The State-of-the-Art in Optimization Software

ISMP 2015

Pittsburgh, PA

15 July 2015

H. D. Mittelmann
School of Math and Stat Sciences
Arizona State University

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]
```

We maintain the following NEOS solvers (cont.)

Mixed Integer Nonlinearly Constrained Optimization

* scip [AMPL Input][CPLEX Input][MPS Input][OSIL Input][ZIMPL Input]

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]

Stochastic Linear Programming

* bnbs [SMPS Input]
* DDSIP [LP Input][MPS Input]
* SD [SMPS Input]

Overview of Talk

- **Current and Selected(*) Benchmarks**
  - Benchmark of Simplex and parallel LP solvers
  - Several SDP-codes on sparse and other SDP problems
  - MISOCP and large SOCP Benchmark
  - MILP benchmarks (MIPLIB2010, EASY)
  - Feasibility/Infeasibility for MILP Problems
- Observations and Conclusions

COMBINATORIAL OPTIMIZATION

Concorde-TSP with different LP solvers (7-2-2015)

LINEAR PROGRAMMING

* Benchmark of Simplex LP solvers (7-3-2015)
* Benchmark of parallel LP solvers (7-9-2015)
Parallel Barrier Solvers on Large LP/QP problems (6-29-2015)
Large Network-LP Benchmark (commercial vs free) (6-28-2015)

SEMIDEFINITE/SQL PROGRAMMING

SQL problems from the 7th DIMACS Challenge (8-8-2002)
* Several SDP codes on sparse and other SDP problems (12-14-2014)
* MISOCP and large SOCP Benchmark (7-6-2015)

MIXED INTEGER LINEAR PROGRAMMING

* MILP Benchmark - MIPLIB2010 (7-8-2015)
* The EASY MIPLIB Instances (7-2-2015) (MIPLIB2010)
MILP cases that are slightly pathological (7-6-2015)
* Feasibility Benchmark (6-29-2015) (MIPLIB2010)
* Infeasibility Detection for MILP Problems (7-5-2015) (MIPLIB2010)

NONLINEAR PROGRAMMING

AMPL-NLP Benchmark (4-23-2015)

MIXED INTEGER QPs and QCPs

MIQ(C)P Benchmark (7-2-2015)

MIXED INTEGER NONLINEAR PROGRAMMING

MINLP Benchmark (1-9-2014)

PROBLEMS WITH EQUILIBRIUM CONSTRAINTS

MPEC Benchmark (6-1-2015)

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

Overview of Talk

- **Current and Selected(*) Benchmarks**
  - **Benchmark of Simplex and parallel LP solvers**
  - Several SDP-codes on sparse and other SDP problems
  - MISOCP and large SOCP Benchmark
  - MILP benchmarks (MIPLIB2010, EASY)
  - Feasibility/Infeasibility for MILP Problems
- Observations and Conclusions

3 Jul 2015

Benchmark of Simplex LP solvers

H. Mittelmann <mittelmann@asu.edu>

This benchmark was run on a Linux-PC (i7-2600, 16GB).
The simplex methods were tested of the codes:

CPLEX-12.6.2	CPLEX
GUROBI-6.0.0	www.gurobi.com/
MOSEK-7.1.0.24	www.mosek.com
XPRESS-7.9.0:	XPRESS
CLP-1.16.6:	CLP
Google-GLOP:	Google
SOPLEX-2.2.0:	SOPLEX
LP_SOLVE-5.5.2:	LPSOLVE
GLPK-4.55:	GLPK
MATLAB-2014b:	Matlab's dual-simplex

Scaled shifted geometric mean of runtimes (40 instances)

	CPXS	GRBS	MSKS	XPRS	CLP$	GLOP	SOPLX	LPSLV	GLPK	MATL
	1.94	1.18	2.37	1.12	1	11.8	9.67	93.9	40.7	14.7
problem	CPXS	GRBS	MSKS	XPRS	CLP$	GLOP	SOPLX	LPSLV	GLPK	MATL

```
 9 Jul 2015   ==================================
               Benchmark of parallel LP solvers
              ==================================
               H. Mittelmann (mittelmann@asu.edu)

Sources of problems:

 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 simplex, barrier, and deterministic automatic/concurrent methods were tested of:

 CPLEX-12.6.2    CPLEX
 GUROBI-6.0.0    www.gurobi.com/
 MOSEK-7.1.0.24  www.mosek.com
 XPRESS-7.9.0:   XPRESS

Scaled shifted (by 10 sec) geometric mean of runtimes (40 instances)

           5.42  3.29  6.59  3.14 1.64 1.07 1.55   1   2.18  1.12  1.85  1.41
=============================================================================
problem    CPXS  GRBS  MSKS  XPRS CPXB GRBB MSKB XPRB  CPXA  GRBA  MSKA  XPRA
=============================================================================
```

Overview of Talk

- **Current and Selected(*) Benchmarks**
  - Benchmark of Simplex and parallel LP solvers
  - **Several SDP-codes on sparse and other SDP problems**
  - MISOCP and large SOCP Benchmark
  - MILP benchmarks (MIPLIB2010, EASY)
  - Feasibility/Infeasibility for MILP Problems
- Observations and Conclusions

14 Dec 2014 ==========

Several SDP-codes on sparse and other SDP problems

==========

Hans D. Mittelmann (mittelmann@asu.edu)

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

CSDP-6.1.1:	www.nmt.edu/~borchers/csdp.html
DSDP-5.8:	www.mcs.anl.gov/hs/software/DSDP/
MOSEK-7.1.0.9:	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

Scaled shifted geometric means of runtimes

90 instances	3.81	3.08	1.54	1.52	1	4.57	2.54
count of "a"	6	22	18	21	10	6	4

problem	CSDP	DSDP	MOSEK	SDPA	SDPT3	SeDuMi	PENSDP

"a": insufficient accuracy (DIMACS errors)

Overview of Talk

- **Current and Selected(*) Benchmarks**
  - Benchmark of Simplex and parallel LP solvers
  - Several SDP-codes on sparse and other SDP problems
  - **MISOCP and large SOCP Benchmark**
  - MILP benchmarks (MIPLIB2010, EASY)
  - Feasibility/Infeasibility for MILP Problems
- Observations and Conclusions

6 Jul 2015 ==

MISOCP and large SOCP Benchmark

==

Hans D. Mittelmann (mittelmann@asu.edu)

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

MOSEK-7.1.0.31 MOSEK
CPLEX-12.6.2 CPLEX
GUROBI-6.0.0 GUROBI
XPRESS-7.9.0 XPRESS
SCIP-3.2.0 SCIP

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

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 resp 1 hr.

MISOCP and large SOCP Benchmark

Scaled shifted geometric means of runtimes

2 hours max	1	4.04	14.2	7.13	27
MISOCP problems	CPLEX	GUROBI	MOSEK	XPRESS	SCIP
solved of 42	42	41	29	35	34

1 hour max	2.59	1.84	1	1.20	49
SOCP problems	CPLEX	GUROBI	MOSEK	XPRESS	SCIP
solved of 18	18	17	18	18	1

Overview of Talk

- **Current and Selected(*) Benchmarks**
  - Benchmark of Simplex and parallel LP solvers
  - Several SDP-codes on sparse and other SDP problems
  - MISOCP and large SOCP Benchmark
  - **MILP benchmarks (MIPLIB2010, EASY)**
  - Feasibility/Infeasibility for MILP Problems
- Observations and Conclusions

7 Jul 2015 Mixed Integer Linear Programming Benchmark (MIPLIB2010)

The following codes were run on the MIPLIB2010 benchmark set with the MIPLIB2010
scripts on two platforms
1/4 threads: Intel i7-2600, 4 cores, 16GB, 3.4GHz, available memory 12GB
12 threads: Intel Xeon X5680, 12 cores, 32GB, 3.33Ghz, available memory 24GB

CPLEX-12.6.2: CPLEX
GUROBI-6.0.0: GUROBI
ug[SCIP/cpx/spx]-3.2.0: Parallel development version of SCIP (SCIP+CPLEX/SOPLEX/CLP on 1 thread)
CBC-2.9.4: CBC
XPRESS-7.9.0: XPRESS
MATLAB-2015a: MATLAB (intlinprog)

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.

Unscaled and scaled geometric means of times, 87 problems, Time limit 2 hrs

1 thr	CBC	CPLEX	GUROBI	SCIPC	SCIPS	XPRESS	MATLAB
unscal	1925	105	117	541	642	97	3925
scaled	19.7	1.08	1.20	5.55	6.59	1	40
solved	48	85	84	72	70	86	22

4 thr	CBC	CPLEX	FSCIPC	FSCIPS	GUROBI	XPRESS
unscal	2401	121	133	600	1015	150
scaled	18	1	1.1	4.97	8.41	1.24
solved	36	83	80	69	60	81

12 thr	CBC	CPLEX	FSCIPC	FSCIPS	GUROBI	XPRESS
unscal	615	44	339	502	44	50
scaled	14	1.01	7.67	11	1	1.14
solved	69	87	72	71	86	86

8 Jul 2015

The EASY MIPLIB Instances (MIPLIB2010)

H. Mittelmann (mittelmann@asu.edu)

CBC-2.9.4: CBC
CPLEX-12.6.2: CPLEX
GUROBI-6.0.0: GUROBI
XPRESS-7.9.0: XPRESS
FiberSCIP[cpx]-3.1.1: Parallel development version of SCIP

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

++
Shifted geometric means of times

The fastest solver is scaled to 1. Max time 2 hours. Max memory 24GB.
Non-successes counted as max-time.

no. of probs	CBC	CPLEX	GUROBI	XPRESS	FSCIP
205	12	1.05	1	1.74	7.64
solved	115	194	194	170	139

Overview of Talk

- **Current and Selected(*) Benchmarks**
  - Benchmark of Simplex and parallel LP solvers
  - Several SDP-codes on sparse and other SDP problems
  - MISOCP and large SOCP Benchmark
  - MILP benchmarks (MIPLIB2010, EASY)
  - **Feasibility/Infeasibility for MILP Problems**
- Observations and Conclusions

29 Jun 2015

Feasibility Benchmark

H. Mittelmann (mittelmann@asu.edu)

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 i7-4790K with 4 threads:
CPLEX-12.6.2: CPLEX
FEASPUMP2: as implemented for interactive use at NEOS (utilizes CPLEX)
GUROBI-6.0.0: GUROBI
XPRESS-7.9.0: XPRESS
CBC-2.9.4: 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(33 tot)	CPLEX	FP2	GUROBI	XPRESS	CBC
geometric mean	1.07	3.62	1	4.46	78
problems solved	33	31	33	28	13

5 Jul 2015

Infeasibility Detection for MILP Problems

H. Mittelmann (mittelmann@asu.edu)

CPLEX-12.6.2: CPLEX
GUROBI-6.0.0: GUROBI
ug[SCIP/spx/cpx]-3.2.0: Parallel development version of SCIP
CBC-2.9.4: CBC
XPRESS-7.9.0: XPRESS

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

++
Shifted scaled geometric means of times

All non-successes are counted as max-time (1 hr). The instance
zib02 has been omitted due to memory issues.

	CBC	CPLEX	FSCIPC	FSCIPS	GUROBI	XPRESS
	84	1	10	14	1.20	1.60
solved of 18:	8	18	14	14	18	18

- Observations and Conclusions: **Declare Winners?**
  - **Simplex LP**: CLP, XPRESS, Gurobi, ...CPLEX
  - **parallel LP**: XPRB, GRBB, GRBA, MSKB, XPRA, CPXB
  - **sparse SDP**: SDPT3, ...SDPA, MOSEK, ...PENSDP, DSDP, CSDP
  - **MISOCP**: CPLEX, ...Gurobi, ...XPRESS, ...MOSEK, ...SCIP
  - **SOCP**: MOSEK, XPRESS, Gurobi, CPLEX, SCIP
  - **MIPLIB**: balanced; **FEASIBLE**: Gurobi, CPLEX, ...XPRESS
  - **INFEASIBLE**: CPLEX, Gurobi, ...XPRESS, ...FSCIP

Thank you!