Latest Benchmarks of Optimization Software

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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 in 9 categories

Combinatorial Optimization * CONCORDE [TSP Input]
Global Optimization   * ICOS [AMPL Input]
  * scip [AMPL Input][CPLEX Input][MPS Input][OSIL Input][ZIMPL Input
Linear Programming
  * bpmpd [AMPL Input][LP Input][MPS Input][QPS Input]
  * SoPlex80bit [LP Input][MPS Input]
Mixed Integer Linear Programming
  * feaspump [AMPL Input][LP Input][MPS Input]
  * proxy [CPLEX Input][MPS Input]
  * qsopt_ex [AMPL Input][LP Input][MPS Input]
  * scip [AMPL Input][LP Input][MPS Input] [ZIMPL Input][OSIL Input]
Nondifferentiable Optimization * condor [AMPL Input]
Semi-infinite Optimization   * nsips [AMPL Input]

Mixed Integer Nonlinearly Constrained Optimization
* scip [AMPL Input][CPLEX Input][MPS Input][OSIL Input][ZIMPL Input]

Semidefinite (and SOCP) Programming (also discrete)
    * csdp [MATLAB_BINARY Input][SPARSE_SDPA Input]
    * mosek [MATLAB_BINARY Input][SPARSE_SDPA Input]
    * penbmi [MATLAB Input][MATLAB_BINARY Input][YALMIP Input]
    * pensdp [MATLAB_BINARY Input][SPARSE_SDPA Input]
    * scipsdp [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]

Stochastic Linear Programming   * bnbs [SMPS Input]
                                  * DDSIP [LP Input][MPS Input]
                                  * SD [SMPS Input]

Overview of Talk

- **Current and Selected Benchmarks**

  - Benchmarks of Continuous Optimization Software

    * Simplex/Barrier LP/QP, SDP, NLP, MPEC

  - Benchmarks of Discrete Optimization Software

    * MILP, MIQP, MIQCQP, MISOCP, MINLP

- Observations and Conclusions

COMBINATORIAL OPTIMIZATION

Concorde-TSP with different LP solvers (4-15-2017)

LINEAR PROGRAMMING

* Benchmark of Simplex LP solvers (8-28-2017)
* Benchmark of commercial LP solvers (8-28-2017)
Parallel Barrier Solvers on Large LP/QP problems (8-29-2017)
Large Network-LP Benchmark (commercial vs free) (8-29-2017)

SEMIDEFINITE/SQL PROGRAMMING

SQL problems from the 7th DIMACS Challenge (8-8-2002)
* Several SDP codes on sparse and other SDP problems (7-29-2017)
Infeasible SDP Benchmark (6-1-2016)
* Large SOCP Benchmark (8-28-2017)
* MISOCP Benchmark (8-28-2017)

MIXED INTEGER LINEAR PROGRAMMING

* MILP Benchmark - MIPLIB2010 (9-10-2017)
The Solvable MIPLIB Instances (8-3-2017) (MIPLIB2010)
MILP cases that are slightly pathological (7-15-2017)
Feasibility Benchmark (7-14-2017) (MIPLIB2010)
Infeasibility Detection for MILP Problems (9-24-2017) (MIPLIB2010)

NONLINEAR PROGRAMMING

AMPL-NLP Benchmark (7-23-2017)

MIXED INTEGER QPs and QCPs

* Binary QPLIB Benchmark (7-17-2017)
* QPLIB-QCQP Benchmark (8-11-2017)
Convex Discrete QPLIB Benchmark (7-15-2017)

MIXED INTEGER NONLINEAR PROGRAMMING

* MINLP Benchmark (9-20-2017)

PROBLEMS WITH EQUILIBRIUM CONSTRAINTS

MPEC Benchmark (12-2-2016)

Important features of all our benchmarks

- NO PERFORMANCE PROFILES! (unreliable, TOMS 43)

- Statistics of problems (dimensions etc)

- Links to codes, problems and logfiles given

- Same selection for commercial/free codes

- many benchmark talks on personal webpage to
  TRACK PERFORMANCE OVER TIME

Reasons for updates

- New versions of commercial software

  - CPLEX-12.7.1, GUROBI-7.5

  - KNITRO-10.3, MOSEK-8.1

  - MATLAB-2017b (linprog, intlinprog, fmincon)

- New versions of free software

  - MIPCL, SDPNAL, GOOGLE, SCIP, IPOPT

Overview of Talk

- Current and Selected Benchmarks

  - **Benchmarks of Continuous Optimization Software**

    * **Simplex/Barrier LP/QP, SOCP, SDP, NLP, MPEC**

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    * MILP, MIQP, MIQCQP, MISOCP, MINLP

- Observations and Conclusions

```
28 Aug 2017    ==================================
                 Benchmark of Simplex LP solvers
               ==================================
                 H. Mittelmann (mittelmann@asu.edu)


This benchmark was run on a Linux-PC (i7-4790K, 4.0GHz, 32GB).


The simplex methods were tested of the codes:

  CPLEX-12.7.1     CPLEX
  GUROBI-7.5.0     www.gurobi.com/
  MOSEK-8.1.0.23   www.mosek.com
  XPRESS-8.2.1     XPRESS (1/8 threads)
  CLP-1.16.10      projects.coin-or.org/Clp (with openblas)
  Google-GLOP      LP with Glop
  SOPLEX-3.0.0     soplex.zib.de/
  LP_SOLVE-5.5.2   lpsolve.sourceforge.net/
  GLPK-4.63        www.gnu.org/software/glpk/glpk.html
  MATLAB-R2016a    mathworks.com (dual-simplex)


Unscaled and scaled shifted (by 10 sec) geometric mean of runtimes

              55.5  29.1  107   35.5  49.0   292   437  5068  1203   485
              1.91    1   3.66  1.22  1.69    10    15   174  41.3  16.7
==========================================================================
problem       CPXS  GRBS  MSKS  XPRS   CLP  GLOP SOPLX LPSLV  GLPK  MATL
==========================================================================
```

```
28 Aug 2017   ====================================
               Benchmark of commercial LP solvers
               ====================================
               H. Mittelmann (mittelmann@asu.edu)


This benchmark was run on a Linux-PC (i7-4790K, 4GHz, 32GB).

The barrier(B) and deterministic automatic/concurrent(A) methods were tested of:

 CPLEX-12.7.1  CPLEX
 GUROBI-7.5.0    www.gurobi.com/
 MOSEK-8.1.0.23 www.mosek.com
 XPRESS-8.2.1    XPRESS
 MATLAB-R2016a   mathworks.com (interior-point, NO CROSSOVER!)


Unscaled and scaled shifted (by 10 sec) geometric mean of runtimes


          29.9  16.2  37.1  16.8  46.9  19.6  22.5    361
          1.84     1  2.29  1.03  2.89  1.21  1.39   22.2
=============================================================
45 probs   CPXB  GRBB  MSKB  XPRB  CPXA  GRBA  XPRA    MATB
=============================================================
```

```
29 Jul 2017   =====================================================
              Several SDP-codes on sparse and other SDP problems
              =====================================================
                    Hans D. Mittelmann (mittelmann@asu.edu)


   CSDP-6.2.0:        www.nmt.edu/~borchers/csdp.html
   DSDP-5.8:          www.mcs.anl.gov/hs/software/DSDP/
   MOSEK-8.0.0.81:    mosek.com
   SDPA-7.3.8:        sdpa.sourceforge.net
   SDPT3-4.0:         www.math.nus.edu.sg/~mattohkc/sdpt3.html
   SeDuMi-1.32:       github.com/sqlp/sedumi/
   PENSDP-2.2:        www.penopt.com/pensdp.html
   SDPNAL-0:          www.math.nus.edu.sg/~mattohkc/SDPNAL.html


The codes were run in default mode on an Intel i7-2600 (16GB) under Linux. Given are total CPU sec

Scaled shifted geometric means of runtimes ("1" is fastest solver)
                1.62      4.74       1      2.27      1.53      7.01      3.93      10.5
-------------------------------------------------------------------------------------
count of "a"      7        22         2        21        10         6         4        13
solved of 90     83        73        87        83        84        79        81        56
=====================================================================================
problem        CSDP      DSDP     MOSEK      SDPA     SDPT3    SeDuMi    PENSDP    SDPNAL
=====================================================================================
"a": insufficient accuracy (DIMACS errors)
```

10 Nov 2016   ===
                    Large Second Order Cone Benchmark
                ===
                  Hans D. Mittelmann (mittelmann@asu.edu)

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

MOSEK-8.1.0.23 MOSEK
CPLEX-12.7.1 CPLEX
GUROBI-7.5.0 GUROBI
XPRESS-8.2.1 XPRESS

These codes were tested on a selection of the SOCP problems from CBLIB2014.
The codes were run in default mode on an Intel i7-4790K (4.0 GHz, 32GB). Time limit 1 hr.

	4.13	1.03	1	1.31
problem	CPLEX	GUROBI	MOSEK	XPRESS
solved of 18	18	18	18	18

Overview of Talk

- **Current Benchmarks**

  – Benchmarks of Continuous Optimization Software

    ∗ Simplex/Barrier LP/QP, SDP, NLP, MPEC

  – **Benchmarks of Discrete Optimization Software**

    ∗ **MILP, MIQP, MIQCQP, MISOCP, MINLP**

- **Observations and Conclusions**

```
10 Nov 2016      =====================================
                      Mixed-integer SOCP Benchmark
                 =====================================
                 Hans D. Mittelmann (mittelmann@asu.edu)


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


MOSEK-8.1.0.23 MOSEK
CPLEX-12.7.1 CPLEX
GUROBI-7.5.0 GUROBI
XPRESS-8.2.1 XPRESS
SCIP-4.0.0 SCIP


These codes were tested on a selection of the MISOCP problems from CBLIB2014 and from here.
The codes were run in default mode (except mipgap=0) on an Intel i7-4790K (4.0 GHz, 32GB).
Time limit 2 hrs.


Scaled shifted geometric means of runtimes (t/m counted as maxtime)
```

	3.19	1	9.25	1.12	36
problem	CPLEX	GUROBI	MOSEK	XPRESS	SCIP
solved of 47	37	46	32	45	25

```
10 Sep 2017 =========================================================
            Mixed Integer Linear Programming Benchmark (MIPLIB2010)
            =========================================================
                      H. Mittelmann (mittelmann@asu.edu)


The following codes were run with a limit of 2 hours on the MIPLIB2010 benchmark
set with the MIPLIB2010 scripts (exc Matlab) on two platforms.
1/4 threads: Intel i7-4790K, 4 cores, 32GB, 4GHz, available memory 24GB;
12 threads: Intel Xeon X5680, 12 cores, 32GB, 3.33Ghz, available memory 24GB


CPLEX-12.7.1: CPLEX
GUROBI-7.5.0 GUROBI
ug[SCIP/cpx/spx]-4.0.0: Parallel development version of SCIP (SCIP+CPLEX/SOPLEX on 1 thread)
CBC-2.9.8: CBC
XPRESS-8.2.1: XPRESS
MATLAB-2017a: MATLAB (intlinprog)
MIPCL-1.4.0: MIPCL


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.
```

The third line lists the number of problems (86 total) solved.

```
------------------------------------------------------------------
 1 thr    CBC     CPLEX    GUROBI    SCIPC    SCIPS    XPRESS    MATLAB
------------------------------------------------------------------
unscal   1639     66.7     50.8      435      473       97       2834
scaled   32       1.31     1         8.56     9.32      1.91     56
solved   53       87       87        74       71        85       36
------------------------------------------------------------------



 4 thr    CBC     CPLEX    FSCIPC    FSCIPS    GUROBI    XPRESS    MIPCL*
------------------------------------------------------------------
unscal    843     41.1     278       355       30        47.9      252
scaled    28.2    1.37     9.28      11.9      1         1.60      8.41
solved    66      86       74        74        87        85        79
------------------------------------------------------------------
* 8 threads



12 thr    CBC     CPLEX    FSCIPC    FSCIPS    GUROBI    XPRESS    MIPCL
------------------------------------------------------------------
unscal    668     32.8     286       448       27.9      40.9      209
scaled    24      1.17     10.2      16        1         1.46      7.48
solved    69      86       73        69        87        86        79
------------------------------------------------------------------
```

```
17 Jul 2017                    ========================
                               Binary QPLIB Benchmark
                               ========================
                                 mittelmann@asu.edu


The following codes were run on a 3 GHz Intel i7-5960X (8 cores, 48GB)
on the 96 binary nonconvex problems (23 unconstrained, 73 constrained)
from QPLIB. Mipgap is zero, time limit 1hr, 8 threads.

CPLEX-12.7.1
GUROBI-7.5.0
Baron-17.4.1
ug[cpx,4.0.0], ug[spx,4.0.0]
ANTIGONE-1.1
XPRESS-8.2.1
```

prob#	CPLEX	GUROBI	BARON	FSCIPC	FSCIPS	ANTIGONE	XPRESS
mean	1.37	1	8.85	4.68	4.70	11.7	2.13
solved	42	47	17	22	20	7	33

```
11 Aug 2017                    ====================
                               QPLIB-QCQP Benchmark
                               ====================


The following codes were run on a 3 GHz Intel i7-5960X (8 cores, 48GB)
on the 35 nonconvex QCQPs with quadratic objective and the 48 continuous
QCQPs with linear objective and the 16 nonbinary QPs from QPLIB.

=================================================
 prob#   BARON    ANTIGONE     SCIP    COUENNE
-------------------------------------------------
 mean     5.93          1     2.91      5.79
 solved     12         28       15         9     CPLEX
-----------------------------------------------===========
 0018        f       6552        9         t       779
 0031        t          t        t         t      2543
 0343        f       7682        8         t       788
 2702        t          t       44      3762       110
 2712        f          t     3480         t      7164
 3060        t          t       49         t        86
 3122        t          t      550         t       105
 3523        t          t     2391         t       197
 3870        t          t        t         t      3641
 8505        t        135        t      1410        18
 8777        t          t        t         t      6679
 9048        t          t        t         t      8602
-----------------------------------------------------------
```

20

```
20 Sep 2017  ============================================================
             Mixed Integer Nonlinear Programming Benchmark (MINLPLib2)
             ============================================================
                        H. Mittelmann (mittelmann@asu.edu)


The following codes were run through GAMS-24.9.1 with a limit of 2 hours on these instances
from MINLPLIB2 and with one thread on an Intel i7-4790K, 32GB, 4GHz, available memory 20GB.

Description of selection process of benchmark instances. Statistics of the instances.

ANTIGONE-1.1, BARON-17.8.7, COUENNE-0.5, LINDO-11.0, SCIP-4.0

Table for all solvers, Result files per solver, Log files per solver,
Trace files per solver, Error files per solver


++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
Scaled and shifted geometric means of run times

The second line lists the number of problems (72 total) solved.

The geometric mean is computed on the 49 instances for which no solver failed.
```

	ANTIGONE	BARON	COUENNE	LINDO	SCIP
geom mean	4.34	1	9.96	5.96	4.50
solved	46	58	24	34	37

- Observations and Conclusions: **Declare Winners?**

  – **Simplex LP**: Gurobi, XPRESS, CLP, ….CPLEX, MOSEK

  – **commercial LP**: GB, XB, ….GA,XA,CB, ….MB,CA

  – **SDP**: MSK, SDPT3, CSDP, …SDPA,PEN,DSDP,SeDuMi

  – **SOCP**: MOSEK, Gurobi, XPRESS, …CPLEX

  – **MISOCP**: Gurobi, XPRESS, …CPLEX, …MOSEK, …SCIP

  – **MIPLIB**: Gurobi, CPLEX, …XPRESS, …MIPCL,SCIP,CBC

  – **QPLIB**: Gurobi, CPLEX,XPRESS - ANT,SCIP,COU,BARON

  – **MINLP**: BARON, ….ANTIG, SCIP, …. LINDO, COU

Thank you!