTEGER LINEAR PROGRAMMING

* MILP Benchmark - MIPLIB2010 (5-25-2013)
* MILP cases that are slightly pathological (5-31-2013)
* Feasibility Benchmark (5-22-2013) (MIPLIB2010)
* Infeasibility Detection for MILP Problems (5-24-2013) (MIPLIB2010)

NONLINEAR PROGRAMMING

Benchmark of commercial and other (QC)QP Solvers (8-15-2012)
AMPL-NLP Benchmark, IPOPT, KNITRO, LOQO, PENNLP, SNOPT & CONOPT (11-9-2011)

MIXED INTEGER QPs and QCPs

* MIQ(C)P Benchmark (6-22-2013)

MIXED INTEGER NONLINEAR PROGRAMMING

MINLP Benchmark (1-28-2013)

PROBLEMS WITH EQUILIBRIUM CONSTRAINTS

MPEC Benchmark (11-28-2012)

Important features of all our benchmarks

- Statistics of problems (dimensions etc)
- Links to codes given
- Links to test problems given
- Links to full logfiles given
- Same selection for commercial/free codes

Reasons for updates

- New version of commercial software
  - CPLEX, GUROBI, XPRESS, KNITRO-8.1, MOSEK-7
- New versions of free software
  - CBC, CLP, SCIP,
  - BONMIN, COUENNE, IPOPT
- More multicore hardware

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- Observations and Conclusions

24 May 2013

Benchmark of parallel LP solvers

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This benchmark was run on a Linux-PC (i7-2600).
The MPS-datafiles for all testcases are in one of (see column "s")

 miplib.zib.de/ [1]
 plato.asu.edu/ftp/lptestset/ [2]
 www.netlib.org/lp/data/ [3,7]
 www.sztaki.hu/~meszaros/public_ftp/lptestset/
(MISC[4], PROBLEMATIC[5], STOCHLP[6], INFEAS[8])

The (dual) simplex, barrier, and concurrent methods were tested of:

 CPLEX-12.5.1pre CPLEX
 GUROBI-5.5.0   www.gurobi.com/
 MOSEK-7.0.0.55 www.mosek.com
 XPRESS-7.5.0:   XPRESS

Scaled shifted geometric mean of runtimes (A automatic) (40 instances)

	4.44	2.65	4.63	3.49	1.15	1	1.54	1.01	1.40	1.28	1.34	1.27
problem	CPXS	GRBS	MSKS	XPRS	CPXB	GRBB	MSKB	XPRB	CPXA	GRBA	MSKA	XPRA

26 May 2013

Parallel Barrier Solvers on Large LP/QP problems

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Logiles at plato.asu.edu/ftp/barrier_logs/

CPLEX-12.5.1pre CPLEX
GUROBI-5.5.0: GUROBI
MOSEK-7.0.0.65: MOSEK
XPRESS-7.5.0: XPRESS

The barrier methods (w/o crossover) of the above solvers were run on
a 3.47 GHz Intel Xeon X5690 (6 cores, 48GB) on large LP problems from here.
Times given are elapsed times in seconds.

problem	CPLEX	GUROBI	MOSEK	XPRESS
L1_250	59015	103	98	slow
L1_500	m	2529a	3608a	m
in	172	164	428	283
pde_1	2525	2034	7934	6267
pde_20	1790	2016	16088a	2867
pde_2	4920	15403	53447a	6486
qap_2	slow	fail	2082	1156
splan1	2577	4186	5632	6308
srd300	9723	>35000	11762	10809
zib01	6520	8461	14982	6433
L2CTA3D	3236	6379	fail	1545a
bdry2_0	1930a	1046	5247a	1521
bdry2_1	9689a	6831	fail	7541
cont5_2_0	515	1049	36a	626a
cont5_2_1	1803	4308a	68a	1550a
cont5_2_2	7326	fail	148a	5465a
twod_00	2460	8785	17627a	2701
twod_0	12429	46410	>100000	12056

"a": red. accuracy, "m": out of memory

problem statistics

problem	constraints	variables	nonzeros	MPS-file
L1_250	986069	428032	4280320	155 MB
L1_500	1769194	790746	7907460	287 MB
in	1526203	1449074	6813128	561 MB
pde_1	26993999	9005998	80970001	4.1 GB
pde_20	13225799	8824196	39669001	2.2 GB
pde_2	26993999	18005996	80970001	4.5 GB
qap_2	57360	14400	203040	70.7 MB
splan1	572800	1317382	5233840	374 MB
srd300	1101467	2052911	59170079	1.6 GB
zib01	5887041	12471400	49877768	2.5 GB
L2CTA3D	210000	10000000	30000000	1.8 GB
bdry2_0	4001998	4003997	19991999	
bdry2_1	12253498	12256997	61235999	
cont5_2_0	1959681	1961081	11749904	
cont5_2_1	3999656	4001656	23986126	
cont5_2_2	8999641	9002641	53979959	
twod_00	505284	511446	4856046	
twod_0	989604	999306	9586066	

18 Jun 2013 ==

MISOCP and large SOCP Benchmark

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Logfiles for these runs are at: plato.la.asu.edu/ftp/socp_logs/

MOSEK-7.0.0.65 www.mosek.com/
CPLEX-12.5.1pre CPLEX
GUROBI-5.5.0 GUROBI

These codes were tested on a selection of the (MI)SOCP problems
from the forthcoming CBLIB2013.

The codes were run in default mode (except mipgap=0 for the MISOCP
problems) on an Intel i7-2600. Given are total CPU seconds. Time limit 2 hrs.

problem	CPLEX	GUROBI	MOSEK
pp-n100-d10	6228	4562	t
uflquad-nopsc-20-100	1135	667	246
uflquad-nopsc-20-150	6453	980	1064
uflquad-nopsc-30-100	t	902	1909
uflquad-nopsc-30-150	t	2959	3981
uflquad-nopsc-30-200	t	5211	t
uflquad-psc-30-150	25	1011	5
uflquad-psc-30-200	89	5572	6
uflquad-psc-30-300	292	t	24
dsNRL	707	296	318
firL1	597	379	101
firL1Linfalph	1087	526	232
firL1Linfeps	331	48	101
firL2L1alph	85	99	33
firL2L1eps	573	371	104
firL2Linfalph	500	529	661
firL2Linfeps	290	152	113
firL2a	388	800	811
firLinf	672	420	664
wbNRL	324	131	35

't': timelimit exceeded

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25 May 2013 Mixed Integer Linear Programming Benchmark (MIPLIB2010)

The following codes were run on the MIPLIB2010 benchmark set with the MIPLIB2010 scripts on an Intel Xeon X5680 (32GB, Linux, 64 bits, 2*6 cores), with one, four and twelve threads. (deterministically) and a time limit of 1 hour. These are up dated and extended versions of the results produced for the MIPLIB2010 paper.

CPLEX-12.5.1pre CPLEX
GUROBI-5.5.0: GUROBI
ug[SCIP/cpx/spx]-3.0.1: Parallel development version of SCIP (SCIP+CPLEX/SOPLEX/CLP on 1 thread)
CBC-2.8.0: CBC
XPRESS-7.5.0: XPRESS
GLPK-4.49: GLPK
LP_SOLVE-5.5.2: LP_SOLVE

Table for single thread, Result files per solver, Log files per solver

Table for 4 threads, Result files per solver, Log files per solver

Table for 12 threads, Result files per solver, Log files per solver

Statistics of the problems can be obtained from the MIPLIB2010 webpage.

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Scaled geometric means of times

All non-successes are counted as max-time. The fastest solver is scaled to 1.
The second line lists the number of problems (87 total) solved.

1 thr	CBC	CPLEX	GLPK	GUROBI	LPSOLVE	SCIPC	SCIPL	SCIPS	XPRESS
scaled	11.3	1	22.8	1.01	20.3	4.05	6.77	5.23	1.30
solved	35	81	3	79	5	62	52	62	78

4 thr	CBC	CPLEX	FSCIPC	FSCIPS	GUROBI	XPRESS
scaled	15.1	1.10	7.30	11.8	1	1.47
solved	52	84	67	63	87	84

12 thr	CBC	CPLEX	FSCIPC	FSCIPS	GUROBI	XPRESS	GUROBI5	CPLEX5
scaled	13.3	1	10.2	17.6	1.19	1.49	0.71	0.86
solved	57	86	68	64	87	85	87	86

CPLEX5/GUROBI5: best of 5 runs with 12 threads and random seeds 1001-5.

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26 Jun 2013 === Feasibility Benchmark ===

Logfiles for these runs are at: plato.asu.edu/ftp/feas_bench_logs/

MILP problems mostly from MIPLIB2010 were solved for a feasible point

The following codes were run on an Intel i7-2600 (3.4 GHz, 16GB, Linux, 4 cores) with 4 threads:

CPLEX-12.5.1pre CPLEX
FEASPUMP2: as implemented for interactive use at NEOS (utilizes CPLEX)
GUROBI-5.5.0: GUROBI
XPRESS-7.5.0: XPRESS
CBC-2.8.2: CBC

Times given are elapsed times in seconds. A time limit of 1 hr was imposed.
Shifted geometric means of the times are listed. For objective values see logfiles.

problem(30 tot)	CPLEX	FP2	GUROBI	XPRESS	CBC
geometric mean	1	3.59	1.91	3.57	84
problems solved	30	28	28	27	12

24 May 2013 Infeasibility Detection for MILP Problems

The following codes were run on the infeasible problems from MIPLIB2010 with the MIPLIB2010 scripts

CPLEX-12.5.1pre CPLEX
GUROBI-5.5.0: GUROBI
ug[SCIP/spx/cpx]: Parallel development version of SCIP
CBC-2.8.0: CBC
XPRESS-7.5.0: XPRESS

Table for 12 threads, Result files per solver, Log files per solver

Statistics of the problems can be obtained from the MIPLIB2010 webpage.

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Shifted geometric means of times

	CBC	CPLEX	FSCIPC	FSCIPS	GUROBI	XPRESS
	55.8	1	26	31.3	1.38	1.55
solved of 19:	7	18	10	11	18	18

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31 May 2013 MILP cases that are slightly pathological

CPLEX-12.5.1pre CPLEX
GUROBI-5.5.0: GUROBI
ug[SCIP/cpx]: FSCIP-Parallel development version of SCIP
CBC-2.8.0: CBC
XPRESS-7.5.0: XPRESS
SCIP-3.0.1: serial SCIP with CPLEX

These codes were run with the MIPLIB2010 scripts in default mode on an Intel Xeon X5680 (32GB, Linux, 64 bits, 2*6 cores) on problems from here. Times given are elapsed CPU seconds. Time limit 3 hrs. Available memory 24GB. This benchmark is not giving a representative impression of the relative performance of the codes.

Table for 12 threads, Result files per solver, Log files per solver

Scaled shifted geometric mean of runtimes and problems solved (25 total)

CBC	CPLEX	FSCIP	GUROBI	SCIP	XPRESS	CPLEX-5	GUROBI-5
8.79	1	9.27	1.65	7.64	2.53	0.69	0.75
10	23	14	24	15	17	25	24

GUROBI/CPLEX-5: Best of 5 runs with random seeds 1001-1005

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  - **MIQ(C)P benchmark**
- Conclusions

22 Jun 2013

Mixed Integer Q(C)P Benchmark

The following codes were run in default mode on a 2.66GHz Intel Core2 Quad,
For accuracy reached, see logfiles. In the second table are results for the
QCQPs obtained by rewriting the QPs as: min t, subject to quadratic obj <= t
plus constraints. SCIP does this transformation itself. SCIP uses relgap=0;

CPLEX-12.5.1pre: CPLEX
Bonmin-1.6.0: projects.coin-or.org/Bonmin (Bonmin: hybrid algorithm. with Cbc)
Couenne-0.4.3: projects.coin-or.org/Couenne
MOSEK-7.0.0.65: mosek.com
GUROBI-5.5.0: gurobi.com (convex only!)
Minotaur-0.1.1: http://wiki.mcs.anl.gov/minotaur/
SCIP-3.0.1: scip.zib.de (with CPLEX and IPOPT)
XPRESS-7.5.0: XPRESS
CBC-2.8.2: CBC

Times given are user times in seconds. A time limit of 10,800 seconds was
imposed. "t" time limit exceeded, "f" fail, "c" problem convex.

QP
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Scaled shifted geometric means of runtimes

120	205	1.04	-	1	12.4	2.29	35.1	30.4

problem	Bonm	Couen	CPLEX	MOSEK	GUROBI	SCIP	XPRESS	MINOTAUR	CBC

QCQP
====

Scaled shifted geometric means of runtimes

70.7	62.4	1.03	4.13	81.9	1

problem	Bonmin	Couenne	CPLEX	XPRESS	Minotaur	GUROBI

- Conclusions: **Declare Winners?**
  - **Parallel LP**: Gurobi, XPRESS, CPLEX
  - **(MI)SOCP**: Gurobi, MOSEK, CPLEX
  - **MIPLIB-bench**: CPLEX, Gurobi, XPRESS
  - **MIPLIB-feas**: CPLEX, Gurobi, XPRESS
  - **MIPLIB-infeas**: CPLEX, Gurobi, XPRESS
  - **Pathological**: (CPLEX, Gurobi, XPRESS)
  - **MIQ(C)P**: Gurobi, CPLEX, XPRESS, MOSEK

Thank you!