

# Latest Benchmark Results

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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**)

# Overview of Talk

- Sources, New Developments
- Current and Selected (\*) Benchmarks (as of 10-22-21)
  - Benchmarks of Continuous Optimization Software
    - \* Simplex/Barrier QPLIB, [SOCP, SDP, NLP]
  - Benchmarks of Discrete Optimization Software
    - \* MILP, QPLIB, MISOCP, MINLP
- Observations and Conclusions

## Sources

- MIPLIB, QPLIB, TSPLIB, CBLIB, MINLPLIB, MPECLIB
- **Own selections** in LP, SDP, NLP, NETWORK

## New Developments

- We cannot benchmark **CPLEX** and XPRESS, but **indirectly**
  - **CPLEX** in Concorde, SCIP; also used in our NEOS solvers
    - \* Concorde is our **most used** solver, SCIP is second

## New Developments "China Rising"

- **Simplex:** Cardinal, AlibabaUS, Huawei
- **Barrier, Network:** Cardinal, AlibabaUS
- **MILP, SOCP:** Cardinal

## Nonlinear SCIP development at **Github**

- Lead to **improvement** in QPLIB benchmarks, expected for MINLP, Implemented at NEOS

## New Benchmarks

- **Infeasibility Detection** for MIPLIB problems
- Several instances **replaced** in Simplex and Barrier benchmarks

## New NEOS solvers

- SCIP for **SOCP** (AMPL, MPS, LP input)

**Next: List of Benchmarks**

## **COMBINATORIAL OPTIMIZATION**

Concorde-TSP with different LP solvers (9-16-2021)

## **LINEAR PROGRAMMING**

- \* Benchmark of Simplex LP solvers (10-3-2021)
- \* Benchmark of Barrier LP solvers (10-3-2021)
- \* Large Network-LP Benchmark (commercial vs free) (10-22-2021)

## **SEMIDEFINITE/SQL PROGRAMMING**

- SQL problems from the 7th DIMACS Challenge (8-8-2002)  
Several SDP codes on sparse and other SDP problems (6-6-2020)  
Infeasible SDP Benchmark (10-12-2020)  
Large SOCP Benchmark (10-2-2021)  
\* MISOCP Benchmark (9-3-2021)

## **PROBLEMS WITH EQUILIBRIUM CONSTRAINTS**

MPEC Benchmark (1-9-2021)

## **MIXED INTEGER LINEAR PROGRAMMING**

- \* MILP Benchmark - MIPLIB2017 (10-5-2021)
- MILP cases that are slightly pathological (10-7-2021)
- Infeasibility Detection for MILP Problems (10-4-2021)

## **NONLINEAR PROGRAMMING**

AMPL-NLP Benchmark (12-10-2020)

## **MIXED INTEGER QPs and QCPS**

- Non-commercial convex QP Benchmark (9-16-2021)
- \* Binary Non-Convex QPLIB Benchmark (8-3-2021)
- \* Discrete Non-Convex QPLIB Benchmark (non-binary) (9-7-2021)
- \* Continuous Non-Convex QPLIB Benchmark (9-16-2021)
- \* Convex Continuous QPLIB Benchmark (5-5-2021)
- \* Convex Discrete QPLIB Benchmark (8-21-2021)

## **MIXED INTEGER NONLINEAR PROGRAMMING**

- \* MINLP Benchmark (8-15-2021)



# Overview of Talk

- Selected Benchmarks
  - **Benchmarks of Continuous Optimization Software**
    - \* **Simplex/Barrier QPLIB, [SOCP, SDP, NLP]**
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3 Oct 2021 =====  
 Benchmark of Simplex LP solvers  
 =====  
 H. Mittelmann (mittelmann@asu.edu)

This benchmark was run on a Linux-PC (i7-11700K, 3.6GHz, 64GB).

MOSEK-9.2/3        www.mosek.com  
 CLP-1.17.6        projects.coin-or.org/Clp  
 Google-GLOP       LP with Glop  
 SOPLEX-5.0.2      soplex.zib.de/  
 Gurobi-9.1.2       gurobi.com  
 GLPK-5.00         www.gnu.org/software/glpk/glpk.html  
 MATLAB-R2020b     mathworks.com (dual-simplex)  
 COPT-2.0.1        Cardinal Optimization  
 MindOpt-0.14.0    alibabaUS  
 Optverse-0.2.1    huawei.com  
 HiGHS-1.1.0       HiGHS@github

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

	653	270	1008	1465	69.9	3758	1415	38.8	30.9	42.6	622
40 probs	21.1	8.73	32.6	47.3	2.26	121	45.7	1.25	1	1.38	20.1
solved	35	37	27	31	40	25	29	40	40	39	31
=====											
40 probs	MSK	CLP	GLOP	SPLX	Gurob	GLPK	MATL	COPT	MDOPT	OPTV	HiGHS
=====											

3 Oct 2021 =====  
 Benchmark of Barrier LP solvers  
 =====  
 H. Mittelmann (mittelmann@asu.edu)

This benchmark was run on a Linux-PC (i7-11700K, 3.6GHz, 64GB).

The barrier methods were tested of:

MOSEK-9.2/3      www.mosek.com  
 MATLAB-R2020b mathworks.com (interior-point, NO CROSSOVER)  
 Gurobi-9.1.2     gurobi.com  
 CLP-1.17.6      projects.coin-or.org/Clp  
 Tulip-0.8.0     [Tulip at Github] (NO CROSSOVER)  
 COPT-2.0.1      [Cardinal Optimization]  
 MindOpt-0.14.0 MindOpt  
 KNITRO-12.4.0 www.artelys.com/knitro/ (NO CROSSOVER)  
 HiGHS-1.1.0     HiGHS@github

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

	90.8	708	30.1	1324	1078	19.3	44.9	275	293
47 probs	4.71	36.7	1.56	68.6	55.9	1	2.33	14.3	15.2
solved	42	35	47	35	31	47	47	37	41
=====									
problem	MOSEK	MATLAB	Gurobi	CLP	TULIP	COPT	MDOPT	KNITRO	HiGHS
=====									

22 Oct 2021 =====  
 Large Network-LP Benchmark (commercial vs free)  
 =====  
 H. Mittelmann (mittelmann@asu.edu)

Logfiles of these runs at: [plato.asu.edu/ftp/net\\_logs/](http://plato.asu.edu/ftp/net_logs/)

This benchmark was run on an Intel i7-11700K (3.6 GHz, 64GB, Linux, 8 cores).  
 The following codes were tested with one thread and in default mode except where indicated:

www.mosek.com/ MOSEK-9.3.1  
 projects.coin-or.org/Clp/ Clp-1.17.6 (-network -dualsimplex)  
 www.math.uwaterloo.ca/~bico/qsopt/ QSopt-1.01 (option -d 9)  
 mathworks.com MATLAB-R2020b (dual-simplex)  
 soplex.zib.de/ SOPLEX-5.0.2  
 COPT COPT-3.0.2  
 Gurobi Gurobi-9.1.2  
 MindOpt MindOpt-0.15.1  
 HiGHS HiGHS-1.1.1  
 Times are elapsed times. 1 hour time limit.

Scaled and shifted geometric means of runtimes.

	38.6	3.04	22.9	12.6	41.4	1	3.64	1.35	6.39		
=====											
problem	nodes	arcs	MOSEK	CLP	QSOPT	MATL	SOPLX	COPT	GUR	MDOPT	HGHS
=====											

16 Sep 2021

```
=====
Continuous Non-Convex QPLIB Benchmark
=====
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```

Logiles at [plato.asu.edu/ftp/cnconv\\_logs/](http://plato.asu.edu/ftp/cnconv_logs/)

```
Baron-21.1.13    BARON
ANTIGONE-1.1     ANTIGONE
SCIP-7.0.3.5     SCIP/SOPLEX
COUENNE-0.5      COUENNE [projects.coin-or.org/Couenne]
MINOTAUR-0.2.1   MINOTAUR
Octeract-3.4.1   OCTERACT
Gurobi-9.1.0     GUROBI
RAPOSA-2.0.2     RAPOSa
```

The above solvers were run on an Intel Xeon E5-4657L (48 cores, 512GB) on the continuous non-convex problems (102 total) from QPLIB. Times given are elapsed times in seconds. Time limit 3hrs. Only those instances are shown for which at least one solver succeeded. Shifted and scaled geometric mean of runtimes:

```
mean      1.59      1.83      4.39      4.63      3.55      2.47      1
solved    29         25         8         6         12        16        28*
```

```
=====
prob# ANTIGONE  BARON  COUENNE  MINOTAUR  SCIP  OCTERACT  GUROBI
-----
```

5 May 2021

```
=====  
Convex Continuous QPLIB Benchmark  
=====  
H. Mittelmann (mittelmann@asu.edu)
```

Logiles at [plato.asu.edu/ftp/cconvex\\_logs/](http://plato.asu.edu/ftp/cconvex_logs/)

```
MOSEK-9.2.43    MOSEK  
KNITRO-12.3    KNITRO  
IPOPT-3.12.13  [Ipoprt at Github]  
Gurobi-9.1.2   GUROBI
```

The above solvers were run on a 3 GHz Intel i7-5960X (8 cores, 48GB) on the 32 continuous convex problems from QPLIB. Times given are elapsed times in seconds; time limit 2hrs, 8 threads  
Shifted and scaled geometric mean of runtimes:

```
mean      1    1.74    3.61    1.27  
solved    31     31     28     31  
=====
```

prob#	MOSEK	KNITRO	IPOPT	Gurobi
-------	-------	--------	-------	--------

```
-----
```

# Overview of Talk

- Selected Benchmarks
  - Benchmarks of Continuous Optimization Software
    - \* Simplex/Barrier QLIB, [SOCP, SDP, NLP]
  - **Benchmarks of Discrete Optimization Software**
    - \* **MILP, QPLIB, MISOCP, MINLP**
- Observations and Conclusions

5 Oct 2021

```
=====
The MIPLIB2017 Benchmark Instances
=====
H. Mittelmann (mittelmann@asu.edu)
```

The following codes were run with a limit of 2 hours on the MIPLIB2017 benchmark set on two platforms.

1 thread: Intel i7-4790K, 4 cores, 32GB, 4Ghz;  
8 thread: Intel i7-11700K, 8 cores, 64GB, 3.6GHz;

```
CBC-2.10.5:      projects.coin-or.org/Cbc
COPT-2.0.1:      Cardinal Optimization
GLPK-5.0:        www.gnu.org/software/glpk/glpk.html
LP_SOLVE-5.5.2: lpsolve.sourceforge.net/
MATLAB-2020a:    MATLAB (intlinprog)
(F)SCIP/spx]-7.0.0: FiberSCIP (SCIP+SOPLEX on 1 thread)
Gurobi-9.1.0:    Gurobi
HiGHS-1.1.1      HiGHS@github
```



10 Aug 2021

```
=====
The MIPLIB2017 Benchmark Instances
=====
H. Mittelmann (mittelmann@asu.edu)
```

The third line lists the number of problems (240 total) solved.

1 thr	CBC	GLPK	LP_SOL	MATLAB	SCIP	Gurobi	COPT
unscal	2107	5044	5335	3301	1100	245	1029
scaled	8.59	20.5	21.7	13.5	4.48	1	4.19
solved	89	23	20	63	125	201	132

Due to wide availability of multi-cores this benchmark will not be updated

8 thr	CBC	FSCIP	Gurobi	COPT	SCIP	HiGHS
unscal	1328	794	100	450	955	1195
scaled	13.3	7.98	1	4.52	9.60	12.0
solved	107	146	225	176	134	134

23 Aug 2021

```

=====
Binary Non-Convex QPLIB Benchmark
=====
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```

Logfiles at [plato.asu.edu/ftp/qplib\\_logs/](http://plato.asu.edu/ftp/qplib_logs/)

```

Baron-21.1.13      BARON
(F)SCIP-7.0.0     (Fiber)SCIP-SOPLEX (only open source code included)
ANTIGONE-1.1      ANTIGONE
MINOTAUR-0.2.1    MINOTAUR
OCTERACT-3.4.1    OCTERACT
Gurobi-9.R1.2     Gurobi

```

The above solvers were run on a 3 GHz Intel i7-5960X (8 cores, 48GB) on the binary nonconvex problems (128 total) from QPLIB. Times given are elapsed times in seconds. Mipgap is zero, time limit 1hr; 8 threads, except SCIP&Minotaur. Only those instances are shown for which at least one solver succeeded. Shifted and scaled geometric mean of runtimes:

	BARON	SCIP	ANTIGONE	MINOTAUR	OCTERACT	GUROBI	FSCIP
mean	13.4	44.3	53.3	71.1	21.0	1	37.6
solved	42	26	23	7	36	85	34
prob#	BARON	SCIP	ANTIGONE	MINOTAUR	OCTERACT	GUROBI	FSCIP

7 Sep 2021

```
=====
Discrete Non-Convex QPLIB Benchmark (non-binary)
=====
```

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Logfiles at plato.asu.edu/ftp/nonbinary\_logs/

```
Baron-21.1.13      BARON
ANTIGONE-1.1      ANTIGONE
SCIP-7.0.3.5      SCIP/SOPLEX
COUENNE-0.5       projects.coin-or.org/Couenne
MINOTAUR-0.2.1    MINOTAUR
OCTERACT-3.4.1    OCTERACT
Gurobi-9.1.0      Gurobi
```

The above solvers were run on an Intel Xeon E5-4657L (48 cores, 512GB) on the discrete non-convex problems (160 total) with not only binary variables from QPLIB. Times given are elapsed times in seconds. Time limit 3hrs. Only those instances are shown for which at least one solver succeeded. Shifted and scaled geometric mean of runtimes:

mean	23.3	20.7	51.5	59.1	10.8	26.0	1
solved	29	27	8	4	37	20	66*
=====							
prob#	ANTIGONE	BARON	COUENNE	MINOTAUR	SCIP	OCTERACT	GUROBI
-----							

21 Aug 2021

```

=====
Convex Discrete QPLIB Benchmark
=====
H. Mittelmann (mittelmann@asu.edu)

```

Logiles at plato.asu.edu/ftp/convex\_logs/

```

MOSEK-9.2.29      MOSEK
KNITRO-12.3       KNITRO
Baron-21.1.13    BARON
Bonmin-1.8.7     BONMIN (with CBC and Ipopt)
SCIP-7.0.0       SCIP with SOPLEX-5.0.0
ANTIGONE-1.1     ANTIGONE
MINOTAUR-0.2.1   MINOTAUR
Gurobi-9.1.2     Gurobi
Shot-1.0         SHOT with CBC
OCTERACT-3.4.1   OCTERACT

```

The above solvers were run on a 3 GHz Intel i7-5960X (8 cores, 48GB) on the 31 discrete convex problems from QPLIB. Times given are elapsed times in seconds. Mipgap zero, time limit 2hrs, 8 threads; SCIP, Minotaur 1 thread  
 Shifted and scaled geometric mean of runtimes:

mean	10.3	16.0	5.46	15.7	12.6	41.3	26.0	1	48.3	34.4
solved	13	9	17	10	11	2	11	23	1	3

```

=====
prob# MOSEK KNITRO  BARON BONMIN  SCIP ANTIGONE MINOTAUR GUROBI SHOT OCTERACT
-----

```

3 Sep 2021       =====

                  Mixed-integer SOCP Benchmark

                  =====

                  Hans D. Mittelmann (mittelmann@asu.edu)

Logfiles for these runs are at: [plato.la.asu.edu/ftp/misocp\\_logs/](http://plato.la.asu.edu/ftp/misocp_logs/)

MOSEK-9.3.1 MOSEK  
 SCIP-7.0.3.5 SCIP+Cplex  
 Gurobi-9.1.2 Gurobi

These codes were tested on a selection of the MISOCP problems from CBLIB2014 and from here. Given are total CPU seconds.

The codes were run in default mode (except mipgap=0) on an Intel i7-11700K (3.6 GHz, 64GB). Time limit 2 hrs.

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

	21.2	26.2	1
=====			
problem	MOSEK	SCIP	GUROBI
solved of 47	32	31	47*
-----			

15 Aug 2021 =====  
Mixed Integer Nonlinear Programming Benchmark (MINLPLIB)  
=====

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The following codes were run through GAMS-36.1.0 with a limit of 2 hours on these instances from MINLPLIB and with one thread on an Intel i7-11700K, 64GB, 3.6GHz.

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

ANTIGONE, BARON, LINDO, SCIP

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

Feasibility tolerance set to 1e-6. All non-successes are counted as max-time.

The shifted geometric mean is computed on the 69 instances for which no solver failed.

87 probs	ANTIGONE	BARON	LINDO	SCIP
geom mean	4.17	1	5.93	2.06
solved	53	63	29	55

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## "TOP PERFORMERS"

LP-Simplex:	MindOpt, COPT, OptVerse, Gurobi
LP-Barrier:	COPT, Gurobi, MindOpt, MOSEK
Network-LP:	COPT, MindOpt, Gurobi
MILP:	Gurobi, COPT, (F)SCIP
SOCP:	MOSEK, Gurobi, COPT
MISOCP:	Gurobi, MOSEK, SCIP
nonc BQCP:	Gurobi, BARON, FSCIP
nonc DQCP:	Gurobi, SCIP, BARON
nonc CQCP:	Gurobi, ANTIGONE, BARON
conv DQCP:	Gurobi, BARON, MOSEK
conv CQCP:	MOSEK, Gurobi, KNITRO
MINLP:	BARON, SCIP, ANTIGONE



*Thank you!*

slides at: <http://plato.asu.edu/talks/>