Independent Evaluation of Optimization Software including in Competitions

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ARPA-E
Grid Optimization Workshop
Arlington, VA
13 November 2014

Outline

Who am I?

in all humility, sorry

Why am I here?

actually, they asked me

What can I do?

that depends

Questions?

or Remarks?

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Short CV

- Education
  - University of Mainz, M.A. 1966-1971
  - Technical University of Darmstadt, Ph.D. 1971-1973
  - Technical University of Darmstadt, Habilitation, 1973-1976
- Employment History
  - University of Mainz, Computing Center 1971-1973
  - Technical University of Darmstadt, Asst. Prof., 1974-1977
  - University of Dortmund, Assoc. Prof., 1977-1982
  - Arizona State University, Professor, 1982-
- Sabbatical stay at Stanford (CS dept) lead to move to US

What else is of interest?

- Standard research/teaching career
  in Computational Mathematics (140 papers etc)
- Early interest in optimization (1976-)
- But initial research activity in PDEs, finite elements
- Side interest since about 1995:
  inform public about optimization incl software
- This grew stronger over time
- My research also moved more and more to optimization

Decision Tree for Optimization Software

Navigation Menu

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- **Problems & Software**
- **Benchmarks**
- **Testcases**
- **Books & Tutorials**
- **Tools**
- **Websubmission**
- **Other Sources**

Search the Decision Tree

Welcome! This site aims at helping you identify ready to use solutions for your optimization problem, or at least to find some way to build such a solution using work done by others. If you know of useful sources not listed here, please let us know. If something is found to be erroneous, please let us know, too. Where possible, public domain software is listed here.

In any case, observe the expressed or implied LICENSE conditions ! In most cases, these accompany the source code. As a rule, most codes are free for research. This means free for academic research and teaching or for trying whether it serves your needs. Commercial uses (either direct or indirect) require licensing, as a rule.

We do not aim at giving an overview over existing commercial products and recommend one of the other guides for that. We have structured the information in the way you can see on the left. Clicking on the corresponding part takes you there. The contents are as follows:

- problems/software: software sorted by problem to be solved
- benchmarks: collection of testresults and performance tests, made by us or others
- testcases: example files ready to use with existing software, in different formats
- books/tutorials: a short list of introductory texts, some online
- tools: software which helps formulating an optimization problem or simplifying its solution
- websubmission: some software can be used directly via the net thanks to implementors who make their computing facilities available to you
- other sources: for more information provided by others

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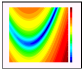

Do people find the decision tree?

Google search for optimization software

- List of optimization software - Wikipedia, the free encyclopedia
  - just alphabetical lists etc
- Comparison of optimization software - Wikipedia, the free ...
  - no performance data, just license info
- Decison Tree for Optimization Software - Hans D. Mittelmann

Decision Tree for Optimization Software

Benchmarks for Optimization Software

by Hans Mittelmann (mittelmann at asu.edu)

Note that on top of the benchmarks a link to logfiles is given!

COMBINATORIAL OPTIMIZATION

- Concorde-TSP with different LP solvers (12-14-2013)

LINEAR PROGRAMMING

- Benchmark of Simplex LP solvers (11-4-2014)
- Benchmark of parallel LP solvers (11-5-2014)
- Parallel Barrier Solvers on Large LP/QP problems (11-6-2014)
- Large Network-LP Benchmark (commercial vs free) (11-5-2014)

MIXED INTEGER LINEAR PROGRAMMING

- MILP Benchmark - MIPLIB2010 (11-6-2014)
- Performance Variability Benchmark (9-22-2014) **(MIPLIB2010)**
- The EASY MIPLIB Instances (11-5-2014) **(MIPLIB2010)**
- MILP cases that are slightly pathological (11-3-2014)
- Feasibility Benchmark (11-5-2014) **(MIPLIB2010)**
- Infeasibility Detection for MILP (11-6-2014) **(MIPLIB2010)**

SEMIDEFINITE/SQL PROGRAMMING

- SQL problems from the 7th DIMACS Challenge (8-8-2002)
- Several SDP codes on sparse and other SDP problems (4-15-2014)

The Benchmarks

some basic facts

- currently 18 benchmarks in 8 categories
- 30 different codes
- fully documented, reproducible
- frequently updated
- no personnel or financial support

```
 4 Nov 2014   ==================================
                Benchmark of Simplex LP solvers
              ==================================
                H. Mittelmann (mittelmann@asu.edu)
```

Logfiles of these runs at: plato.asu.edu/ftp/lp_logs/

This benchmark was run on a Linux-PC (i7-2600).
The MPS-datafiles for all testcases are in one of (see column "s")

```
 miplib.zib.de/ [1]
 plato.asu.edu/ftp/lptestset/ [2]
 www.netlib.org/lp/data/ [3,7]
 www.sztaki.hu/~meszaros/public_ftp/lptestset/
(MISC[4], PROBLEMATIC[5], STOCHLP[6], INFEAS[8])
```

NOTE: files in [2-8] need to be expanded with emps in same directory!

The simplex methods were tested of the codes:

```
 CPLEX-12.6.1beta  CPLEX
 GUROBI-5.6.0    www.gurobi.com/
 MOSEK-7.0.0.134 www.mosek.com
 XPRESS-7.8.0:   XPRESS
 CLP-1.15.10   projects.coin-or.org/Clp
 Google-GLOP   LP with Glop
 SOPLEX-2.0.0  soplex.zib.de/
 LP_SOLVE-5.5.2:   lpsolve.sourceforge.net/
 GLPK-4.55:  www.gnu.org/software/glpk/glpk.html
```

Scaled shifted (by 10 sec) geometric mean of runtimes

problem	CPXS	GRBS	MSKS	XPRS	CLP	GLOP	SOPLX	LPSLV	GLPK
	1.39	1	1.85	1.02	2.70	7.98	9.07	62.9	29.5

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DIMACS

Center for Discrete Mathematics & Theoretical Computer Science
Founded as a National Science Foundation Science and Technology Center

DIMACS Implementation Challenges

The *DIMACS Implementation Challenges* address questions of determining realistic algorithm performance where worst case analysis is overly pessimistic and probabilistic models are too unrealistic: experimentation can provide guides to realistic algorithm performance where analysis fails. Experimentation also brings algorithmic questions closer to the original problems that motivated theoretical work. It also tests many assumptions about implementation methods and data structures. It provides an opportunity to develop and test problem instances, instance generators, and other methods of testing and comparing performance of algorithms. And it is a step in technology transfer by providing leading edge implementations of algorithms for others to adapt.

The information on challenges includes pointers to WWW/FTP sites that include calls for participation, algorithm implementations, instance generators, bibliographies, and other electronic artifacts. The challenge organizers are also producing refereed volumes in the AMS-DIMACS book series; these contain selected papers from the workshops that culminate each challenge.

If you are using the implementations, generators or other files, please take a few minutes to tell us how you are using it, what applications you are working on, and how it impacts your work. We need to document the impact of this research to the agencies and foundations that support it - your stories are essential to doing that. Send comments to: froberts@dimacs.rutgers.edu

The Famous DIMACS Graph Format

Quite a few research papers have been referring to the DIMACS graph format. The first Challenge

The DIMACS Challenges

11 Steiner Tree Problems (current)
10 Algorithm Implementation Challenge: Graph Partitioning and Graph Clustering
9 The Shortest Path Problem
8 The Traveling Salesman Problem
7 Semidefinite and Related Optimization Problems
6 Near Neighbor Searches
5 Priority Queues, Dictionaries, and Multi-Dimensional Point Sets
4 Two Problems in Computational Biology: Fragment Assembly and Genome Rearrangements
3 Effective Parallel Algorithms for Combinatorial Problems
2 NP Hard Problems: Maximum Clique, Graph Coloring, and Satisfiability
1 Network Flows and Matching

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7th DIMACS Implementation Challenge: Semidefinite and Related Optimization Problems

Dates: November 2 - 3, 2000
DIMACS Center, Rutgers University, Piscataway, NJ

Organizers:
David Johnson, AT&T Labs - Research, dsj@research.att.com
Gabor Pataki, Columbia University, gabor@ieor.columbia.edu
Farid Alizadeh, RUTCOR, Rutgers University

conference email: challenge@dimacs.rutgers.edu

Presented under the auspices of the Special Year on Large Scale Discrete Optimization.

- Workshop Announcement and Call for Participation
- Program
- Participant List

The Competitors

9 groups, 10 codes, 6 countries

- SDPA: K. Fujisawa (Kyoto University), M. Kojima, K. Nakata (Tokyo Institute of Technology)
- MOSEK: Erling Andersen, Knud Andersen (Odense University)
- DSDP: Steve Benson (Argonne National Laboratory), Yinyu Ye (University of Iowa)
- BMZ, BMPR: Sam Burer, Renato Monteiro (Georgia Tech), Yin Zhang (Rice University)
- SDPT3: Mike Todd (Cornell University), Kim Chuan Toh (Tokyo Institute of Technology), Reha Tutuncu (Carnegie Mellon)
- SeDuMi: Jos Sturm (Maastricht University)
- LOQO: Hande Y. Benson, Bob Vanderbei (Princeton University)
- BUNDLE: Christoph Helmberg (Konrad Zuse Centrum, Berlin)
- CSDP: Brian Borchers (New Mexico Tech)

My role in the competition

I had volunteered, so no complaints

- Over about 18 months
  - Receive regularly latest versions of codes
  - Run them on the growing number of instances provided by the organizers
  - Discuss with authors
  - Publish results on web
  - Discuss again with authors
- at the very end present talk at workshop and write paper

Math. Program., Ser. B 95: 407–430 (2003)

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H.D. Mittelmann

An independent benchmarking of SDP and SOCP solvers

Received: March 27, 2001 / Accepted: April 5, 2002
Published online: October 9, 2002 –

Abstract. This work reports the results of evaluating all computer codes submitted to the Seventh DIMACS Implementation Challenge on Semidefinite and Related Optimization Problems. The codes were run on a standard platform and on all the benchmark problems provided by the organizers of the challenge. A total of ten codes were tested on fifty problems in twelve categories. For each code the most important information is summarized. Together with the tabulated and commented benchmarking results this provides an overview of the state of the art in this field.

Key words. semidefinite programming – second order cone programming – optimization software – performance evaluation

1. Introduction

1.1. The problems solved

The primal and dual pair of conic optimization problems over a self-dual cone are defined as

$$
(P) \qquad \begin{array}{ll} \min & \langle c, x\rangle \\ \text{s.t.} & x \in K \\ & \mathcal{A}x = b \end{array} \qquad\qquad \begin{array}{ll} \max & b^T y \\ s.t. & z \in K \\ & \mathcal{A}^* y + z = c \end{array} \qquad (D)
$$

where

- K is a closed, convex cone in a euclidean space X.
- $\mathcal{A} : X \to \mathbb{R}^m$ is a linear operator, and $\mathcal{A}^*$ is its adjoint.
- $b \in \mathbb{R}^m$, and $c \in X$.

Springer Link

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International Series in Operations Research & Management Science
Volume 166 2012

Handbook on Semidefinite, Conic and Polynomial Optimization

ISBN: 978-1-4614-0768-3 (Print) 978-1-4614-0769-0 (Online)

Table of contents (31 chapters)

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I can certainly do something similar

Adapted to electrical grids

- Am I clueless? Fortunately not quite, see IEEE 2012

1

Transmission Expansion Planning Using an AC Model: Formulations and Possible Relaxations

Hui Zhang, *Student Member, IEEE*, Gerald Thomas Heydt, *Life Fellow, IEEE*, Vijay Vittal, *Fellow, IEEE*, and Hans D. Mittelmann

***Abstract*—Transmission expansion planning (TEP) is a rather complicated process which requires extensive studies to determine *when, where* and *how many* transmission facilities are needed. A well planned power system will not only enhance the system reliability, but also tend to contribute positively to the overall system operating efficiency. Starting with two mixed-integer nonlinear programming (MINLP) models, this paper explores the possibility of applying AC-based models to the TEP problem. Two nonlinear programming (NLP) relaxation models are then proposed by relaxing the binary decision variables. A reformulation-linearization-technique (RLT) based relaxation model in which all the constraints are linearized is also presented and discussed in the paper. Garvers's 6-bus test system and the IEEE 24-bus system are used to test the performance of the proposed models and related solvers. A validation process guarantees that the resultant TEP plan is strictly AC feasible. The simulation results show that by using proper reformulations or relaxations, it is possible to apply the AC models to TEP problems and obtain a**

P_k	Active power flow on line k
PG_g	Active power output of generator g
$PG_{g.\max}$	Active power capacity of the generator g
Q_k	Reactive power flow on line k
QD_i	Total reactive power of the load at bus i
QG_g	Reactive power output of generator g
$QG_{g.\max}$	Reactive power capacity of the generator g
$\mathbf{R}_+$	Set of positive real numbers
$S_{k.\max}$	MVA capacity of line k
V_i	Voltage at bus i
$V_{\max}$	Bus voltage upper bound
$V_{\min}$	Bus voltage lower bound
x_L, y_L	Lower bound of x, y

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Thank you for your attention

- I am offering my participation

- maybe we should have a discussion