# MB07: The Science of (Optimizing) Better

**Benchmarking of (Continuous) Optimization Software**
Presenting Author: Hans D. Mittelmann

**MIPLIB 20XX: On the Difficulties to Find a Good Set of MIP Instances for Benchmarking**
Presenting Author: Thorsten Koch

**Performance Analysis of Grid-Enabled GAMS**
Presenting Author: Steven Dirkse

**State-of-the-Optimization Using Xpress-MP v2006**
Presenting Author: Alkis Vazacopoulos

# Benchmarking 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 (8 categories)

```
Combinatorial Optimization  * concorde [TSP Input]
Global Optimization         * icos [AMPL Input]
Linear Programming
  * bpmpd [AMPL Input][LP Input][MPS Input][QPS Input]
  * qsopt_ex [LP Input][MPS Input]
Mixed Integer Linear Programming
  * feaspump [AMPL Input][CPLEX Input][MPS Input]
  * scip [AMPL Input][CPLEX Input][MPS Input][ZIMPL 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]
* sdpa-c [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]

NEOS solver usage statistic for 2006 (1/1-10/31)

- BPMPD **5324**
- SCIP **3116**
- FEASPUMP **1819**
- SDPA **1237**
- CONCORDE **1190**

NEOS solver usage statistic for 2006 (1/1-10/31)

- SDPT3 **218**
- CSDP **192**
- CONDOR **183**
- SEDUMI **142**
- BNBS **141**

NEOS solver usage statistic for 2006 (1/1-10/31)

- PENBMI **133**
- ICOS **87**
- SDPLR **71**
- DDSIP **59**
- PENSDP **42**

# Overview of Talk

- **Current and some recently updated Benchmarks**
  - Parallel Benchmarks (CSDP on SDP, CPLEX on MIP)
  - SDPs with free variables (more at 4:30 in MD07)
  - MILP benchmark (free codes)
  - MI(Q)QP Benchmark
  - Commercial and other (QC)QP Solvers
- Conclusions

SERIAL vs PARALLEL OPTIMIZATION

* Parallel CSDP on SDP problems (8-22-2006)
* Parallel CPLEX on MIP problems (9-9-2006)

COMBINATORIAL OPTIMIZATION

Concorde-TSP with different LP solvers (8-8-2006)

LINEAR PROGRAMMING

Benchmark of commercial LP solvers (7-12-2006)

Benchmark of free LP solvers (8-3-2006)

NONLINEAR PROGRAMMING

* Benchmark of commercial and other (QC)QP Solvers (11-3-2006)

AMPL-NLP Benchmark, IPOPT, KNITRO, LOQO, PENNLP & SNOPT (10-27-2006)

SEMIDEFINITE/SQL PROGRAMMING

* Several SDP-codes on SDP problems with free variables (10-17-2006)

Several SDP codes on problems from SDPLIB (7-19-2006)

SQL problems from the 7th DIMACS Challenge (8-8-2002)

Newer SDP/SOCP-codes on the 7th DIMACS Challenge problems(7-18-2006)

Several SDP codes on sparse and other SDP problems (7-19-2006)

SOCP (second-order cone programming) Benchmark (10-28-2006)

MIXED INTEGER LINEAR PROGRAMMING

* MILP Benchmark - free codes (9-25-2006)

MIXED INTEGER NONLINEAR PROGRAMMING

* MI(Q)QP Benchmark (8-2-2006)

PROBLEMS WITH EQUILIBRIUM CONSTRAINTS

MPEC Benchmark (9-12-2006)

**Important features of all our benchmarks**

- Links to codes given
- Links to test problems given
- Links to full logfiles given

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22 Aug 2006

## Parallel CSDP on SDP problems

A partly Open-MP parallelized version of CSDP was run on a 24-proc Sun E6500 HPC server. Given is the speedup for 2 to 16 processors. The problems are taken from our Sparse SDP Benchmark (more in MD07)

| problem | var | cons | 2 | 4 | 8 | 16 |
|---|---|---|---|---|---|---|
| trto-4 | 1,200 | 1,874 | 1.57 | 2.53 | 3.64 | 4.52 |
| taha1b | 1,610 | 8,007 | 1.80 | 3.36 | 6.01 | 11.18 |
| mater-4 | 4,807 | 12,498 | 1.74 | 2.82 | 3.84 | 5.25 |
| mater-5 | 10,143 | 26,820 | 1.90 | 3.43 | 5.66 | 8.81 |
| mater-6 | 20,463 | 56,311 | 1.94 | 3.71 | 6.34 | 11.57 |

9 Sep 2006

## Parallel CPLEX on MIP problems

elapsed CPU seconds on 2.4GHz Opteron (64-bit, Linux)

| class | problem | Opter-1 | Opter-2 | Opt-dual |
|---|---|---|---|---|
| MILP | bienst2 | 2529 | 608 | 762 |
| | lrn | 114 | 85 | 356 |
| | mas74 | 897 | 441 | 483 |
| | neos13 | 2073 | 1694 | 2266 |
| | neos5 | 1169 | >40000 | |
| | seymour1 | 669 | 449 | 526 |

"c": problem convex

| | | | | | |
|---|---|---|---|---|---|
| MIQP | ibienst1 | | 2742 | 1330 | 1105 |
| | inug08 | c | 7973 | 4761 | 10209 |
| | iqap10 | | 1679 | 457 | 687 |
| | isqp | c | 4755 | 2824 | 8827 |
| MIQQP | ibienst1 | | 3132 | 1878 | 2644 |
| | imisc07 | | 6460 | 3255 | 3445 |
| | imod011 | c | 7348 | 9463 | 10014 |
| | inug06-3rd | c | 6588 | 6890 | 7833 |
| | inug08 | c | 4221 | 2336 | 2768 |
| | iran13x13 | | 8756 | 3876 | 4278 |
| | CLay0304M | c | 1278 | 630 | 1329 |

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Several SDP-codes on SDP problems with free variables

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Thirty problems, first twenty were generated for [1]
Last ten were generated with [3]  (solveMaxCut.m)

[1] M. Anjos, S. Burer, On Handling Free Variables in
Interior-Point Methods for Conic Linear Optimization
technical report 1456, University of Iowa (2006)

[2] K. Kobayashi, K. Nakata and M. Kojima, A Conversion
of an SDP Having Free Variables into the Standard Form SDP
June 2005. Revised April 2006. to appear in COAP

[3] http://www.is.titech.ac.jp/~kojima/SparsePOP/

SDP-codes on problems with free variables (summary)

Accuracy (vanilla/default codes)

| code | best | sec best |
|---|---|---|
| CSDP | 16 | 9 |
| SeDuMi | 7 | 9 |
| SeDuMif | 6 | 5 |
| SDPT3 | 1 | 7 |

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Mixed Integer Linear Programming Benchmark (free codes)

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The MPS-datafiles for all testcases are in one of
http://miplib.zib.de/
http://plato.asu.edu/ftp/fctp/
http://coral.ie.lehigh.edu/mip-instances/
http://plato.asu.edu/ftp/milp/
http://www.ps.uni-sb.de/~walser/acc/acc.html
http://www.ieor.berkeley.edu/~atamturk/data/

| | |
|---|---|
| CBC-1.01: | https://projects.coin-or.org/Cbc |
| GLPK-4.11: | http://www.gnu.org/software/glpk/glpk.html |
| MINTO-3.1: | http://coral.ie.lehigh.edu/~minto/ |
| SCIP-0.90: | http://scip.zib.de/ |
| SYMPHONY-5.1a: | https://projects.coin-or.org/SYMPHONY |
| CPLEX-10.01: | (for comparison purposes; mipgap=0, absmipgap=1e-9) |

```
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Mixed Integer Linear Programming Benchmark (free codes)
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Solved of 67 total cases in 2 hrs on 3.2GHz P4:

   CPLEX-10:       64
   SCIP-CPLEX:     63
   SCIP-MOSEK:     58
   SCIP-SOPLEX:    53
   CBC:            40
   MINTO:          30      (with CLP, with CPLEX: 39)
   GLPK:           22
   SYMPHONY:       18
```

```
=====================================================
Mixed Integer Linear Programming Benchmark (free codes)
=====================================================

60 cases solved by both CPLEX and SCIP-C
   CPLEX faster by 5 or more:  25
   SCIP-C faster by 5 or more:  4
   CPLEX solves, SCIP-C not:    4
   SCIP-C solves, CPLEX not:    3

38 cases solved by both CBC and SCIP-S
   CBC faster by 3 or more:     8
   SCIP-S faster by 3 or more: 15
```

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# Mixed Integer (Q)QP Benchmark

MIQP cases from http://plato.asu.edu/ftp/ampl_files/miqp_ampl/
also solved as MIQQP with

CPLEX-10.01: http://www.cplex.com/
Bonmin-0.9: https://projects.coin-or.org/Bonmin
(Bonmin: default hybrid algorithm. with Clp)
Bonmin-0.9: https://projects.coin-or.org/Bonmin
(B-OA-C: outer approx. with CPLEX)

on a 2.4GHz Opteron (Linux). "t" > 3 hrs, "f" fail

Mixed Integer (Q)QP Benchmark (convex cases)

| | QP | | | QQP | | |
|---|---|---|---|---|---|---|
| problem | Bonmin | B-OA-C | CPLEX | Bonmin | B-OA-C | CPLEX |
| ibell3a | 48 | 8 | 9 | 53 | 8 | 607 |
| ibienst1 | 1482 | 6304 | 2668 | 1615 | 7636 | 3129 |
| icap6000 | 3250 | 51 | 14 | t | 156 | t |
| ilaser0 | f | 28 | 741 | f | 58 | t |
| imod011 | 8122 | t | 124(?) | t | t | 8629 |
| inug08 | t | t | 8426 | t | t | 4102 |
| iqiu | 807 | t | 417 | 781 | t | t |
| isqp0 | (1)f | f | 99 | (2)f | f | t |

(1) B-BB solves in 4273 s (2) B-BB solves in 4487 s

Mixed Integer (Q)QP Benchmark (nonconvex cases)

| | QP | | | QQP | | |
|---|---|---|---|---|---|---|
| problem | Bonmin | B-OA-C | CPLEX | Bonmin | B-OA-C | CPLEX |
| ivalues | 2010 | t | f | 1767 | t | f |
| iair04 | 3460 | 1043 | 196 | 4986 | 1584 | t |
| iair05 | 1846 | 181 | 202 | 1690 | 124 | t |
| ieilD76 | 859 | 131 | 27 | 1032 | 113 | f |
| imas284 | 780 | 13 | 22 | 798 | 14 | t |
| imisc07 | 986 | 3489 | 162 | 1044 | 3356 | 6511 |
| iqap10 | 5485 | 2084 | 1637 | t | 4830 | f |
| iran13x13 | 3766 | 126 | 55 | 3808 | 231 | 8839 |
| iran8x32 | 257 | 61 | 18 | 525 | 210 | t |
| iswath2 | (3)t | 148 | 245 | (4)t | 132 | f |

(3) B-QG solves in 3627 s (4) B-OA solves in 2853 s

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Benchmark of commercial and other (QC)QP solvers

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Given below is the number of successful runs.
B: dir BRUNEL (46), C: dir CUTE (76), M: dir MISC (16)

| | QP | | | | | QCQP | | | |
|---|---|---|---|---|---|---|---|---|---|
| dir | BPMPD | CPLEX | KNITRO | IPOPT | MOSEK | CPLEX | KNITRO | IPOPT | MOSEK |
| B | 46 | 46 | 46 | 46 | 46 | 45 | 37 | 46 | 46 |
| C | 76 | 74 | 76 | 76 | 75 | 67 | 62 | 74 | 65 |
| M | 16 | 15 | 16 | 16 | 16 | 14 | 16 | 15 | 15 |

Benchmark of commercial and other (QC)QP solvers

| | QP | | | | QCQP | | | |
|---|---|---|---|---|---|---|---|---|
| no | BPMPD | CPLEX | KNITRO | IPOPT | MOSEK | CPLEX | KNITRO | IPOPT | MOSEK |
| 1 | 8 | 8 | 427 | 239 | 10 | 34 | 499 | 252 | 11 |
| 2 | 58 | 18 | 599 | f | 22 | 25 | 786 | f | f |
| 3 | 10 | 9 | 46 | 451 | 19 | 23 | 243 | 505 | 34 |
| 4 | 31 | 24 | 231 | 1644 | 65 | 41 | 1031 | 2293 | 92 |
| 5 | 39 | 157 | 388 | 1926 | f | 774 | 1475 | 5032 | 467 |
| 6 | 27 | 58 | 121 | 675 | 29 | 332 | 474 | 807 | 53 |
| 7 | 59 | 287 | 766 | 3261 | 509 | 968 | 3102 | 8851 | 4825 |
| 8 | 23 | 138 | 367 | 219 | 17 | 362 | 30202 | 249 | 20 |
| 9 | 1 | 1 | 1 | 2 | 1 | 1 | f | 31 | 1 |
| 10 | 1 | 1 | 4 | 6 | 1 | 1 | 2600 | 22 | 1 |

Problem statistics for the QPs

| no | example | var | bounds | equal | nz(A) | nz(Q) |
|---|---|---|---|---|---|---|
| 1 | BOYD1 | 93261 | 93261 | 18 | 802156 | 93261 |
| 2 | BOYD2 | 93263 | 93263 | 186531 | 423784 | 2 |
| 3 | CONT-201 | 40397 | 40397 | 40198 | 199199 | 10400 |
| 4 | CONT-300 | 90597 | 90597 | 90298 | 448799 | 23100 |
| 5 | CVXQP1_L | 10000 | 10000 | 5000 | 14998 | 69968 |
| 6 | CVXQP2_L | 10000 | 10000 | 2500 | 7499 | 69968 |
| 7 | CVXQP3_L | 10000 | 10000 | 7500 | 22497 | 69968 |
| 8 | EXDATA | 1500 | 1500 | 3001 | 7500 | 2250000 |
| 9 | QSHELL | 1476 | 1476 | 487 | 2958 | 2165 |
| 10 | QSHIP08L | 3149 | 3149 | 520 | 9346 | 34495 |

# Conclusions

- Parallel versions effective in continuous and discrete optimization
- Sufficient accuracy on SDPs with free variables with SeDuMi and CSDP
- SCIP-CPLEX competitive for MILP with CPLEX except for speed
- good free MILP solvers: SCIP-SOPLEX, CBC

# Conclusions (cont.)

- free BONMIN competitive with CPLEX for MI(Q)QP, can handle MINLP
- convex QP: BPMPD, CPLEX, MOSEK, KNITRO, IPOPT (in order)
- convex QQP: MOSEK/CPLEX, IPOPT, KNITRO (in order)

**Thank you for your attention**