Selected Benchmark Results

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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]
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]
  * 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**
  – Benchmark of Simplex and commercial LP solvers
  – Several SDP-codes on sparse and other SDP problems
  – MISOCOP and large SOCP Benchmarks
  – MILP benchmarks (MIPLIB2010, SOLVABLE)
  – AMPL-NLP and MINLP benchmarks

• Observations and Conclusions
COMBINATORIAL OPTIMIZATION

Concorde-TSP with different LP solvers (11-30-2015)

LINEAR PROGRAMMING

* Benchmark of Simplex LP solvers (11-10-2016)
* Benchmark of commercial LP solvers (11-11-2016)
Parallel Barrier Solvers on Large LP/QP problems (11-11-2016)
Large Network-LP Benchmark (commercial vs free) (11-9-2016)

SEMIDEFINITE/SQL PROGRAMMING

SQL problems from the 7th DIMACS Challenge (8-8-2002)
* Several SDP codes on sparse and other SDP problems (10-13-2016)
Infeasible SDP Benchmark (10-18-2016)
* Large SOCP Benchmark (11-10-2016)
* MISOCP Benchmark (11-10-2016)
MIXED INTEGER LINEAR PROGRAMMING

* MILP Benchmark - MIPLIB2010 (11-11-2016)
* The Solvable MIPLIB Instances (11-11-2016) (MIPLIB2010)
MILP cases that are slightly pathological (11-8-2016)
Feasibility Benchmark (11-8-2016) (MIPLIB2010)
Infeasibility Detection for MILP Problems (11-8-2016) (MIPLIB2010)

NONLINEAR PROGRAMMING

* AMPL-NLP Benchmark (9-26-2016)

MIXED INTEGER QPs and QCPs

MIQ(C)P Benchmark (11-8-2016)

MIXED INTEGER NONLINEAR PROGRAMMING

* MINLP Benchmark (9-24-2016)

PROBLEMS WITH EQUILIBRIUM CONSTRAINTS

MPEC Benchmark (9-21-2016)
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, GUROBI-7
  – (KNITRO-10.2), MOSEK-8
  – MATLAB-2016b(linprog, intlinprog, fmincon)

• New versions of free software
  – MIPCL, SDPNAL, CBC, CLP, GOOGLE, SCIP, IPOPT
Overview of Talk

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  - AMPL-NLP and MINLP benchmarks

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

The simplex methods were tested of the codes:

- CPLEX-12.7.0  CPLEX
- GUROBI-7.0.0  www.gurobi.com/
- MOSEK-8.0.0.42  www.mosek.com
- XPRESS-8.0.0  XPRESS (1/8 threads)
- CLP-1.16.8  projects.coin-or.org/Clp (with openblas)
- Google-GLOP  LP with Glop
- SOPLEX-2.2.0  soplex.zib.de/
- LP_SOLVE-5.5.2  lpsolve.sourceforge.net/
- GLPK-4.60  www.gnu.org/software/glpk/glpk.html
- MATLAB-R2016a  mathworks.com (dual-simplex)

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

<table>
<thead>
<tr>
<th>Problem</th>
<th>CPXS</th>
<th>GRBS</th>
<th>MSKS</th>
<th>XPR1</th>
<th>XPRS</th>
<th>CLP</th>
<th>GLOP</th>
<th>SOPLX</th>
<th>LPSLV</th>
<th>GLPK</th>
<th>MATL</th>
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<tr>
<td></td>
<td>78.7</td>
<td>41.8</td>
<td>105</td>
<td>45.3</td>
<td>42.3</td>
<td>42.9</td>
<td>292</td>
<td>434</td>
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<td>1843</td>
<td>485</td>
</tr>
<tr>
<td></td>
<td>1.88</td>
<td>1</td>
<td>2.52</td>
<td>1.08</td>
<td>1.01</td>
<td>1.03</td>
<td>6.98</td>
<td>10.4</td>
<td>121</td>
<td>44.1</td>
<td>11.6</td>
</tr>
</tbody>
</table>

10 Nov 2016  ==================================
Benchmark of Simplex LP solvers  
==================================
H. Mittelmann (mittelmann@asu.edu)

=============================================================================
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-12.7.0 CPLEX
- GUROBI-7.0.0 www.gurobi.com/
- MOSEK-8.0.0.42 www.mosek.com
- XPRESS-8.0.0 XPRESS
- MATLAB-R2016a mathworks.com (interior-point, NO CROSSOVER!)

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

<table>
<thead>
<tr>
<th></th>
<th>CPXB</th>
<th>GRBB</th>
<th>MSKB</th>
<th>XPRB</th>
<th>CPXA</th>
<th>GRBA</th>
<th>XPRA</th>
<th>MATB</th>
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</thead>
<tbody>
<tr>
<td>runtime</td>
<td>27.5</td>
<td>17.9</td>
<td>34.0</td>
<td>17.6</td>
<td>44.9</td>
<td>23.4</td>
<td>23.3</td>
<td>361</td>
</tr>
<tr>
<td>scaled</td>
<td>1.56</td>
<td>1.01</td>
<td>1.95</td>
<td>1</td>
<td>2.55</td>
<td>1.33</td>
<td>1.32</td>
<td>20.5</td>
</tr>
</tbody>
</table>

45 probs CPXB GRBB MSKB XPRB CPXA GRBA XPRA MATB
Overview of Talk

• Current and Selected(*) Benchmarks
  – Benchmark of Simplex and commercial LP solvers
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    – MISOCP and large SOCP Benchmark
    – MILP benchmarks (MIPLIB2010, SOLVABLE)
    – AMPL-NLP and MINLP benchmarks

• Observations and Conclusions
Several SDP-codes on sparse and other SDP problems

Hans D. Mittelmann (mittelmann@asu.edu)

<table>
<thead>
<tr>
<th>Code</th>
<th>Website/Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSDP-6.1.1</td>
<td><a href="http://www.nmt.edu/~borchers/csdp.html">www.nmt.edu/~borchers/csdp.html</a></td>
</tr>
<tr>
<td>DSDP-5.8</td>
<td><a href="http://www.mcs.anl.gov/hs/software/DSDP/">www.mcs.anl.gov/hs/software/DSDP/</a></td>
</tr>
<tr>
<td>MOSEK-8.0.0.36</td>
<td>mosek.com</td>
</tr>
<tr>
<td>SDPA-7.3.8</td>
<td>sdpa.sourceforge.net</td>
</tr>
<tr>
<td>SDPT3-4.0</td>
<td><a href="http://www.math.nus.edu.sg/~mattohkc/sdpt3.html">www.math.nus.edu.sg/~mattohkc/sdpt3.html</a></td>
</tr>
<tr>
<td>SeDuMi-1.32</td>
<td>github.com/sqlp/sedumi/</td>
</tr>
<tr>
<td>PENSDP-2.2</td>
<td><a href="http://www.penopt.com/pensdp.html">www.penopt.com/pensdp.html</a></td>
</tr>
<tr>
<td>SDPNAL-0</td>
<td><a href="http://www.math.nus.edu.sg/~mattohkc/SDPNAL.html">www.math.nus.edu.sg/~mattohkc/SDPNAL.html</a></td>
</tr>
</tbody>
</table>

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

Scaled shifted geometric means of runtimes ("1" is fastest solver)

<table>
<thead>
<tr>
<th></th>
<th>5.21</th>
<th>4.21</th>
<th>1</th>
<th>2.08</th>
<th>1.37</th>
<th>6.24</th>
<th>3.46</th>
<th>9.42</th>
</tr>
</thead>
<tbody>
<tr>
<td>count of &quot;a&quot;</td>
<td>6</td>
<td>22</td>
<td>2</td>
<td>21</td>
<td>10</td>
<td>6</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>solved of 90</td>
<td>82</td>
<td>73</td>
<td>87</td>
<td>83</td>
<td>84</td>
<td>79</td>
<td>81</td>
<td>56</td>
</tr>
</tbody>
</table>

================================================================================================

problem     | CSDP | DSDP | MOSEK | SDPA | SDPT3 | SeDuMi | PENSDP | SDPNAL |
================================================================================================
"a": insufficient accuracy (DIMACS errors)
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• Observations and Conclusions
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-8.0.0.42 MOSEK
CPLEX-12.7.0 CPLEX
GUROBI-7.0.0 GUROBI
XPRESS-8.0.0 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.

<table>
<thead>
<tr>
<th>problem solved of 18</th>
<th>CPLEX</th>
<th>GUROBI</th>
<th>MOSEK</th>
<th>XPRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18</td>
<td>18</td>
<td>17</td>
<td>18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>time</th>
<th>4.10</th>
<th>1.26</th>
<th>1.62</th>
</tr>
</thead>
</table>

10 Nov 2016
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-8.0.0.42 MOSEK
CPLEX-12.7.0 CPLEX
GUROBI-7.0.0 GUROBI
XPRESS-8.0.0 XPRESS
SCIP-3.2.0 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)

<table>
<thead>
<tr>
<th>problem solved of 47</th>
<th>CPLEX</th>
<th>GUROBI</th>
<th>MOSEK</th>
<th>XPRESS</th>
<th>SCIP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>37</td>
<td>46</td>
<td>32</td>
<td>45</td>
<td>23</td>
</tr>
</tbody>
</table>

3.40 1 9.66 1.37 54
Overview of Talk

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  - AMPL-NLP and MINLP benchmarks

- Observations and Conclusions
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-12.7.0: CPLEX
Gurobi-7.0.0 Gurobi
ug[Scip/cpx/spx]-3.2.1: Parallel development version of SCIP (SCIP+CPLEX/SOPLEX on 1 thread)
CBC-2.9.8: CBC
Xpress-8.0.0: Xpress
Matlab-2016b: MATLAB (intlinprog)
Mipcl-1.1.2: 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.
Unscaled and scaled shifted geometric means of run times

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

<table>
<thead>
<tr>
<th>thr</th>
<th>CBC</th>
<th>CPLEX</th>
<th>GUROBI</th>
<th>SCIPC</th>
<th>SCIPS</th>
<th>XPRESS</th>
<th>MATLAB</th>
<th>MIPCL</th>
<th>unscal</th>
<th>scaled</th>
<th>solved</th>
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<tbody>
<tr>
<td>1</td>
<td>1611</td>
<td>75</td>
<td>59.6</td>
<td>420</td>
<td>631</td>
<td>92</td>
<td>3117</td>
<td>849</td>
<td></td>
<td></td>
<td>53</td>
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<tr>
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<td></td>
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<td></td>
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<td>27</td>
<td>1.26</td>
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<td>86</td>
</tr>
<tr>
<td>4</td>
<td>824</td>
<td>45.2</td>
<td>345</td>
<td>638</td>
<td>32.9</td>
<td>48.4</td>
<td>382</td>
<td></td>
<td></td>
<td></td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>25.1</td>
<td>1.38</td>
<td>10.5</td>
<td>19</td>
<td>1</td>
<td>1.47</td>
<td>11.6</td>
<td></td>
<td></td>
<td></td>
<td>65</td>
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<td></td>
<td>65</td>
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<tr>
<td>12</td>
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<td>33.7</td>
<td>331</td>
<td>510</td>
<td>31.6</td>
<td>44</td>
<td>324</td>
<td></td>
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<tr>
<td></td>
<td>21</td>
<td>1.07</td>
<td>10.5</td>
<td>16</td>
<td>1</td>
<td>1.39</td>
<td>10</td>
<td></td>
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</tr>
<tr>
<td></td>
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<td>86</td>
<td>85</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Solvable MIPLIB Instances (MIPLIB2010)

H. Mittelmann (mittelmann@asu.edu)

The following codes were run on the "green" problems from MIPLIB2010

CBC-2.9.8: CBC
CPLEX-12.7.0: CPLEX
GUROBI-7.0.0: GUROBI
XPRESS-8.0.0: XPRESS
FiberSCIP[cpx]-3.2.0: Parallel development version of SCIP

<table>
<thead>
<tr>
<th>no. of probs</th>
<th>CBC</th>
<th>CPLEX</th>
<th>GUROBI</th>
<th>XPRESS</th>
<th>FiberSCIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 threads</td>
<td>1183</td>
<td>85.7</td>
<td>76</td>
<td>158</td>
<td>727</td>
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<tr>
<td>solved</td>
<td>118</td>
<td>201</td>
<td>207</td>
<td>178</td>
<td>142'</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>no. of probs</th>
<th>CPLEX</th>
<th>GUROBI</th>
<th>XPRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 threads</td>
<td>79.9</td>
<td>69.3</td>
<td>139</td>
</tr>
<tr>
<td>solved</td>
<td>206</td>
<td>210</td>
<td>181</td>
</tr>
</tbody>
</table>
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• Observations and Conclusions
26 Sep 2016

AMPL-NLP Benchmark

(mittelmann@asu.edu)

IPOPT-3.12.3 projects.coin-or.org/Ipopt (MA97, also MA86 results, 4 threads)
KNITRO-10.0 www.artelys.com/knitro/
LOQO-7.03 www.princeton.edu/~rvdb/
PENNON-0.9 www.penopt.de/pennlp.html
SNOPT-7.5-1.5 www.scicomp.ucsd.edu/~peg/
CONOPT-3.17A www.conopt.com/
WORHP-1.8 www.worhp.de/
XPRESS-8.0.0(Nonlinear) www.fico.com
FMINCON-2016a www.mathworks.com

For AMPL models see plato.asu.edu/ftp/ampl-nlp-source

The codes were run in default mode, except as indicated and with a CPU time limit of 2hrs on a 16GB, 3.4GHz Intel i7-2600. Means for table instances only.

Partial listing (123 instances; logfiles are complete)

<table>
<thead>
<tr>
<th></th>
<th>IPOPT</th>
<th>KNIT</th>
<th>LOQO</th>
<th>PENN</th>
<th>SNOPT</th>
<th>CONOPT</th>
<th>WORHP</th>
<th>XPRESS</th>
<th>FMNCON</th>
</tr>
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<tr>
<td>scaled</td>
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<td>1</td>
<td>21.2</td>
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<td>11.6</td>
<td>1.05</td>
<td>15</td>
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<tr>
<td>shifted</td>
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<td></td>
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<tr>
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</tbody>
</table>

23
The following codes were run through GAMS-24.7.4 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-16.8.24, COUENNE-0.5, LINDO-9.0, SCIP-3.2

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 54 instances for which no solver failed.

<table>
<thead>
<tr>
<th></th>
<th>ANTIGONE</th>
<th>BARON</th>
<th>COUENNE</th>
<th>LINDO</th>
<th>SCIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>geom mean</td>
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<td>11.5</td>
<td>13.5</td>
<td>6.49</td>
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<tr>
<td>solved</td>
<td>39</td>
<td>58</td>
<td>24</td>
<td>19</td>
<td>35</td>
</tr>
</tbody>
</table>
- Observations and Conclusions: **Declare Winners?**
  - **Simplex LP**: CLP, XPRESS, Gurobi, ....CPLEX, MOSEK
  - **commercial LP**: XB, GB, ....XA,GA,CB, ....MB,CA
  - **SDP**: MSK, SDPT3, ...SDPA, ...PEN,DSDP,CSDP,SDPNAL
  - **SOCP**: MOSEK, ...Gurobi, ...XPRESS, ...CPLEX
  - **MISOCP**: Gurobi, XPRESS, ...CPLEX, ....MOSEK, ....SCIP
  - **MIPLIB**: Gurobi, CPLEX, ...XPRESS, ...SCIP,MIPCL,CBC
  - **MINLP**: BARON, ....ANTIG, SCIP, ....COU, LINDO
Thank you!