Benchmarks for Global Optimization and Continuous Constraint Satisfaction

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September 19, 2002

To evaluate experimentally global optimization software, it is important to have a properly tested set of optimization problems written as executable models and with known and checked results (i.e., the optimal value of objective function and preferably an optimal solution).

To do this it is necessary is to provide a **benchmark** consisting of a comprehensive suite of representative problems, covering as far as possible all the categories of scientific, economical, technical, or industrial optimization problems.

A good benchmark must be one that can be interfaced with existing global optimization systems, in a way that a sufficient number of comparative results can be obtained. It is not sufficient only to collect test problems on a Webpage, but it is necessary to check and run them, to compare the solutions obtained with known ones, and to sort test problems by their complexity and dimension.

The current situation for test problems on global optimization is characterized by the availability of rather big collections of test problems; but some of these problems have errors in the model, or a wrong solution is given. We considered some of the existing libraries. A recent web site by GAMS World [8] collects real life global optimization problems with industrial relevance, but currently most problems on this site are without computational results. Another well-known library is CUTE [10] by N.I.M. Gould, D. Orban and Ph.L.Toint, also part of Vanderbei's AMPL test collection [11].

The benchmark collected for the COCONUT project includes most of the problems from these two collections, and many additional constraint satisfaction problems (collected by EPFL, Lausanne). To use the benchmark efficiently in our environment we must have AMPL-formulations of all test problems. The library GlobaLLib is written in GAMS-format. To get the AMPL-formulation, it is possible to use the gams2xx-converter from GAMS format to AMPL. But this tool fails sometimes (e.g., for unconstrained problems).

DAG's = directed acyclic graphs form the internal representation from which other representations are generated. DAG-formulations of almost all test problems for test libraries 1 (GlobalLib) and 2 (CUTE) were built from AMPL files. Further programs transform DAG-file for optimization model into GAMS format, LGO format, Globsol format.

All problems in our benchmark are represented in a common format suitable for automatic execution on global optimization and constraint satisfaction software. To ensure that benchmarking results are comparable across different solvers and environments, a **benchmarking protocol** is defined, whose execution on the benchmark will provide a number of objective performance measures for any implementation of global optimization and constraint satisfaction techniques.

The full benchmarking suite is a comprehensive collection of 329 constraint satisfaction and 993 optimization problems from academic, industrial and real-life environments. Executable versions of these test problems, as well as information on their sources, are publicly available at

`http://www.mat.univie.ac.at/~neum/glopt/coconut/benchmark.html`

The problems range in difficulty from easy to very huge, their sizes from a few number of variables to over 1000 variables. These test problems come from both the research literature and a wide spectrum of applications, including: Chemical engineering, Computational chemistry,Civil engineering problems, Robotics problems, Operations research problems, Economics problems, Multicommodity network flow problems, Stability analysis problems etc.

Some problems (e.g. linear or convex quadratic programs) are known to be solvable by local optimization alone. They were retained in the benchmark to be able to measure the overhead which global solvers have in order to prove optimality, compared with local solvers who assume the convex structure from the outset and hence are usually significantly faster.

As far as reasonable, all problems were checked for correctness; inconsistencies with information available from other sources were removed if possible. Information about (approximate) solutions and putative global minimizers and minima were provided in all but a few cases (where runtime constraints became active).

A few problems from the collections mentioned are missing in the present benchmark because of our inability to get a valid authentic version (e.g., the 'handbook' [4] contains numerous inconsistencies), because of the presence of constructs or functions not supported by our current system (such as `if`, `erf`).

The AMPL code for all problems in the benchmark is available online at the web site mentioned, through links from tables with one line summaries of problem characteristics.

Each problem is classified as in the CUTE collection of test problems, with a few enhancements in the coding. In most cases, we also report the number of nonzeros and nonlinear nonzeros in an internal representation used in the GAMS system [7]. These give additional information about complexity.

The following table summarizes the benchmark problems.

Number of variables		$1-9$	$10-99$	$100-999$	≥ 1000	total
Library 1	# problems	84	90	44	48	266
Library 2	# problems	347	100	93	187	727
Library 3	# problems	225	76	22	6	329
total	# problems	656	266	159	241	1322

References

[1] L.C.W. Dixon and G.P. Szegö, The global optimization problem: an introduction, pp. 1–15 in: L.C.W. Dixon and G.P. Szegö (eds.), Towards Global Optimisation 2, North-Holland, Amsterdam 1978.

[2] E.D. Dolan and J.J. Moré, Benchmarking Optimization Software with COPS, Tech. Report ANL/MCS-246, Argonne Nat. Lab., November 2000.
`http://www-unix.mcs.anl.gov/~more/cops`

[3] E.D. Dolan and J.J. Moré, Benchmarking Optimization Software with Performance Profiles, Tech. Report ANL/MCS-P861-1200, Argonne Nat. Lab., January 2001
`http://www-unix.mcs.anl.gov/~more/cops`

[4] C.A. Floudas, P.M. Pardalos, C.S. Adjiman, W.R. Esposito, Z.H. Gümüs, S.T. Harding, J.L. Klepeis, C.A. Meyer and C.A. Schweiger, Handbook of Test Problems in Local and Global Optimization, Kluwer, Dordrecht 1999.

[5] R. Fourer, D.M. Gay and B.W. Kernighan, AMPL: A Modeling Language for Mathematical Programming, Duxbury Press / Brooks/Cole Publishing Company, 1993.
`http://www.ampl.com/cm/cs/what/ampl/`

[6] GAMS/Convert 4.0 User Notes, PDF-document, 2002.
`http://www.gams.com/docs/contributed/convert.pdf`

[7] GAMS World, WWW-document, 2002.
`http://www.gamsworld.org`

[8] GLOBAL Library, WWW-document, 2002.
`http://www.gamsworld.org/global/globallib.htm`

[9] GMS2XX Translator, WWW-document, 2002.
`http://www.gamsworld.org/translate.htm`

[10] N.I.M. Gould, D. Orban and Ph.L. Toint, CUTEr, a constrained and unconstrained testing environment, revisited, WWW-document, 2001.
`http://cuter.rl.ac.uk/cuter-www/problems.html`

[11] B. Vanderbei, Nonlinear Optimization Models, WWW-document.
`http://www.orfe.princeton.edu/~rvdb/ampl/nlmodels/`

[12] P. Van Hentenryck, L. Michel and Y. Deville, Numerica. A Modeling Language for Global Optimization, MIT Press, Cambridge, MA 1997.