

# **Benchmark Updates in Integer and Nonlinear Programming**

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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 (**35 percent of NEOS**)

We maintain the following NEOS solvers (8 categories)

Combinatorial Optimization \* CONCORDE [TSP Input]

Global Optimization \* ICOS [AMPL Input]

Linear Programming

\* bmpd [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]

\* qsopt\_ex [LP Input][MPS 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-gmp [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 10/1/07-9/30/08

- **SCIP 12990**
- **BPMPD 9405**
- **FEASPUMP 1971**
- **CONCORDE 1136**
- **QSOPT-EX 881**

## NEOS solver usage statistic for 10/1/07-9/30/08

- **SDPT3 391**
- **BNBS 387**
- **SDPA 277**
- **CONDOR 201**
- **CSDP 194**

## NEOS solver usage statistic for 10/1/07-9/30/08

- **PENBMI 189**
- **ICOS 148**
- **SDPLR 137**
- **NSIPS 110**
- **SEDUMI 85**

NEOS solver usage statistic for 10/1/07-9/30/08

- PENS DP **33**
- SDPA-GMP **14**
- DDSIP **6**

# Overview of Talk

- **Current and the Discrete Benchmarks**
  - Concorde-TSP with different LP solvers
  - Parallel CPLEX on MIP problems
  - Feasibility Benchmark
  - MILP benchmark (free codes)
  - MI(QC)QP Benchmark
- Conclusions

## SERIAL vs PARALLEL OPTIMIZATION

Parallel CSDP on SDP problems (8-22-2006)

\* Parallel CPLEX on MIP problems (6-11-2008)

Parallel CPLEX and MOSEK on LP problems (8-10-2008)

## COMBINATORIAL OPTIMIZATION

\* Concorde-TSP with different LP solvers (8-20-2008)

## LINEAR PROGRAMMING

Benchmark of commercial LP solvers (8-23-2008)

Benchmark of free LP solvers (8-23-2008)

Large Network-LP Benchmark (commercial vs free) (8-21-2008)

## NONLINEAR PROGRAMMING

Benchmark of commercial and other (QC)QP Solvers (8-28-2008)

AMPL-NLP Benchmark, IPOPT, KNITRO, LOQO, PENNLP & SNOPT (8-28-2008)

## 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 (4-4-2008)

SOCP (second-order cone programming) Benchmark (8-15-2008)

## MIXED INTEGER PROGRAMMING

\* MILP Benchmark - free codes (10-4-2008)

\* Feasibility Benchmark - FEASPUMP vs CPLEX and SCIP (9-30-2008)

\* MI(QC)QP Benchmark (10-10-2008)

## PROBLEMS WITH EQUILIBRIUM CONSTRAINTS

MPEC Benchmark (5-2-2008)

## **Important features of all our benchmarks**

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

## Reasons for updates

- New commercial software
  - CPLEX-11.2 (SCIP, Feaspump, Bonmin, Concorde)
  - MOSEK 5.0.0.93, KNITRO-5.2
- New free software
  - CLP-1.8\*, CBC-2.2.\*, GLPK-4.3\*, SCIP-1.1
  - IPOPT-3.5.\*, SeDuMi (64-bit), Boncouenne
- New multicore hardware

## Benchmarks still in need of updates

- MINLP Benchmark, nonconvex/Boncouenne
- MINLP Benchmark, not only MIQCQP
- Benchmarks in new areas
  - Parallelism on Multicores (Matlab)
  - Compressive Sensing, other sparse optimization
  - Derivative free/nonsmooth optimization etc

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20 Aug 2008

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Concorde-TSP Benchmark (excerpt)

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| problem | Cplex-11.11 | QSopt-1.0\$ | GLPK-4.11 | MOSEK-5.0.0.93 |
|---------|-------------|-------------|-----------|----------------|
| d1655   | 54          | 100         | 1360      | 131            |
| f11400  | 403         | 11368       | 2518      | 1186           |
| f13795  | 3520        | >50000      |           | 28460          |
| nrv1379 | 70          | 126         | 462       | 108            |
| pcb3038 | 18941       | 33706       |           | 30643          |
| r11304  | 86          | 112         | >64000    | 152            |
| r11889  | 1389        | 6710        | fail      | 6082           |
| u1817   | 31933       |             |           |                |
| vm1748  | 243         | 536         | 2030      | 799            |

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11 Jun 2008

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Parallel CPLEX on MIP problems  
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Logiles at [http://plato.asu.edu/ftp/ser\\_par\\_logs/](http://plato.asu.edu/ftp/ser_par_logs/)

CPLEX-11.1 was run in opportunistic and deterministic parallel modes on 4 and 8 processors of a dual-quad 2.2GHz Opteron (64-bit, Linux), as well as on 1, 2, 4 processors of a 2.667GHz Intel Core 2 Quad (64-bit, Linux) on problems from the benchmarks:

<http://plato.asu.edu/ftp/milpf.html>

<http://plato.asu.edu/ftp/miqp.html>

Times given are elapsed CPU times in seconds.

10 Apr 2008

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Parallel CPLEX on MILP problems  
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elapsed CPU sec on AMD Opteron resp Intel Core2 (64-bit, Linux)

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problem    Opt4o   Opt4d   Opt8o   Opt8d   Int1l   Int2o   Int2d   Int4o   Int4d

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|          |     |     |     |     |     |     |     |     |     |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| bienst2  | 59  | 119 | 34  | 64  | 156 | 71  | 97  | 40  | 89  |
| lrn      | 41  | 58  | 39  | 55  | 38  | 27  | 44  | 49  | 39  |
| mas74    | 120 | 131 | 91  | 109 | 237 | 116 | 182 | 65  | 105 |
| neos13   | 236 | 290 | 214 | 127 | 72  | 98  | 90  | 126 | 282 |
| neos5    | 57  | 202 | 40  | 117 | 189 | 64  | 247 | 21  | 150 |
| seymour1 | 91  | 123 | 67  | 101 | 166 | 100 | 114 | 65  | 84  |

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Parallel CPLEX on MIQP and MIQCQP problems ("c" convex)

| problem   | c | Opt4o | Opt4d | Opt8o | Opt8d | Int11 | Int2o | Int2d | Int4o | Int4d |
|-----------|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| ibienst1  |   | 236   | 421   | 121   | 458   | 1174  | 453   | 584   | 295   | 298   |
| inug08    | y | 1989  | 1852  | 1483  | 1695  | 3113  | 1632  | 1570  | 1732  | 1652  |
| iqap10    |   | 350   | 480   | 347   | 543   | 664   | 191   | 222   | 179   | 267   |
| isqp      | y | 1735  | 2029  | 1690  | 1954  | 1798  | 1061  | 1140  | 2193  | 2033  |
| ibienst1  |   | 49    | 317   | 23    | 311   | 253   | 75    | 480   | 34    | 241   |
| imisc07   |   | 40    | 113   | 42    | 57    | 110   | 75    | 236   | 48    | 76    |
| imod011   | y | 3481  | 7705  | 3736  | 8021  | 5292  | 3822  | 5300  | 3123  | 5303  |
| inug06-3  | y | 4301  | 6284  | 4211  | 6483  | 4317  | 3280  | 4371  | 3130  | 4280  |
| inug08    | y | 2520  | 2007  | 1035  | 1559  | 2762  | 1576  | 1941  | 1068  | 1357  |
| iran13x13 |   | 8     | 94    | 7     | 103   | 27    | 12    | 100   | 7     | 64    |

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3 Oct 2008 =====  
Feasibility Benchmark - Feaspump vs CPLEX/SCIP  
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The following codes were run on a 2.67GHz Intel Core2 under Linux:

CPLEX-11.11: <http://www.ilog.com/cplex/>

"h"/"f": emphasis on hidden feasible solutions/feasibility

FEASPUMP: [www.or.deis.unibo.it/research\\_pages/ORcodes/FP-gen.html](http://www.or.deis.unibo.it/research_pages/ORcodes/FP-gen.html)

"ab"/"bfl": Achterberg-Berthold/Bertacco-Fischetti-Lodi variants

free use at NEOS: <http://neos.mcs.anl.gov/> (utilizes CPLEX)

SCIP-1.1: <http://scip.zib.de/> (uses CPLEX for LP)

Times given are user times in seconds. Time limit of 2 hrs.

## Feasibility Benchmark (excerpt)

| problem       | CPLEX-h | CPLEX-f | FP-ab | FP-bf1 | SCIP |
|---------------|---------|---------|-------|--------|------|
| atlanta-ip    | 251     | 786     | 22    | 23     | 184  |
| core4872-1529 | 1       | 1       | 267   | -      | 341  |
| ds            | 1       | 1       | -     | -      | 35   |
| germanrr      | 23      | 178     | 15    | 4      | 168  |
| momentum1     | 1       | 1       | 17    | 20     | -    |
| momentum2     | 3488    | 260     | 37    | -      | 1353 |
| momentum3     | 2       | 2       | 252   | -      | -    |
| msc98-ip      | 201     | 191     | 14    | 16     | 229  |
| neos16        | 118     | 302     | 281   | 64     | 114  |
| neos-506428   | -       | -       | 1958  | 237    | 1338 |

### Feasibility Benchmark (continued)

| problem     | CPLEX-h | CPLEX-f | FP-ab | FP-bf1 | SCIP |
|-------------|---------|---------|-------|--------|------|
| neos-595925 | 3       | 1       | 991   | 142    | 5    |
| net12       | 47      | 843     | 7     | 5      | 233  |
| ns808444    | 515     | -       | 45    | 2349   | 3207 |
| ns894236    | 2585    | 1719    | 122   | 29     | -    |
| ns894244    | 3791    | -       | 433   | 772    | 2890 |
| ns894786    | -       | -       | 3331  | -      | -    |
| ns894788    | -       | 1696    | 93    | 15     | -    |
| ns897005    | 135     | 398     | 117   | 91     | 233  |
| ns897642    | 6       | 5       | 399   | 19     | 118  |
| ns903616    | 225     | 1126    | 136   | 76     | -    |
| ns930473    | 299     | 498     | 606   | 25     | -    |

Feasibility Benchmark (continued)

| problem      | CPLEX-h | CPLEX-f | FP-ab | FP-bf1 | SCIP |
|--------------|---------|---------|-------|--------|------|
| ns1061051    | 540     | 1162    | 3     | 4      | -    |
| ns1116954    | -       | -       | 1131  | 188    | 6191 |
| ns1208400    | 653     | 6887    | 2861  | 180    | 473  |
| ns1219534    | 37      | 116     | 81    | 32     | 59   |
| ns1405304    | 697     | -       | 522   | 31     | -    |
| ns1425622    | 5830    | 339     | 43    | 8      | 11   |
| ns1456591    | 3       | -       | 118   | -      | 1256 |
| NSR8K        | 336     | 306     | 4468  | 643    | 3193 |
| protfold     | 40      | 215     | 137   | 139    | 363  |
| ramos3       | 1       | 1       | 330   | 271    | 68   |
| rd-rplusc-21 | 139     | 21      | 595   | 682    | 216  |
| van          | 1347    | 1216    | 650   | 388    | 486  |

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4 Oct 2008 =====  
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-2.2.1: <https://projects.coin-or.org/Cbc>

GLPK-4.31: <http://www.gnu.org/software/glpk/glpk.html>

MINTO-3.1: <http://coral.ie.lehigh.edu/~minto/>

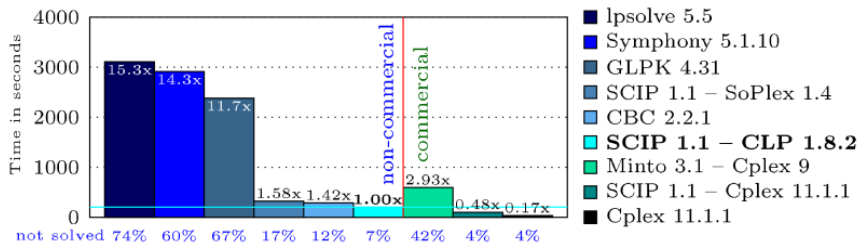
SCIP-1.1: <http://scip.zib.de/>

SYMPHONY-5.1.10: <https://projects.coin-or.org/SYMPHONY>

CPLEX-11.11: (for comparison purposes; mipgap=0, absmipgap=1e-9)

## Graphical summary of our MILP benchmark

From The SCIP webpage [scip.zib.de](http://scip.zib.de):



Geometric mean of results taken from the homepage of Hans Mittelmann (10/4/2008)

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10 Oct 2008

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Mixed Integer (QC)QP Benchmark  
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MIQP cases from [http://plato.asu.edu/ftp/ampl\\_files/miqp\\_ampl/](http://plato.asu.edu/ftp/ampl_files/miqp_ampl/)  
also solved as MIQCQP with

CPLEX-11.2: <http://www.cplex.com/>

Bonmin-0.1.4: <https://projects.coin-or.org/Bonmin>

(Bonmin: default hybrid algorithm. with Clp)

(B-OA-C: outer approx. with CPLEX)

Bonmin-0.100.2: (hybrid and B-OA-C)

FilMINT: currently only at NEOS

LaGO-0.3: <https://projects.coin-or.org/LaGO>

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

Mixed Integer (QC)QP Benchmark (convex cases)

| problem  | QP     |        |       |         |      | QCQP   |        |       |         |
|----------|--------|--------|-------|---------|------|--------|--------|-------|---------|
|          | Bonmin | B-0A-C | CPLEX | FilMINT |      | Bonmin | B-0A-C | CPLEX | FilMINT |
| ibell3a  | 48     | 6      | 25    | t       | 55   | 6      | 14     | 1600  |         |
| ibienst1 | 1466   | 6237   | 3988  | t       | 1285 | 5838   | 785    | t     |         |
| icap6000 | 3315   | 38     | 18    | 1961    | t    | 32     | 23     | 1065  |         |
| ilaser0  | f      | 4      | 5480  | f       | f    | 14     | 339    | f     |         |
| imod011  | 7954   | t      | 214   | 8134    | t    | t      | t      | f     |         |
| inug08   | t      | t      | t     | f       | t    | t      | t      | t     |         |
| iqiu     | 389    | t      | 498   | 1510    | 1528 | t      | 401    | 2758  |         |
| isqp0    | (1)f   | 10     | 121   | f       | (2)f | f      | t      | f     |         |

(1) B-BB solves in 4408 s

(2) B-BB solves in 4485 s

Mixed Integer (QC)QP Benchmark (nonconvex cases)

QP

|

QCQP

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problem  Bonmin B-OA-C CPLEX FilmINT  Bonmin B-OA-C CPLEX FilmINT
=====
  iair04   3387    992    785    2188   5475    1358    212    5151
  iair05   1812    168    238         f   1628    118    131    1218
  ieild76   845    166     61   3122   1032    150     59    910
  imas284   806      9     48     87    845      9     15    562
  imisc07   974   4541    691   7627   1054   5332    407      t
  iqap10   5591   2163   2609   3691   9086   4638      t      t
  iran13x13 3739     89    148   2515   4971    124     95    2026
  iran8x32   257     45     26   3680    546     68     43    5856
  iswath2   (3)t    396    406      t   (4)t    283     f      t
  ivalues  1396      t     f     t   1658      t     f      t
=====

```

(3) B-QG solves in 3770 s

(4) B-QG solves in 4066 s

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Mixed Integer (QC)QP Benchmark  
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- 25 MI(QC)QP cases total
- MIQP cases solved:
  - CPLEX 21, Bonmin 17, Bonmin-0.100.2 6, FiLMINT 10, LaGO 5
- MIQCQP cases solved:
  - CPLEX 12, Bonmin 16, Bonmin-0.100.2 4, FiLMINT 9, LaGO 4

## Conclusions

- Parallel CPLEX effective most of the time, MOSEK competitive
- FEASPUMP competitive with CPLEX and SCIP
- SCIP-CPLEX competitive for MILP with CPLEX except for speed
- SCIP-CLP best free MILP solver, then CBC, SCIP-SOPLEX

- BONMIN-0.1.4 competitive with CPLEX for MIQCQP, much slower for MIQP
- BONMIN-0.100.2 still unstable

**Thank you for your attention**