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)

```
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] [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]

Overview of Talk

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

COMBINATORIAL OPTIMIZATION

Concorde-TSP with different LP solvers (8-16-2011)

LINEAR PROGRAMMING

Benchmark of serial LP solvers (11-9-2011)
* Benchmark of parallel LP solvers (11-11-2011)
* Parallel Barrier Solvers on Large LP/QP problems (11-12-2011)
Large Network-LP Benchmark (commercial vs free) (11-10-2011)

MIXED INTEGER LINEAR PROGRAMMING

MILP Benchmark - serial codes (9-29-2011) (to be phased out)
* MILP Benchmark - MIPLIB2010 (11-11-2011)
* MILP cases that are slightly pathological (11-9-2011)
* Feasibility Benchmark (11-9-2011) (MIPLIB2010)
* Infeasibility Detection for MILP Problems (11-9-2011) (MIPLIB2010)

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 (10-29-2011)

NONLINEAR PROGRAMMING

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

MIXED INTEGER NONLINEAR PROGRAMMING

* MI(QC)QP Benchmark (11-11-2011)

PROBLEMS WITH EQUILIBRIUM CONSTRAINTS

MPEC Benchmark (10-18-2010)

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-12.4, GUROBI-4.6.0, KNITRO-7.2.1, MOSEK-6.0.0.124
- New versions of free software
  - CBC, CLP, SCIP, SYMPHONY
  - BONMIN, COUENNE, IPOPT, FEASPUMP2
- More multicore hardware

Benchmarks still in need of updates

- SDP Benchmark (parallel, iterative, nonlinear)
- MINLP Benchmark, not only MIQCQP
- Benchmarks in new areas
  - Compressive Sensing, other sparse optimization
  - Derivative free/nonsmooth optimization etc
  - More commercial codes

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11 Nov 2011 Benchmark of parallel LP solvers

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

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 and barrier methods of the following codes were tested:

 CPLEX-12.4.0.0 CPLEX
 GUROBI-4.6.0   www.gurobi.com/
 MOSEK-6.0.0.124 www.mosek.com
 XPRESS-7.2.1:   XPRESS

Scaled geometric mean of runtimes

  3.71 2.47 4.40   3.27   1   1.15   1.47 1.52 1.43 1.01 1.33
==
  CPX-S GRB-S MSK-S XPR-S CPX-B GRB-B MSK-B XPR-B CPX-A GRB-A MSK-A
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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-4.6.0: GUROBI
MOSEK-6.0.0.124: MOSEK
XPRESS-7.2.1: 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	46454	186	898	309	
pde_10	2271	747	3351	15906	
pde_1	2516a	2023	6323	fail	
pde_200	299a	526	1326	1528	
pde_20	1896a	2349	16184	3186	
pde_2	5269a	16164	60426	9889	
qap_2	slow	fail	slow	1581	
srd300	10091	fail	17369	>60000	
zib01	6010a	8254	9124	7113	
L2CTA3D	3271	6562	5681	2169	
bdry2_0	1925a	998	4223a	2412	4609
bdry2_1	10977a	3919	fail	10111	30590
cont5_2_0	512	1123	31	564	1157
cont5_2_1	1746	4167a	65	1545	3242
cont5_2_2	7979	fail	155	4181	11414
twod_00	2499	8412	16526a	2848	9348
twod_0	12391	47549	fail	12841	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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11 Nov 2011 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-4.6.0: GUROBI
ug[SCIP/cpx/spx]: Parallel development version of SCIP (SCIP+CPLEX/SOPLEX/CLP on 1 thread)
CBC-2.7.4: CBC
XPRESS-7.2.1: 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 iMIPLIB2010 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	8.82	1.25	19.14	1	16.8	3.19	5.3	4.88	1.12
solved	41	73	3	78	5	61	52	56	74

threads	CBC	CPLEX	FSCIPC	FSCIPS	GUROBI	XPRESS
4	10.27	1	5.78	9.41	1.06	1.23
solved	52	84	66	64	84	79

threads	CBC	CPLEX	FSCIPC	FSCIPS	GUROBI	XPRESS
12	11.1	1	8.08	11.9	1.07	1.21
solved	56	84	68	65	87	83

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11 Nov 2011 Feasibility Benchmark (30 instances)

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 Xeon X5680 (32GB, Linux, 64 bits, 2*6 cores) with 4 threa
CPLEX-12.4.0.0: CPLEX
FEASPUMP2: as implemented for interactive use at NEOS (utilizes CPLEX)
GUROBI-4.6.0: GUROBI
XPRESS-7.2.1: XPRESS
CBC-2.7.4: 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	4.23	12.94	1	13.5	35.6
problems solved	21	17	27	18	9

9 Nov 2011 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-4.6.0: GUROBI
ug[SCIP/spx/cpx]: Parallel development version of SCIP
CBC-2.7.4: CBC
XPRESS-7.2.1: 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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Geometric means of times (19 instances)

All non-successes are counted as max-time. The fastest solver is scaled to 1.

	CBC	CPLEX	FSCIPC	FSCIPS	GUROBI	XPRESS
	33.4	1.06	15.2	19.6	1.00	3.22
solved	6	16	12	14	18	15

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MILP cases that are slightly pathological

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CPLEX-12.4.0.0: CPLEX to be added
GUROBI-4.6.0: GUROBI
ug[SCIP/spx]: FSCIP-Parallel development version of SCIP
CBC-2.7.4: CBC
XPRESS-7.2.1: XPRESS
SCIP-2.1.0: 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

Problems solved (total 22)

CPLEX	GUROBI	FSCIP	CBC	XPRESS	SCIP
15	18	12	5	10	12

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Mixed Integer (QC)QP Benchmark

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

The MPS-datafiles are in plato.asu.edu/ftp/miqp/ and the AMPL files in plato.asu.edu/ftp/ampl_files/miqp_ampl/ and egon.cheme.cmu.edu/ibm/files/

The following codes were run in default mode on a 2.66GHz Intel Core2 Quad, For accuracy reached, see logfiles. In the last columns 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-12.4.0.0: CPLEX
Bonmin-1.5.1: projects.coin-or.org/Bonmin (Bonmin: hybrid algorithm. with Cbc)
Couenne-0.3.1: projects.coin-or.org/Couenne
FilMINT: currently only at NEOS, (run locally)
GUROBI-4.6.0: gurobi.com
SCIP-2.1.0: scip.zib.de (with CPLEX and IPOPT)
XPRESS-7.2.1: XPRESS

Times given are user times in seconds. Time limit 10,800 seconds.

QP
==

Scaled geometric means of runtimes

60	317	2.69	260	1	14.5	2.29

problem	Bonm	Couen	CPLEX	FilMI	GUROBI	SCIP	XPRESS

QCQP
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Scaled geometric means of runtimes

11.8	35.98	2.46	30.0	1	

problem	Bonmin	Couenne	CPLEX	FilMINT	XPRESS

Observations and Conclusions

- Observation: TTB (**Tuning To the Benchmarks**)
  - CPLEX-12.3 -> CPLEX-12.4preview
    - better for MIPLIB benchmarks
    - worse for pathological ones
  - MOSEK-6.0.0.122 -> 6.0,0.124 Changelog
    - Improved the interior point optimizers for linear problems for certain hard problems.

- Conclusions: **Declare Winners?**
  - **MIPLIB-bench**: CPLEX/Gurobi-XPRESS
  - **MIPLIB-feas**: Gurobi-CPLEX-XPRESS, FEASPUMP close
  - **MIPLIB-infeas**: Gurobi, CPLEX close, XPRESS slow
  - **Pathological**: Gurobi-CPLEX, SCIP,FSCIP respectable
  - **MIQP**: Gurobi
  - **MIQCQP**: XPRESS
  - **LP**: CPLEX/Gurobi; **QP/QCQP**: XPRESS/MOSEK

Thank you!