Performance of Commercial and Noncommercial Optimization Software

IINFORMS 2012

Phoenix, AZ

October 2012

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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]
```

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]

Solving the MIPLIB 2010 Problems

- In late 2010 we had solved a number of instances
  In early 2012 we decided to solve those problems that a commercial solver could solve in 1-3 days.

- We used four platforms
  - Intel Xeon E7540 (2.0 Ghz, 1TB, 24 resp 32 cores)
  - Intel Xeon X5680 (3.33 GHz, 32GB, 12 cores)
  - Intel Xeon X5690 (3.47 GHz, 48GB, 6 cores)
  - Intel i7-2600 (3.4 GHz, 16GB, 4 cores)

We solved 24 cases plus 4 feasible solves

instance	cores	time	category
b2c1s1	12/12	116575	hard
berlin_5_8_0	10/12	32413	hard
blp-ic97	12/12	1868	easy
buildingenergy	1/4	895	easy
g200x740i	12/12	104738	hard
maxgasflow	6/6	66726	hard
neos-631710	12/12	1265	easy
neos-948126	8/12	15959	hard
ns1696083	8/12	6834	hard
opm2-z10-s2	12/12	10131	hard
opm2-z11-s8	12/12	18286	hard

instance	cores	time	category
opm2-z12-s14	4/4	49164	hard
opm2-z12-s7	12/12	72492	hard
p100x588b	8/12	19820	hard
pigeon-13	32/32	77757	hard
r80x800	12/12	283303	hard
rmatr200-p10	4/4	19644	hard
satellites3-40-fs	4/6	32952	hard
satellites3-40	4/4	21205	hard
set3-15	24/24	231777	hard
transportmoment	12/12	30	easy
uc-case3	8/12	158881	hard
uct-subprob	12/12	2106	easy
vpphard2	4/4	43985	hard
wnq-n100-mw99-14	12/12	28124	hard

Overview of Talk

- **Current and Selected(*) Benchmarks**
  - Parallel LP benchmarks
  - MILP benchmark (MIPLIB2010)
  - Feasibility/Infeasibility Detection benchmarks (MIPLIB2010)
  - slightly pathological MILP cases
  - MINLP benchmark
- Conclusions

COMBINATORIAL OPTIMIZATION

Concorde-TSP with different LP solvers (5-29-2012)

LINEAR PROGRAMMING

Benchmark of serial LP solvers (8-8-2012)
* Benchmark of parallel LP solvers (5-4-2012)
* Parallel Barrier Solvers on Large LP/QP problems (5-16-2012)
Large Network-LP Benchmark (commercial vs free) (5-15-2012)

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)
SOCP (second-order cone programming) Benchmark (5-15-2012)

MIXED INTEGER LINEAR PROGRAMMING

* MILP Benchmark - MIPLIB2010 (8-9-2012)
* MILP cases that are slightly pathological (8-12-2012)
* Feasibility Benchmark (6-21-2012) (MIPLIB2010)
* Infeasibility Detection for MILP Problems (8-13-2012) (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 (8-2-2012)

MIXED INTEGER NONLINEAR PROGRAMMING

* MINLP Benchmark (9-27-2012)

PROBLEMS WITH EQUILIBRIUM CONSTRAINTS

MPEC Benchmark (2-26-2012)

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

```
 4 May 2012   ==================================
               Benchmark of parallel LP solvers
              ==================================
              H. Mittelmann <mittelmann@asu.edu>

This benchmark was run on a Linux-PC (2.67 GHz Intel Core 2 Quad).
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-12.4.0.0  CPLEX
 GUROBI-5.0.0    www.gurobi.com/
 MOSEK-6.0.0.135 www.mosek.com
 XPRESS-7.3.1:   XPRESS

Scaled geometric mean of runtimes (A automatic)

   4.43  2.97  5.00   3.59  1.14  1.06  1.74  1.43  1.80   1    1.52   3.58
=============================================================================
   CPX-S GRB-S  MSK-S XPR-S CPX-B GRB-B MSK-B XPR-B CPX-A GRB-A MSK-A XPR-A
=============================================================================
```

16 May 2012

Parallel Barrier Solvers on Large LP/QP problems

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

CPLEX-12.4.0.0: CPLEX
GUROBI-5.0.0: GUROBI
MOSEK-6.0.0.137: MOSEK
XPRESS-7.3.1: XPRESS
IPOPT-3.10.1: IPOPT

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.

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Parallel Barrier Solvers on Large LP/QP problems

problem	CPLEX	GUROBI	MOSEK	XPRESS	IPOPT
in	46462	165	914	303	
pde_10	2269	756	4485	2098	
pde_1	2523	2114	9586	6358	
pde_200	299	547	4515	622	
pde_20	1894	2018	23727	2785	
pde_2	5269	15393	47523	24941	
qap_2	slow	fail	slow	1499	
srd300	10112	>35000	18212	12206	
zib01	6027a	8435	9172	6682	
L2CTA3D	3269	6415	5672	1975	
bdry2_0	1931a	1045	2628a	2545	4641
bdry2_1	10999a	6824	31211a	5192	31089
cont5_2_0	516	1051	28	556	1186
cont5_2_1	1746	4314a	57a	1352	3270
cont5_2_2	8005	fail	127	3625	11579
twod_00	2471	8795	14733a	2824	9348
twod_0	12411	46287	fail	13261	41616

"a": reduced accuracy

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Parallel Barrier Solvers on Large LP/QP problems

problem	constraints	variables	nonzeros	MPS-file
in	1526203	1449074	6813128	561 MB
pde_10	13225799	4414198	39669001	1.96 GB
pde_1	26993999	9005998	80970001	4.1 GB
pde_200	5067399	3382596	15197001	824 MB
pde_20	13225799	8824196	39669001	2.2 GB
pde_2	26993999	18005996	80970001	4.5 GB
qap_2	57360	14400	203040	70.7 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	

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9 Aug 2012 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-12.4.0.0: CPLEX
GUROBI-5.0.0: GUROBI
ug[SCIP/cpx/spx]-3.0.0: Parallel development version of SCIP (SCIP+CPLEX/SOPLEX/CLP on 1 thread)
CBC-2.7.7: CBC
XPRESS-7.3.1: XPRESS
GLPK-4.47: 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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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.

threads	CBC	CPLEX	GLPK	GUROBI	LPSOLVE	SCIPC	SCIPL	SCIPS	XPRESS
1	10.1	1.26	21.6	1	18.9	3.37	5.30	5.00	1.09
solved	41	75	3	77	5	64	55	58	76

threads	CBC	CPLEX	FSCIPC	FSCIPS	GUROBI	XPRESS
4	11.6	1.13	6.03	10.2	1	1.17
solved	52	84	69	65	83	81

threads	CBC	CPLEX	FSCIPC	FSCIPS	GUROBI	XPRESS
12	13.4	1.2	9.51	15.6	1	1.25
solved	55	84	71	66	87	82

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21 Jun 2012 === Feasibility Benchmark ===

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

MILP problems 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-12.4.0.0: CPLEX
FEASPUMP2: as implemented for interactive use at NEOS (utilizes CPLEX)
GUROBI-5.0.0: GUROBI
XPRESS-7.3.1: XPRESS
CBC-2.7.7: CBC

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

problem(30 tot)	CPLEX	FP2	GUROBI	XPRESS	CBC
geometric mean	8.31	16.95	1	2.06	65.4
problems solved	22	17	28	25	7

21 Jun 2012 Infeasibility Detection for MILP Problems

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

CPLEX-12.4.0.0: CPLEX
GUROBI-5.0.0: GUROBI
ug[SCIP/spx/cpx]: Parallel development version of SCIP
CBC-2.7.7: CBC
XPRESS-7.3.1: 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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	CBC	CPLEX	FSCIPC	FSCIPS	GUROBI	XPRESS
geom mean	52.6	1.75	25.2	31.5	1.00	3.05
solved of 19:	7	16	10	11	18	15

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12 Aug 2012

MILP cases that are slightly pathological

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CPLEX-12.4.0.0: CPLEX
GUROBI-5.0.0: GUROBI
ug[SCIP/cpx]: FSCIP-Parallel development version of SCIP
CBC-2.7.7: CBC
XPRESS-7.3.1: XPRESS
SCIP-3.0.0: 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 geometric mean of runtimes and problems solved (24 total)

CBC	CPLEX	FSCIP	GUROBI	SCIP	XPRESS
13.4	1	6.23	1.37	6.53	1.84
5	17	14	21	14	15

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================================================================================
MINLP benchmarh with GAMS and AMPL solvers on 155 convex and 252 general cases
================================================================================
            Stefan Vigerske and  Hans Mittelmann                  9-27-2012

For benchmark results of solvers with GAMS interface we refer to

this excerpt of the ISMP 2012 talk by Stefan Vigerske

Updated and more detailed results with GAMS 23.9.2 are located here: MINLPLib results, convex MINLP

To benchmark solvers with AMPL interface, the GAMS files used above were converted to AMPL and writ

The shifted geometric means of runtimes in the GAMS benchmarks are

                  BARON      Couenne      LINDO-global      SCIP+CPLEX
========          ------------------------------------------------
MINLPLIB          175.6       236.5          262.1             135.4
========          ------------------------------------------------

                    SCIP*  AlphaECP   Bon-OA-Cpl   Bon-Hyb   Dicopt     SBB
===========         ---------------------------------------------------------
conv MINLPs         74.7     186.5       45.1       152.1     121.6    651.8
==========          ---------------------------------------------------------
```

The shifted geometric means for the AMPL solvers are

	Minotaur	KNITRO	SCIP+CPLEX
MINLPLIB	52.3	77.8	123.1

	Minotaur	KNITRO	SCIP+CPLEX*	
conv MINLP	173.3	442.9	78.3	"*" SCIP assumes convexity

Adjusting the means for the common solver SCIP and scaling the fastest solver to 1 the combined tables are

	BARON	Couenne	KNITRO	LINDO-global	Minotaur	SCIP+CPLEX
MINLPLIB	3.06	4.11	1.49	4.56	1	2.35

	KNITRO	SCIP	AlphaECP	Bon-OA	Bon-Hyb	Dicopt	Minot	SBB
conv MINLP	9.4	1.66	4.10	1	3.37	2.70	3.67	14.5

- Conclusions: **Declare Winners?**
  - **MIPLIB-bench**: Gurobi, CPLEX, XPRESS
  - **MIPLIB-feas**: Gurobi, XPRESS, CPLEX
  - **MIPLIB-infeas**: Gurobi, CPLEX, XPRESS
  - **Pathological**: CPLEX, Gurobi, XPRESS
  - **MINLP**: Minotaur, KNITRO, SCIP
  - **conv MINLP**: Bonmin, SCIP, Dicopt
  - **LP**: Gurobi, CPLEX, XPRESS, MOSEK

Thank you!