

Recent Developments in SDP and SOCP 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**)

From the NEOS solvers webpage

- * Semidefinite & Second Order Cone Programming
- * CSDP [Matlab Binary Input] [Sparse SDPA Input]
- * DSDP [Sparse SDPA Input]
- * PENBMI [Matlab Binary Input] [Matlab 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] [Sparse SDPA Input] [SDPLR input]
- * SDPT3 [Matlab Binary Input] [Sparse SDPA Input]
- * SeDuMi [Matlab Binary Input] [Sparse SDPA Input]

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

SDPA	1237
DSDP	708
SDPT3	218
CSDP	192
SEDUMI	142
PENBMI	133
SDPLR	71
PENSDP	42
SDPA-C	25

Overview of Talk

- State of SDP/SOCP Software
- SDP/SOCP Benchmarks
 - SOCP Benchmark (FIR)
 - Parallel CSDP on SDP problems
 - SDPs with free variables
 - Large Sparse SDP Benchmark
- Conclusions

The following SOCP/SDP codes are available

LOQO-6.06: <http://www.princeton.edu/~rvdb/>

MOSEK-4.0: <http://www.mosek.com/>

SDPT3-4.0-beta: <http://www.math.nus.edu.sg/~mattohkc/sdpt3.html>

SeDuMi-1.1: <http://sedumi.mcmaster.ca>

CSDP-5.0: <http://www.nmt.edu/~borchers/csdp.html>

SDPA-6.20: <http://grid.r.dendai.ac.jp/sdpa/>

DSDP-5.8: <http://www-unix.mcs.anl.gov/DSDP/>

PENSDP-2.2: <http://www.penopt.com/pensdp.html>

SBmethod-1.1.3 <http://www-user.tu-chemnitz.de/~helmberg/SBmethod/>

SDPLR-1.02: <http://dollar.biz.uiowa.edu/~burer/software/SDPLR/>

Apart from minor updates current software dates approximately from

SDPT3-4.0-beta:	7/2006	
MOSEK-4.0:	2/2006	
PENSDP-2.2:	2/2006	
CSDP-5.0:	9/2005	
DSDP-5.8:	9/2005	(stopped?)
SDPLR-1.02:	5/2005	(stopped?)
SeDuMi-1.1:	11/2004	
SBmethod-1.1.3:	1/2004	(stopped?)
LOQO-6.06:	9/2003	
SDPA-6.20:	7/2002	(stopped?)

From my benchmark page

<http://plato.asu.edu/bench.html>

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

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

Several SDP-codes on SDP problems with free variables (10-14-2006)

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

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)

Important features of all our benchmarks

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

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

SDPT3-4.0-beta: <http://www.math.nus.edu.sg/~mattohkc/sdpt3.html>
SeDuMi-1.1: <http://sedumi.mcmaster.ca>
LOQO-6.06: <http://www.princeton.edu/~rvdb/>
MOSEK-4.0.0.43: <http://www.mosek.com/>

Input: SDPT3&SeDuMi: SeDuMi-format, MOSEK: ext MPS, LOQO: AMPL

These codes were used to solve SOCP problems generated with the Matlab FIR toolbox (<http://www.csee.umbc.edu/~dschol2/opt.html>)

We had solicited this testsuite. It is included in the toolbox.

Problem Statistics (as reported by SeDuMi)

```

=====
problem          variables    constraints    nonzeros      blocks
=====
firL1            15805        8302           6321201       7903
firL1Linfalph   31609        8303           12642402      15805
firL1Linfeps    15450        11785          1548465       7725
firL2L1alph     7848         11968          1592132       3924
firL2L1eps      15807        8303           6401802       7904
firL2Linfalph   11857        402            4821802       5929
firL2Linfeps    8857         9155           2673609       4429
firL2a           3            3001           4504501        2
firLinf         29857        1001           19903001      9953
dsNRL           10509        406            4309501       5255
wbNRL           17196        460            8061190        10
=====

```

CPU seconds on a 3.2 GHz P4

```

=====
problem          K      MOSEK      SeDuMi*      SDPT3*      LOQO
=====
firL1            400      157         664          1474         716
firL1Linfalph   400      498        2059         1486         fail
firL1Linfeps    198      96          409           m           828
firL2L1alph     201      24          103           116          413
firL2L1eps      400      163         627          1606         1004
firL2Linfalph   400      151         752           245          fail
firL2Linfeps    300      83          492           311          386
firL2a          3000     360         247           614          434
firLinf         1000     116         5506          348           m
dsNRL           166      808         975           340
wbNRL           144      719         700           885
=====

```

"m": memory exceeded, "*" : DIMACS error measures

- SOCP (second-order cone programming) Benchmark (10-28-2006)
- **Parallel CSDP on SDP problems (8-22-2006)**
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- Several SDP codes on sparse and other SDP problems (7-19-2006)

22 Aug 2006

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Parallel CSDP on SDP problems
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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 the Sparse SDP Benchmark (below)

=====
=====

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

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Several SDP-codes on SDP problems with free variables
=====

14 Oct 2006

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/>

problem	constr	vars	free	blocks
q_17_0.5_*	5984	189	2907	2
s_17_0.5_*	5984	477	272	18
MaxC_100_1	6252	1850	2094	79
MaxC_100_2	6252	1850	2094	79
MaxC_100_3	7767	2134	2295	79
MaxC_100_4	5679	1775	1938	82
MaxC_100_5	6717	1877	2238	77
MaxC_100_6	6059	1759	2022	77
MaxC_100_7	7221	2103	2450	80
MaxC_100_8	7375	2121	2200	81
MaxC_100_9	6495	1937	2164	82
MaxC_100_10	7228	1923	2408	74

=====
SDP-codes on problems with free variables (DIMACS-err)
=====

problem	SeDuMi	SDPT3	SeDuMif	CSDP	SDPA
q_17_0.5_1	1.9e-07	2.9e-08	1.3e-06	1.3e-08	3.0e-06
q_17_0.5_2	8.8e-07	5.8e-07	5.3e-07	6.9e-09	6.1e-07
q_17_0.5_3	7.6e-09	3.6e-08	1.4e-08	1.2e-08	1.2e-06
q_17_0.5_4	1.9e-06	3.6e-03	1.5e-06	4.9e-08	2.7e-05
q_17_0.5_5	1.6e-06	9.9e-09	1.7e-07	1.0e-08	1.6e-06
q_17_0.5_6	1.6e-07	4.8e-08	2.1e-07	2.0e-08	4.8e-07
q_17_0.5_7	2.3e-09	3.3e-08	1.8e-07	4.3e-08	8.6e-07
q_17_0.5_8	8.7e-08	5.8e-09	1.0e-06	4.4e-09	2.0e-06
q_17_0.5_9	8.5e-09	1.9e-02	1.9e-06	2.2e-08	7.1e-07
q_17_0.5_10	2.1e-07	2.7e-07	9.5e-09	5.0e-09	1.4e-07

=====
SDP-codes on problems with free variables (CPU secds)
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problem	SeDuMi	SDPT3	SeDuMif	CSDP	CSDP2	SDPA
q_17_0.5_1	4831	2083	4380	1546	1218	7614
q_17_0.5_2	5162	1324	4945	1325	1057	7395
q_17_0.5_3	5355	1251	5127	1305	994	7644
q_17_0.5_4	4755	1280	4356	1720	1380	8658
q_17_0.5_5	5047	1498	4736	1315	1023	4956
q_17_0.5_6	5162	1251	4735	1129	914	7085
q_17_0.5_7	4181	700	3977	998	804	4599
q_17_0.5_8	3988	832	4168	1042	849	5600
q_17_0.5_9	5117	817	4737	1246	991	6876
q_17_0.5_10	4953	957	5137	1157	929	6842

=====
SDP-codes on problems with free variables (DIMACS-err)
=====

problem	SeDuMi	SDPT3	SeDuMif	CSDP	SDPA
s_17_0.5_1	2.3e-07	1.8e-06	1.4e-07	9.7e-09	2.6e-01
s_17_0.5_2	7.2e-08	5.6e-06	4.4e-08	1.2e-09	2.2e-01
s_17_0.5_3	1.6e-07	7.0e-06	2.4e-07	6.9e-09	2.3e-01
s_17_0.5_4	4.3e-07	2.4e-06	1.6e-07	7.5e-09	2.3e-01
s_17_0.5_5	5.3e-07	8.5e-06	2.8e-07	2.2e-09	2.1e-01
s_17_0.5_6	2.3e-07	2.8e-06	1.1e-07	6.6e-09	2.5e-01
s_17_0.5_7	4.4e-07	1.4e-06	4.7e-07	5.0e-09	2.6e-01
s_17_0.5_8	6.4e-08	4.0e-06	1.2e-07	6.4e-09	2.4e-01
s_17_0.5_9	3.7e-07	1.4e-06	3.7e-08	3.8e-09	2.4e-01
s_17_0.5_10	4.6e-08	3.4e-07	1.3e-08	1.2e-09	2.5e-01

=====
SDP-codes on problems with free variables (CPU secds)
=====

problem	SeDuMi	SDPT3	SeDuMif	CSDP	CSDP2	SDPA
s_17_0.5_1	2366	767	2560	718	544	1937
s_17_0.5_2	3292	904	3588	833	633	1933
s_17_0.5_3	2570	795	2579	770	550	1944
s_17_0.5_4	3937	974	4274	946	712	1930
s_17_0.5_5	3503	875	3676	841	632	1945
s_17_0.5_6	3676	938	3853	869	655	2051
s_17_0.5_7	3411	953	3806	942	669	1793
s_17_0.5_8	2258	783	2559	729	554	1671
s_17_0.5_9	3697	988	3784	832	635	1649
s_17_0.5_10	3146	857	3442	880	622	1937

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SDP-codes on problems with free variables (DIMACS-err)
=====

problem	SeDuMi	SDPT3	SeDuMif	CSDP	SDPA
MaxC_100_1	1.0e-09	3.2e-08	1.3e-10	8.2e-08	4.0e-03
MaxC_100_2	1.0e-09	3.2e-08	1.3e-10	8.2e-08	4.0e-03
MaxC_100_3	1.1e-09	2.4e-08	2.1e-09	6.8e-08	8.9e-04
MaxC_100_4	4.7e-09	1.8e-07	4.1e-10	1.6e-08	3.7e-03
MaxC_100_5	3.0e-09	4.8e-04	2.0e-09	3.9e-07	3.1e-03
MaxC_100_6	9.8e-10	4.2e-06	2.2e-09	3.1e-08	7.4e-04
MaxC_100_7	1.7e-09	3.3e-04	1.1e-08	3.1e-08	4.1e-03
MaxC_100_8	5.5e-09	2.2e-08	3.0e-09	1.8e-08	3.1e-03
MaxC_100_9	4.1e-10	4.5e-08	8.0e-09	2.0e-08	2.9e-03
MaxC_100_10	8.0e-09	3.9e-04	1.0e-08	2.1e-08	8.8e-05

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SDP-codes on problems with free variables (CPU secds)
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problem	SeDuMi	SDPT3	SeDuMif	CSDP	CSDP2	SDPA
MaxC_100_1	548	333	27	844	590	11131
MaxC_100_2	612	308	27	853	588	11162
MaxC_100_3	737	873	52	1516	1011	21877
MaxC_100_4	709	283	33	748	550	8538
MaxC_100_5	724	293	43	1969	1207	15067
MaxC_100_6	460	235	26	725	480	11131
MaxC_100_7	1149	375	54	1890	1103	17932
MaxC_100_8	612	697	39	1510	912	18542
MaxC_100_9	578	374	32	1029	655	13563
MaxC_100_10	998	391	110	1579	1090	19801

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SDP-codes on problems with free variables (summary)
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Accuracy (vanilla/default codes)

=====
code | best | sec best

CSDP | 16 | 9
SeDuMi | 7 | 9
SeDuMif | 6 | 5
SDPT3 | 1 | 7
=====

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Several SDP-codes on sparse and other SDP problems

=====

- CSDP-5.0: <http://www.nmt.edu/~borchers/csdp.html>
- PENSDP-2.2: <http://www.penopt.com/pensdp.html>
- SDPT3-4.0-beta: <http://www.math.nus.edu.sg/~mattohkc/sdpt3.html>
- SeDuMi-1.1: <http://sedumi.mcmaster.ca>
- DSDP-5.8: <http://www-unix.mcs.anl.gov/DSDP/>
- SDPA-6.0: <http://grid.r.dendai.ac.jp/sdpa/index.html>
- SDPLR-1.02: <http://dollar.biz.uiowa.edu/~burer/software/SDPLR/>

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Several SDP-codes on sparse and other SDP problems
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These codes were used to solve SDP problems from

- <http://plato.asu.edu/ftp/sdp/ ../qap/> (see also README)
- <http://www2.am.uni-erlangen.de/~kocvara/pennon/problems.html>
- <http://www.is.titech.ac.jp/~mituhiro/software.html>
- <http://www.is.titech.ac.jp/~mituhiro/Software/05/>

In addition to taking problems from existing collections we have used the following application programs to generate instances:

GLOPTIPOLY-2.3: www.laas.fr/~henrion/software/gloptipoly/

SOSTOOLS-2.01: control.ee.ethz.ch/~parrilo/sostools/index.html

SeDuMiInt-1.04: www.laas.fr/%7Epeaucell/software/SeDuMiInt.html

SDE-1.3: www.seas.upenn.edu/~kilianw/sde/

YALMIP: control.ee.ethz.ch/~joloef/yalmip.msql

genhardSDP.m: Henry Wolkowicz's generator for hard SDPs

We have solicited problems from the Computer Vision and Pattern Recognition Group, University of Mannheim/Germany

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Several SDP-codes on sparse and other SDP problems

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Total:	70 problems
Kocvara collection:	16
GLOPTIPOLY:	11
Fukuda collection:	8
Pattern recognition:	8
SOSTOOLS:	8
Graph relaxations:	5
Wolkowicz:	4
SDE:	3
SparsePOP:	3
misc:	4

item	PENSDP	SeDuMi	SDPT3	CSDP	DSDP	SDPA	SDPLR
fastest	13	4	20	1	11	4	18
second	16	12	9	6	13	10	5
slowest	5	18	1	8	8	5	24
fastest	18	4	24	1	18	6	
second	11	13	13	9	9	12	
slowest	5	32	1	9	11	8	
fastest	19	5	32	3		11	
second	22	12	11	16		7	
slowest	5	43	1	8		11	
parallel	n	n	n	y	y	y	n

Conclusions

The state of the art of SDP&SOCP solvers for large (but not huge) problems is **quite** satisfactory

Strong SQL solvers: SDPT3, SeDuMi

Strong SDP solvers:

general: CSDP, PENNON, SDPA

specialty: SDPLR, DSDP

Strong SOCP solvers: MOSEK, LOQO

Thank you for your attention