Quality Assurance and Global Optimization

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ARKI Consult and GAMS Development Corporation

Global Constrained Optimization and Constraint Satisfaction (Cocos'02),
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Introduction

- Background and Motivation
- Global Optimization with GAMS
  - Available solvers
  - Issues specific to global optimization codes
- Framework for reliability and performance testing
- Examples

GAMS Overview

- Started as a Research Project at the World Bank 1976
- GAMS went commercial in 1987
- Opened European Office in Cologne, Germany 1996
- 10,000s of users in over 100 countries
- Unique position between the academic and commercial world

Basic Principles

- Separation of model and solution methods
- Model types
  - LP, MIP, **NLP**, **MINLP**, MCP, MPEC
  - Stochastic Programming, MPSGE
- Multiple solvers
- Computing platform independence

Supported Solvers

BDMLP	LP solver that comes with any GAMS system
CONOPT	Large scale NLP solver from ARKI Consulting and Development
CPLEX	High-performance LP/MIP solver from Ilog
DECIS	Large scale stochastic programming solver from Stanford University
DICOPT	Framework for solving MINLP models. Needs both an NLP solver and a MIP solver. From Carnegie M
MILES	MCP solver from University of Colorado at Boulder that comes with any GAMS system
MINOS	NLP solver from Stanford University
MPSGE	Modeling Environment for CGE models from University of Colorado at Boulder
OSL	High performance LP/MIP solver from IBM
OSLSE	OSL Stochastic Extension for solving stochastic models
PATH	Large scale MCP solver from University of Wisconsin at Madison
SBB	Branch-and-Bound algorithm from ARKI Consulting and Development for solving MINLP models, requi
SNOPT	Large scale SQP based NLP solver from Stanford University
XA	Large scale LP/MIP system from Sunset Software
XPRESS	High performance LP/MIP solver from Dash

Beta Solvers

BARON	Branch-And-Reduce Optimization Navigator for proven global solutions from The Optimization Firm
CONVERT	Frame work for translating models into scalar models of other languages
LGO	Lipschitz global optimizer from Pinter Consulting Services
MOSEK	Large scale LP/MIP plus conic and convex non-linear programming system from EKA Consulting
NLPEC	MPEC to NLP translator that uses other GAMS NLP solvers
OQMS	Multi-start method for global optimization from Optimal Methods Inc.
PATHNLP	Large scale NLP solver for convex problems from University of Wisconsin at Madison

Contributed Plug&Play Solvers

AMPLwrap	Framework for using AMPL solver for GAMS models
DEA	Large scale Data Envelop Analysis Solver from University of Wisconsin at Madison
Kestrel	Framework for using remote NEOS solvers with a local GAMS system
QPwrap	Quadratic programming in GAMS

Supported Platforms

Solver/Platform availability - 20.7 June 14, 2002							
	Intel		Sun Sparc	HP 9000	DEC Alpha	IBM RS-6000	SGI
	Windows 95/98/Me/NT/2000/XP	Linux	Solaris	HP-UX 10	Digital Unix 4.0	AIX 4.3	IRIX
BDMLP	✔	✔	✔	✔	✔	✔	✔
CONOPT	✔	✔	✔	✔	✔	✔	✔
CPLEX 7.5	✔	✔	✔	✔	✔	✔	✔
DECIS	✔	✔	✔		✔		✔
DICOPT	✔	✔	✔	✔	✔	✔	✔
MILES	✔	✔	✔	✔	✔	✔	✔
MINOS	✔	✔	✔	✔	✔	✔	✔
MPSGE	✔	✔	✔	✔	✔	✔	✔
OSL V3	✔	✔	✔	✔		✔	✔
PATH	✔	✔	✔	✔	✔	✔	✔
SBB	✔	✔	✔	✔	✔	✔	✔
SNOPT	✔	✔	✔	✔	✔	✔	✔
XA	✔	✔	✔	✔	✔	✔	
XPRESS 13.02	✔	✔	✔	13.01			

GAMS/GLOBAL Solvers

The solvers differ in the methods they use, in whether they find globally optimal solution with proven optimality, and in the size of models they can handle, and in the format of models they accept.

- **BARON**. Branch-and-Reduce algorithm from N.Sahinidis, University of Illinois Urbana-Champaign
- **LGO**. Lipschitz Global Optimization from Pinter Consulting Services, Canada
- **OQMS**. OptQuest/NLP algorithms by OptTek Systems and Optimal Methods

GAMS

BARON

BARON is a computational system for solving non convex optimization problems to global optimality. Purely continuous, purely integer, and mixed-integer nonlinear problems can be solved with the software. The Branch And Reduce Optimization Navigator derives its name from its combining interval analysis and duality in its reduce arsenal with enhanced branch and bound concepts as it winds its way through the hills and valleys of complex optimization problems in search of global solutions.

LGO

LGO combines rigorous statistical methods with traditional mathematical programming methods to find solutions within well defined bounds. Tailored versions of LGO have been applied successfully in number of large scale special purpose applications.

OQMS

OQMS. This system combines existing the robust nonlinear optimization technologies with OptTek's state-of-the-art metaheuristic search procedures, including Tabu Search, Neural Networks, and Scatter Search, into a single composite method.

Local Optimization Today

- Nonlinear modeling available in GAMS from the very beginning
- Variety of local solvers
  - NLP: MINOS, CONOPT, SNOPT, LSGRG,PATHNLP
  - MINLP: DICOPT, SBB

  implementing different methods (SLP, SQP, GRG, B&B, outer approximation…) improve reliability of nonlinear modeling
- Initial point is crucial for success

Global Codes and GAMS

- Global codes provide
  - Independence of starting point
  - Global/improved solutions
  - Bounds for solution quality
- (Almost) seamlessly exchange of local solvers with global solvers: `Option nlp=oqms;`
- Minimize risk of new technology for customers
  - Multiple Global Codes
  - Fallback to Local Solvers

Open Issues for Global Codes

- Termination criteria
  - When to stop a multi-start method?
- Problem modification
  - Global solvers require bounding box
- Limited algebra
  - E.g. External functions (black box)
- Solution quality metrics

Research v.Commercial Codes

- Run in “expert mode” tuned by the developer for a particular problem
- User wants to solve his business problem and wants to treat the solver as a black box
- Solver has to work decently in *all* cases
- Even if the algorithm fails, the solver has to be “*fail-safe*”

QA Tests for Reducing Risk

- Replication of quality assurance results critical factor for establishing a new solver technology in the commercial world
- Non-reproducible tests damage the reputation of a solver
- Requirement: low cost replication of such results by an independent auditor

GAMS

Effective Testing

- Test cases
  - Widely available collection of standardized test instances
- Data collection tools
  - Automatic collection of solution and statistics
  - Capture test environment setting (hardware, software)
- Data analysis tools
  - Standard quality and performance measurements

Test Cases

- Classification
  - Toy models
  - Academic Application Models
  - Commercial Application Models (difficult to collect)
- Growing GAMS Model Collections
  - GAMS Model library http://www.gams.com/modlib/modlib.htm, with about 250 models from over 18 application areas
  - GLOBALLib http://www.gamsworld.org/global/globallib.htm, with about 250 scalar NLP models
  - MINLPLib http://www.gamsworld.org/minlp/minlplib.htm, with about 180 scalar MINLP models
  - MPECLib http://www.gamsworld.org/mpec/mpeclib.htm, which produces over 10,000 NLP models

GAMS World Home Page

GAMS World

The Worlds
- GLOBAL
- MINLP
- MPEC
- MPSGE
- Performance
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Welcome to the GAMS World

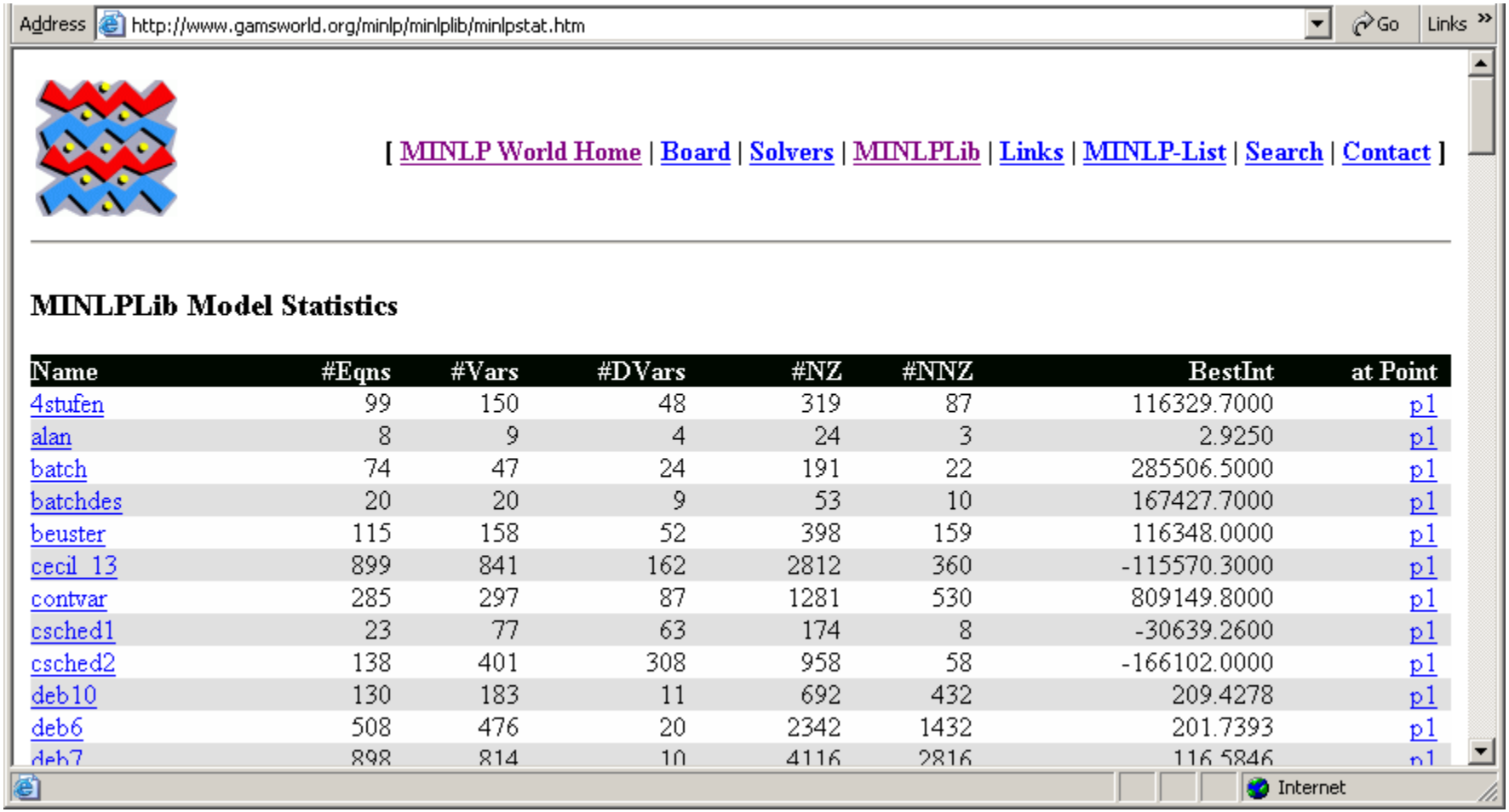
This is the home page of the GAMS World, a web site aiming to bridge the gap between academia and industry by providing highly focused forums and dissemination services in specialized areas of mathematical programming.

Substantial progress was made in the 1980s and 1990s with the development of algebra based modeling systems, algorithms, and computer codes to solve large and complex mathematical programs. The application of these tools, however, was less than expected. The abstraction, expression, and translation of real world problems into reliable and effective operational systems requires highly specialized and domains specific knowledge. The process of acquisition and dissemination of this knowledge is complex and poorly understood and the number of "good modelers" is much less than we all hoped for. Similarly, the process of transforming a new algorithm into a reliable and effective solution system is a slow and expensive process and there are few "good implementers". This web site hopes to address some of these problems by helping with the collection and dissemination of domain specific information and knowledge that is outside the established channels because of its content or form.

For example, model structures and results get published in commercial and academic papers but it is virtually impossible to reproduce any of those results or lift model components and data from one study to be used in some other study. Algorithm implementers face a similar dilemma when trying to get their hands on real world data models and data to test and refine their systems. This web site offers a few, well focused and maintained services to help with the dissemination of problems and solutions.

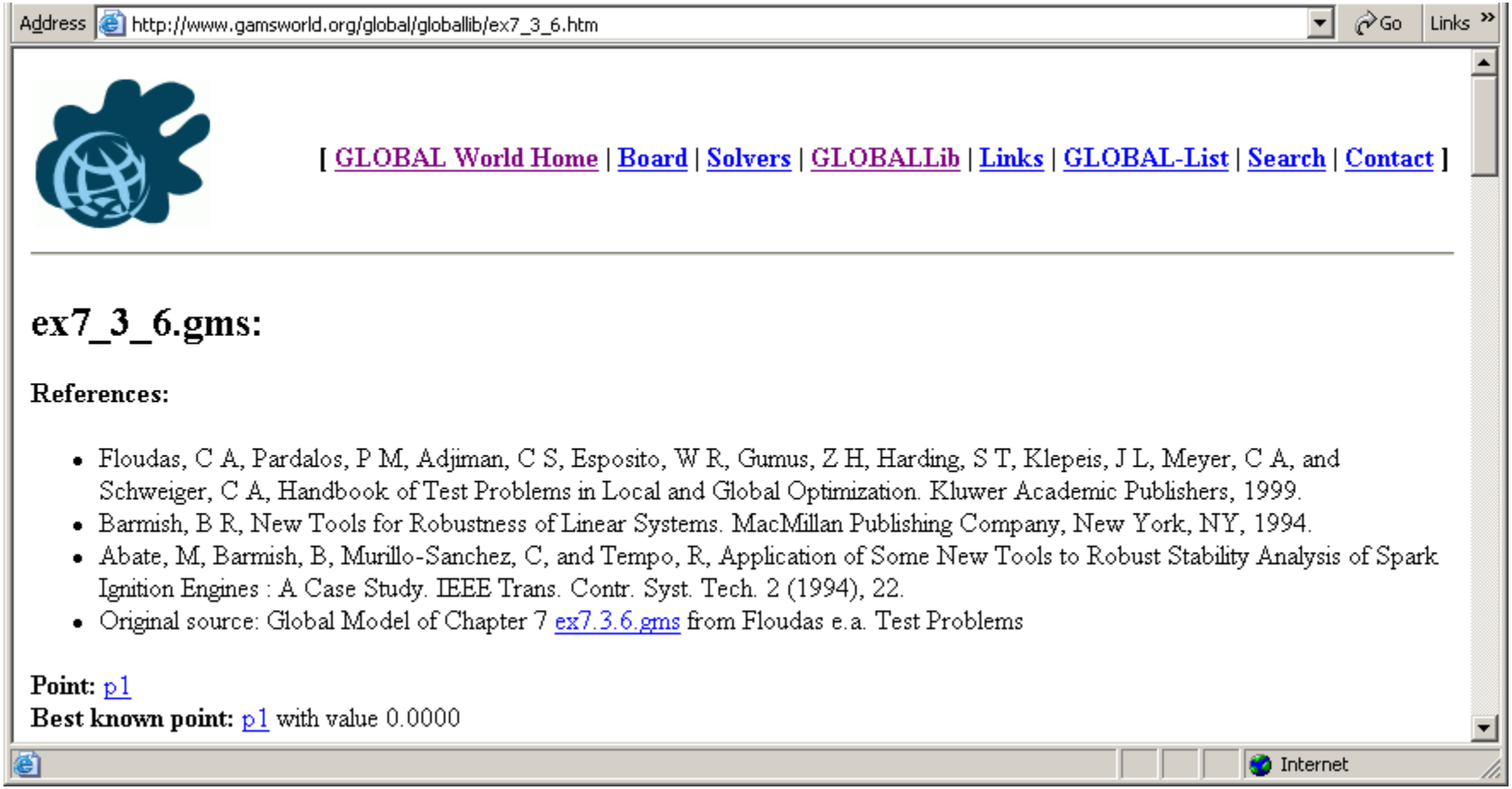
GAMS World is featured by GAMS Development Corp. and GAMS Software GmbH

MINLP Lib

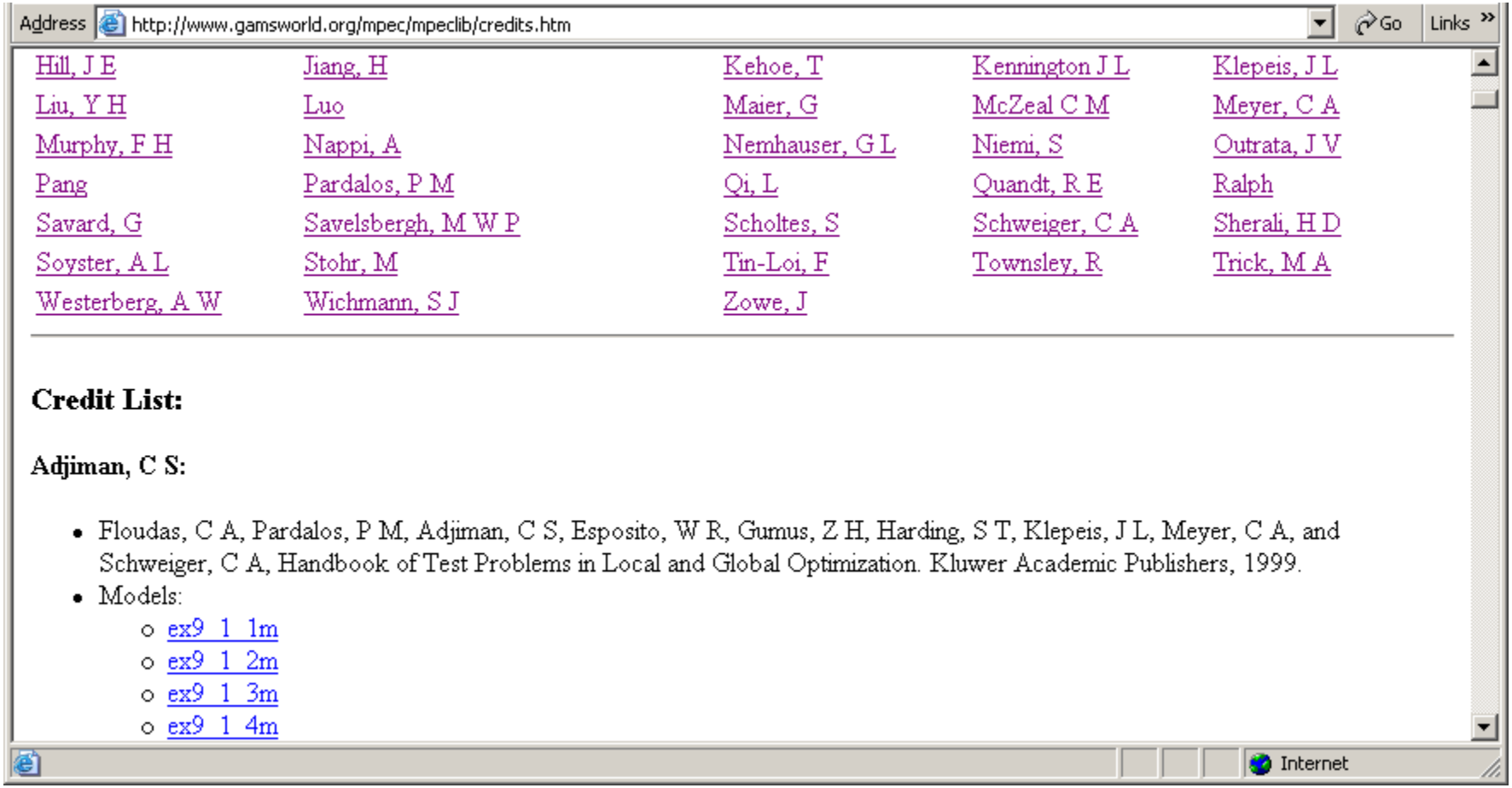


Name	#Eqns	#Vars	#DVars	#NZ	#NNZ	BestInt	at Point
4stufen	99	150	48	319	87	116329.7000	p1
alan	8	9	4	24	3	2.9250	p1
batch	74	47	24	191	22	285506.5000	p1
batchdes	20	20	9	53	10	167427.7000	p1
beuster	115	158	52	398	159	116348.0000	p1
cecil_13	899	841	162	2812	360	-115570.3000	p1
contvar	285	297	87	1281	530	809149.8000	p1
csched1	23	77	63	174	8	-30639.2600	p1
csched2	138	401	308	958	58	-166102.0000	p1
deb10	130	183	11	692	432	209.4278	p1
deb6	508	476	20	2342	1432	201.7393	p1
deb7	898	814	10	4116	2816	116.5846	p1

Global Lib


Address
http://www.gamsworld.org/global/globallib/ex7_3_6.htm
Go
Links
[GLOBAL World Home | Board | Solvers | GLOBALLib | Links | GLOBAL-List | Search | Contact]
ex7_3_6.gms:
References:
Floudas, C A, Pardalos, P M, Adjiman, C S, Esposito, W R, Gumus, Z H, Harding, S T, Klepeis, J L, Meyer, C A, and Schweiger, C A, Handbook of Test Problems in Local and Global Optimization. Kluwer Academic Publishers, 1999.
Barmish, B R, New Tools for Robustness of Linear Systems. MacMillan Publishing Company, New York, NY, 1994.
Abate, M, Barmish, B, Murillo-Sanchez, C, and Tempo, R, Application of Some New Tools to Robust Stability Analysis of Spark Ignition Engines : A Case Study. IEEE Trans. Contr. Syst. Tech. 2 (1994), 22.
Original source: Global Model of Chapter 7 ex7.3.6.gms from Floudas e.a. Test Problems
Point: p1
Best known point: p1 with value 0.0000
Internet

MPEC Lib


Address
http://www.gamsworld.org/mpec/mpeclib/credits.htm
Go
Links
Hill, J E
Jiang, H
Kehoe, T
Kennington J L
Klepeis, J L
Liu, Y H
Luo
Maier, G
McZeal C M
Meyer, C A
Murphy, F H
Nappi, A
Nemhauser, G L
Niemi, S
Outrata, J V
Pang
Pardalos, P M
Qi, L
Quandt, R E
Ralph
Savard, G
Savelsbergh, M W P
Scholtes, S
Schweiger, C A
Sherali, H D
Soyster, A L
Stohr, M
Tin-Loi, F
Townsley, R
Trick, M A
Westerberg, A W
Wichmann, S J
Zowe, J
Credit List:
Adjiman, C S:
Floudas, C A, Pardalos, P M, Adjiman, C S, Esposito, W R, Gumus, Z H, Harding, S T, Klepeis, J L, Meyer, C A, and Schweiger, C A, Handbook of Test Problems in Local and Global Optimization. Kluwer Academic Publishers, 1999.
Models:
ex9_1_1m
ex9_1_2m
ex9_1_3m
ex9_1_4m
Internet

Data Collection Tools

- Status/performance/exception information
- GAMS Trace facility automatically collects
  - Model statistics
  - Non-default input options
  - Solver and solution statistics
  - Execution environment information
    - Version control of solvers

Data Analysis Tools

- Integral part of the quality assurance process at GAMS
- Processing of trace results
  - Build-in tools for status information
  - Custom GAMS programs
  - Performance World Tools
    - Performance measurements
    - Graphical/tabular representations

Performance World

Performance World

Editorial Board

PerformanceLib

Performance Tools

Performance List

Related Links

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Welcome to the Performance World!

Performance World is a forum for discussion and dissemination of information and tools about all aspects of performance testing of mathematical programming problems. This world has been established in response to user demands for independent and reproducible performance results.

Overall performance highly depends on problem formulation, solver, and tuning parameters. Our performance tools are designed to serve the different needs of our user community. One user may be interested in finding the most reliable way to solve a proprietary or classified model. On the other hand, an academic researcher may be interested in testing a new algorithm against a set of existing test problems and competing approaches. The main features are:

- Uniform access to a comprehensive set of established and new test problems
- Automation tools for collecting performance measurements
- Tools for analyzing and visualizing test results

What's New:

- Try our online PAVER Server for automated performance analysis and batch file creation
- New tools for analyzing non-convex or discrete models
- MINLP type models from the MINLP World have been added to the PerformanceLib A tutorial (August, 2002)

Open Testing Architecture

- Test models
  - Open source GAMS models
  - Automatic translation into different formats, e.g. AMPL
  - Web/Email interface for this translation service
- Trace facility API
  - ASCII import/export of trace files
- Analysis tools
  - open source GAMS programs
  - Web interface for PAVER (**P**erformance **A**nalysis and **V**isualization for **E**ffortless **R**eproducibility)

Translation Services

Instructions

In order to use the GMS2XX translation service which is based on the "solver" GAMS/CONVERT you have to attach your model to an email and send it to our translation server at gms2xx@gamsworld.org. You specify the language in the subject line, for example

```
Subject: GAMS
```

At the moment we support the following *languages*:

- AMPL
- BARON
- CplexLP
- CplexMPS
- GAMS
- LGO
- LINGO
- MINOPT
- ALL (this creates scalar versions of all supported languages, listed above)

```
Set I Products         /P1*P2/
    J Cutting Patterns /C1*C2/;

Parameter c(J)    cost of raw material                  /C1 1, C2 1/
          cc(J)   cost of change-over of knives         /C1 0.1, C2 0.2/
          b(I)    width of product roll-type I          /P1 460, P2 570/
          nord(I) number of orders of product type I    /P1 8, P2 7/
          Bmax    width of raw paper roll               /1900/
          Delta   tolerance for width                   / 200/
          Nmax    max number of products in cut         /   5/
          bigM    max number of repeats of any pattern  /  15/;

Variable  y(J)    cutting pattern
          m(J)    number of repeats of pattern j
          n(I,J)  number of products I produced in cut J
          obj     objective variable;

Binary Variable y; Integer Variable m, n;

Equation defobj, max_width(J), min_width(J), max_n_sum(J),
                 min_order(I), cut_exist(J), no_cut(J);

defobj..         sum(j, c[j]*m[j] + cc[j]*y[j]) =e= obj;
max_width(j)..   sum(i, b[i]*n[i,j])            =l= Bmax;
min_width(j)..   sum(i, b[i]*n[i,j]) + Delta    =g= Bmax;
max_n_sum(j)..   sum(i, n[i,j])                 =l= Nmax;
min_order(i)..   sum(j, m[j]*n[i,j])            =g= nord[i];
cut_exist(j)..   y[j]                           =l= m[j];
no_cut(j)..      m[j]                           =l= bigM*y[j];

m.up[j] =  bigM; n.up[i,j] = nmax;

model trimloss /all/;
solve trimloss minimize obj using minlp;
```

```
*  MINLP written by GAMS Convert
Variables
b1,b2,i3,i4,i5,i6,i7,i8,x9;
Binary Variables b1,b2;
Integer Variables i3,i4,i5,i6,i7,i8;
Equations
e1,e2,e3,e4,e5,e6,e7,e8,e9,e10,
           e11,e12,e13;

e1..  0.1*b1 + 0.2*b2 + i3 + i4 - x9
=E= 0;
e2..  460*i5 + 570*i7 =L= 1900;
e3..  460*i6 + 570*i8 =L= 1900;
e4..  460*i5 + 570*i7 =G= 1700;
e5..  460*i6 + 570*i8 =G= 1700;
e6..  i5 + i7 =L= 5;
e7..  i6 + i8 =L= 5;
e8..  i3*i5 + i4*i6 =G= 8;
e9..  i3*i7 + i4*i8 =G= 7;
e10.. b1 - i3 =L= 0;
e11.. b2 - i4 =L= 0;
e12.. - 15*b1 + i3 =L= 0;
e13.. - 15*b2 + i4 =L= 0;

* set non default bounds
i3.up = 15; i4.up = 15; i5.up = 5;
i6.up = 5;  i7.up = 5;  i8.up = 5;

Model m / all /;
Solve m using MINLP minimizing x9;
```

```
#  MINLP written by GAMS Convert
var b1 binary;
var b2 binary;
var i3 integer >= 0, <= 15;
var i4 integer >= 0, <= 15;
var i5 integer >= 0, <= 5;
var i6 integer >= 0, <= 5;
var i7 integer >= 0, <= 5;
var i8 integer >= 0, <= 5;

minimize obj:
     0.1*b1 + 0.2*b2 + i3 + i4;

subject to

e2:  460*i5 + 570*i7 <= 1900;
e3:  460*i6 + 570*i8 <= 1900;
e4:  460*i5 + 570*i7 >= 1700;
e5:  460*i6 + 570*i8 >= 1700;
e6:  i5 + i7 <= 5;
e7:  i6 + i8 <= 5;
e8:  i3*i5 + i4*i6 >= 8;
e9:  i3*i7 + i4*i8 >= 7;
e10: b1 - i3 <= 0;
e11: b2 - i4 <= 0;
e12: - 15*b1 + i3 <= 0;
e13: - 15*b2 + i4 <= 0;
```

Trace Facility ASCII Interface

Trace file parameters

The column headers for `traceopt=3` are as follows:

```
 1. filename:     GAMS model filename
 2. modeltype:    LP, MIP, NLP, etc.
 3. solvername:
 4. NLP def:      default NLP solver
 5. MIP def:      default MIP solver
 6. juliantoday:  start day/time of job
 7. direction:    0=min, 1=max
 8. equnum:       total number of equations
 9. varnum:        total number of variables
10. dvarnum:      number of discrete variables
11. nz:           number of nonzeros
12. nlnz:         number of nonlinear nonzeros
13. optfile:      1= optfile included
14. modelstatus:
15. solvestatus:
16. obj:          value of objecive function
17. objest:       objective function estimate
18. res used:     resource time used (sec)
19. iter used:    number of solver iterations
20. dom used:
21. nodes used:
22. user1:        user comment - preceded by a #
```

Performance Tools

Download Performance tools:

Download the Performance Tools and sample data.

- Ptools.zip

Includes the following tools:

- pprocess.gms - performs all performance tools on a given set of trace files and combines output in a summary HTML page.
- pprofile.gms - performance profile routine for solver comparisons
- plotprof.gms - performance profile plotting routine using Gnuplotxy (Windows only)
- restime.gms - Resource time comparison utility
- schulz.gms - termination routine to ensure solvers terminate at resource time limit
- square.gms - solver outcome comparison utility

Also includes the following sample data files, where solvers have been renamed to generic A, B, C to hide proprietary data:

PAVER Web Submission

[Performance World Home | Board | Tools | PerformanceLib | Links | Performance-List | Search | Contact]

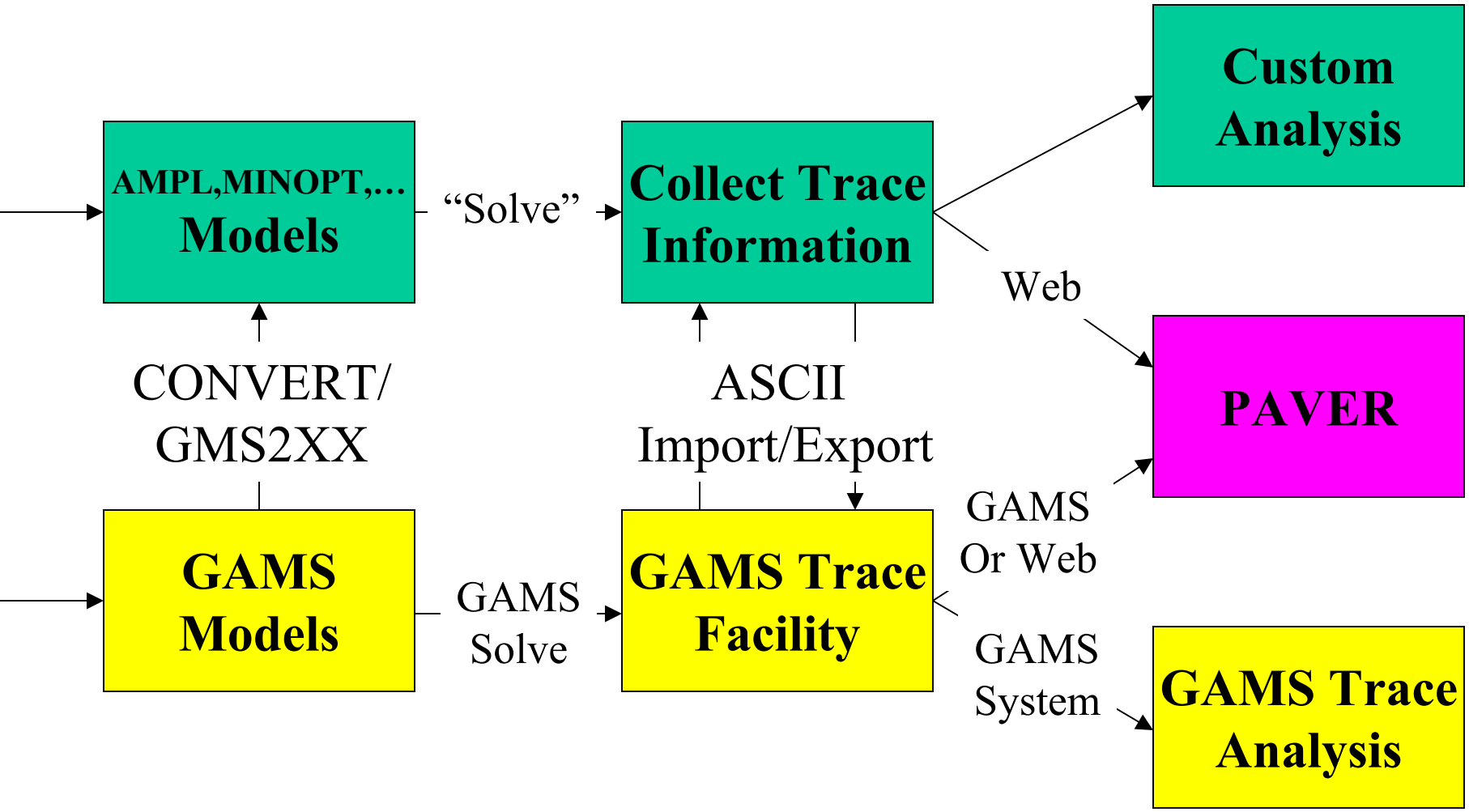
PAVER - Performance Analysis Web Submission Tool

Email Address (required): michael@gams.com

	Submit trace file:		Rename solver:
Trace 1 (required)	baron.trc	Browse...	
Trace 2 (required)	baronoptcr.trc	Browse...	BARON 0.1 OptCr
Trace 3		Browse...	
Trace 4		Browse...	
Trace 5		Browse...	
Trace 6		Browse...	
Trace 7		Browse...	
Trace 8		Browse...	

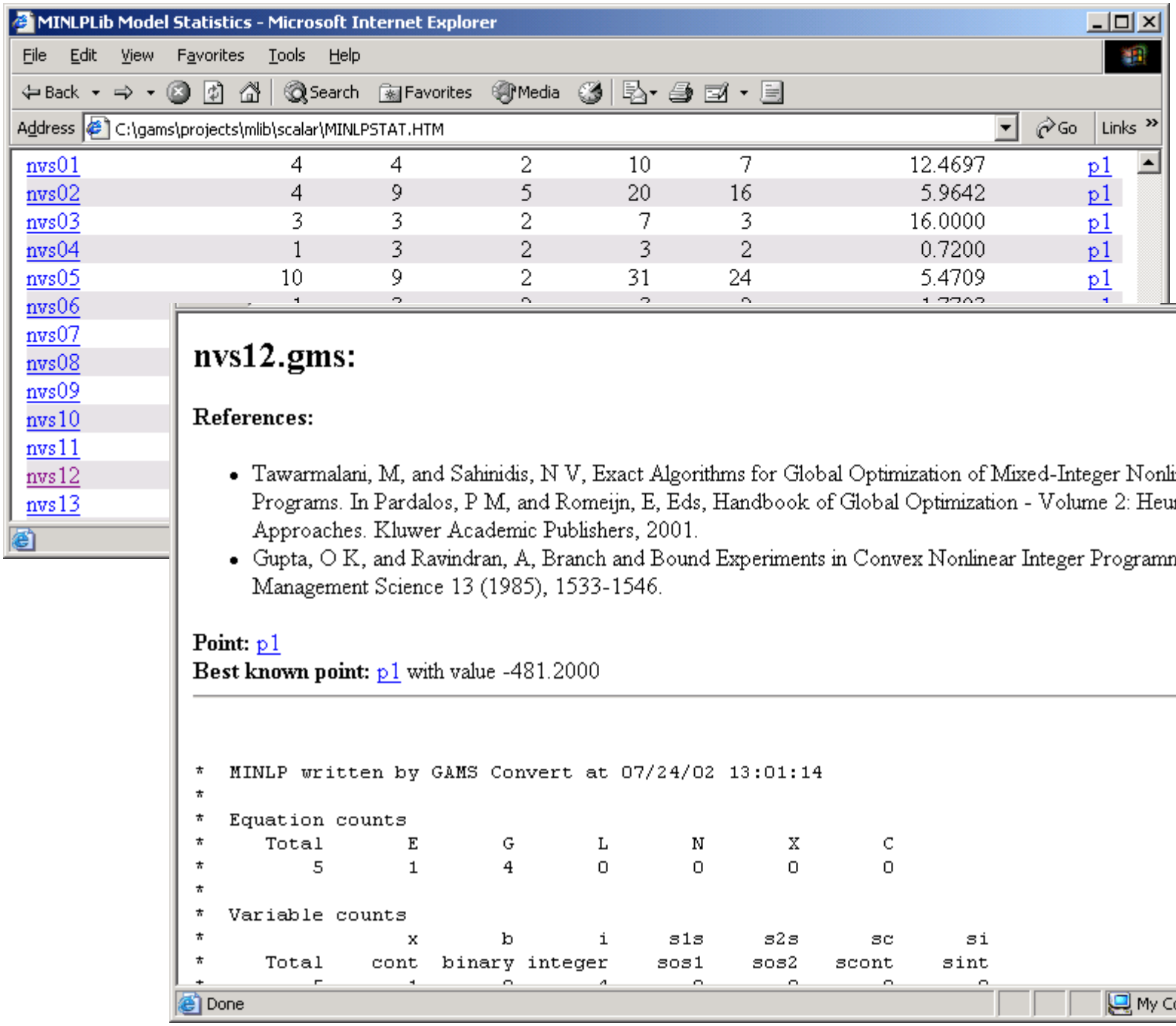
Submit Trace Files | Clear Form

Open Testing Architecture

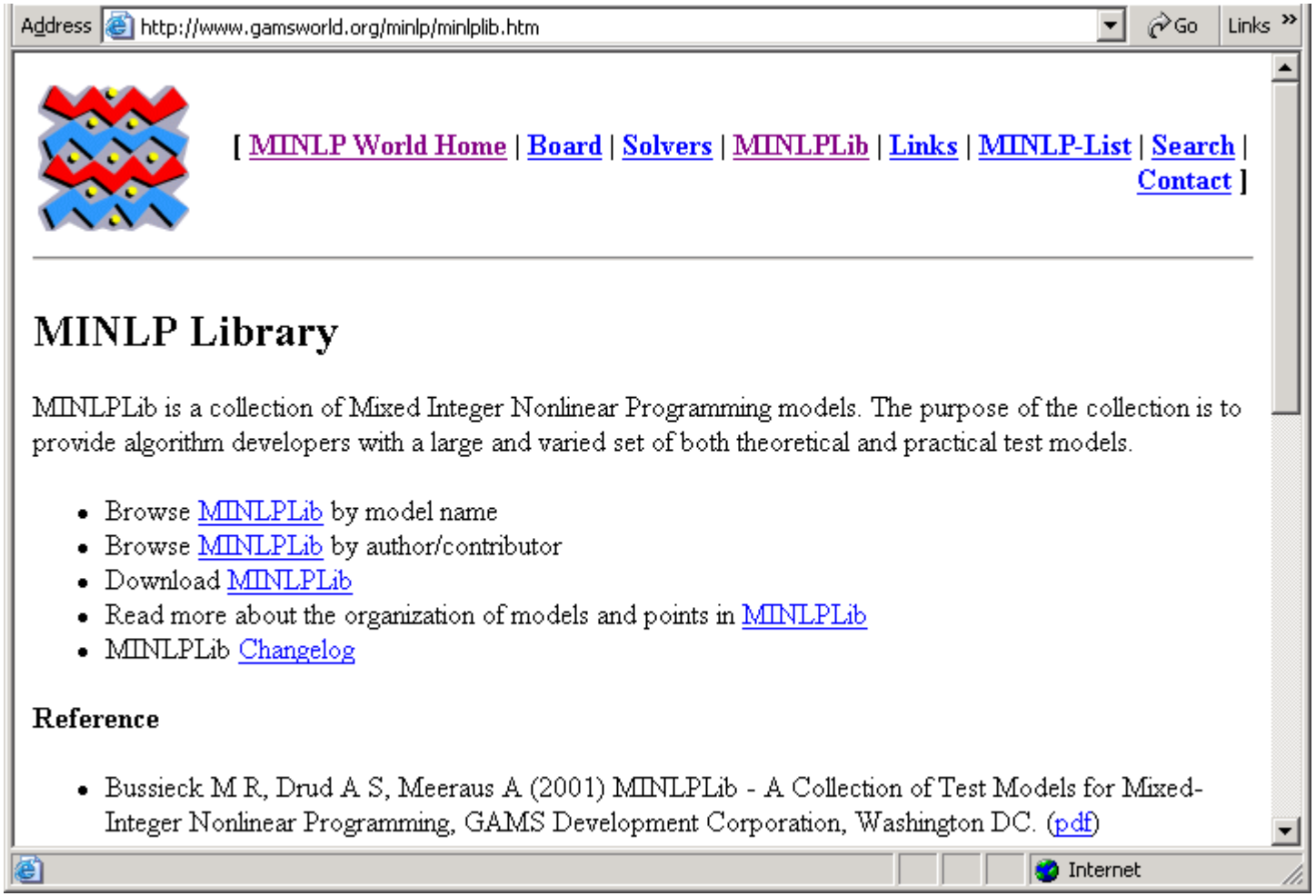


Example 1

- 24 MINLP Models from *Gupta, O K, and Ravindran, A, Branch and Bound Experiments in Convex Nonlinear Integer Programming. Management Science 13 (1985), 1533-1546.*
- Run all available GAMS MINLP solvers (*BARON, DICOPT, OQMS, SBB*) and *MINLP* (B&B based on FILTER by Fletcher and Leyffer) available through NEOS.
- Run all 24 models with all solvers (time limit 20 seconds) compare objective value with reference point.


MINLPLib Model Statistics - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites Media
Address C:\gams\projects\mlib\scalar\MINLPSTAT.HTM
Go Links
nvs01 4 4 2 10 7 12.4697 p1
nvs02 4 9 5 20 16 5.9642 p1
nvs03 3 3 2 7 3 16.0000 p1
nvs04 1 3 2 3 2 0.7200 p1
nvs05 10 9 2 31 24 5.4709 p1
nvs06
nvs07
nvs08
nvs09
nvs10
nvs11
nvs12
nvs13
nvs12.gms:
References:
Tawarmalani, M, and Sahinidis, N V, Exact Algorithms for Global Optimization of Mixed-Integer Nonlinear Programs. In Pardalos, P M, and Romeijn, E, Eds, Handbook of Global Optimization - Volume 2: Heuristic Approaches. Kluwer Academic Publishers, 2001.
Gupta, O K, and Ravindran, A, Branch and Bound Experiments in Convex Nonlinear Integer Programming. Management Science 13 (1985), 1533-1546.
Point: p1
Best known point: p1 with value -481.2000
* MINLP written by GAMS Convert at 07/24/02 13:01:14
* Equation counts
* Total E G L N X C
* 5 1 4 0 0 0 0
* Variable counts
* x b i s1s s2s sc si
* Total cont binary integer sos1 sos2 scont sint
Done
My Computer

Download MINLPLib



Trace Data Generation for all GAMS Solvers

gamside: C:\gams\tmp\nvs\nvs.gpr - [C:\gams\tmp\nvs\batch.gms]

File Edit Search Windows Help

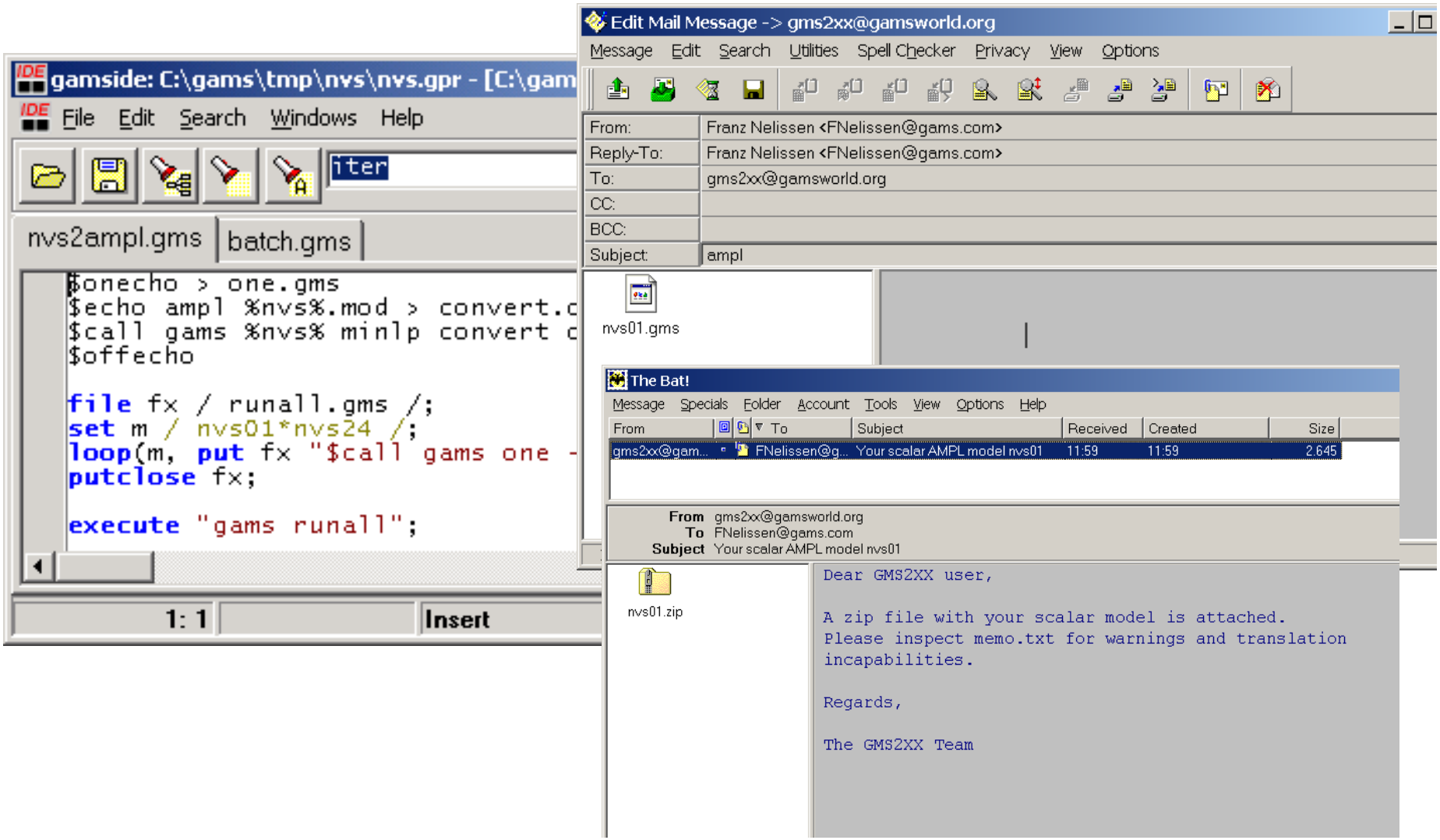
iter

nvs2ampl.gms | batch.gms

```
$eolcom //
$onecho > dorun.gms                                                    // Create batch script
set   m / nvs01*nvs24 /
file fx / run.gms /; loop(m, put fx "$call gams " m.tl " pf=param" /);
$offecho
$call gams dorun.gms
$call gmsunzip -o -q minlplib nvs*.gms                                 // Extract nvs problems from MINLPLib
$call rm -f baron.trc dicopt.trc oqms.trc sbb.trc                      // Clear the trace files

$echo reslim=20 traceopt=3 iterlim=1000000 lo=2 optcr=0 > param         // Global options

$onecho > oqms.opt                                                     // Options to let OQMS terminate on time
iteration_limit   10000
max_solver_calls  10000
max_locals        10000
$offecho
$onecho > dicopt.opt                                                   // Option for convex problems
stop          1
optcr    0.0001
maxcycles   500
$offecho

$echo minlp=baron trace=baron.trc                                  >> param
$include run
$echo minlp=dicopt mip=cplex nlp=conopt optfile 1 trace=dicopt.trc >> param
$include run
$echo minlp=oqms trace=oqms.trc optfile=1                          >> param
$include run
$echo minlp=sbb nlp=conopt domlim=100 trace=sbb.trc                >> param
$include run
$call cat oqms.trc baron.trc sbb.trc dicopt.trc > trace.trc
```

30: 107 | Insert

AMPL Model Generation



AMPL Models

Emacs 20.7.1 c:/gams/tmp/nvs/nvs01.mod

Buffers Files Tools Edit Search Mule Help

```
#  MINLP written by GAMS Convert at 08/26/
#
#  Equation counts
#     Total        E        G        L
#         4        2        2        0
#
#  Variable counts
#                  x        b        i       s1
#     Total     cont   binary  integer      sos
#         4        2        0        2
#  FX     0        0        0        0
#
#  Nonzero counts
#     Total    const       NL      DLL
#        10        3        7        0
#
#  Reformualtion has removed 1 variable ar


var i1 integer := 100, >= 0, <= 200;
var i2 integer := 100, >= 0, <= 200;
var x3 := 100, >= 0, <= 100;

minimize obj: 0.04712385*i2*(900 + i1^2)^0

subject to

e1: 420.169404664517*sqrt(900 + i1^2) - x3

e2:  - x3 >= -100;

e3: (2960.87631843 + 18505.4769901875*i2^2

--\--  nvs01.mod          (Text Fill)--L1--
End of buffer
```

Emacs 20.7.1 c:/gams/tmp/nvs/nvs02.mod

Buffers Files Tools Edit Search Mule Help

```
#  MINLP written by GAMS Convert at 08/26/02 18:06:51
#
#  Equation counts
#     Total        E        G        L        N        X        C
#         4        4        0        0        0        0        0
#
#  Variable counts
#                  x        b        i      s1s      s2s       sc       si
#     Total     cont   binary  integer     sos1     sos2    scont    sint
#         9        4        0        5        0        0        0        0
#  FX     0        0        0        0        0        0        0        0
#
#  Nonzero counts
#     Total    const       NL      DLL
#        20        4       16        0
#
#  Reformualtion has removed 1 variable and 1 equation


var i1 integer := 100, >= 0, <= 200;
var i2 integer := 100, >= 0, <= 200;
var i3 integer := 100, >= 0, <= 200;
var i4 integer := 100, >= 0, <= 200;
var i5 integer := 100, >= 0, <= 200;
var x6 >= 0, <= 92;
var x7 := 90, >= 90, <= 110;
var x8 := 20, >= 20, <= 25;

minimize obj: 9.99999999999999e-5*(5.3578547*i3^2 + 0.8356891*i1*i5 + 37.293239
              *i1) + 5.9207859;

subject to

e1:  - (0.0056858*i2*i5 + 0.0006262*i1*i4 - 0.0022053*i3*i5) + x6 = 85.334407;

e2:  - (0.0071317*i2*i5 + 0.0029955*i1*i2 + 0.0021813*i3^2) + x7 = 80.51249;

e3:  - (0.0047026*i3*i5 + 0.0012547*i1*i3 + 0.0019085*i3*i4) + x8 = 9.300961;

--\--  nvs02.mod          (Text Fill)--L1--C0--All----------------------------
```

NEOS Server: MINLP (AMPL input) WWW Interface - Netscape

File Edit View Go Communicator Help

WWW Interface

MINLP (AMPL input)

The user must submit a model in AMPL format to solve a mixed integer nonlinearly constrained optimization problem. Examples of models in AMPL format can be found in the MINLP - AMPL library .

The model is specified by a model file, and optionally, a data file and a commands file. If the command file is specified it must contain the AMPL solve command.

The commands file can contain any AMPL command or set options for MINLP . Printing directed to standard out is returned to the user with the output.

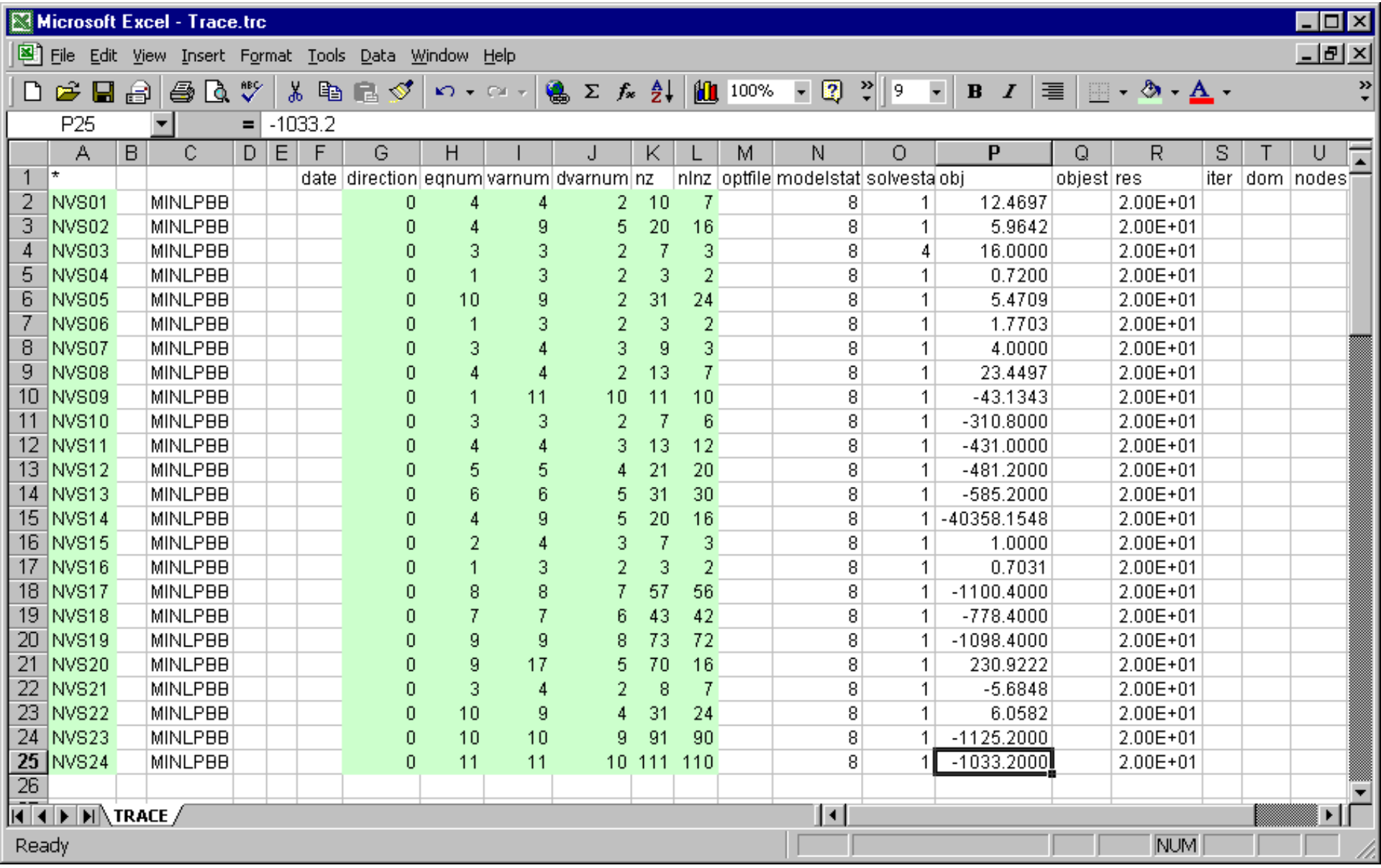
Enter the AMPL model.

AMPL model(local file):

M:\nvs\nvs24.mod Browse...

Document: Done


```
**************************************************************

                      NEOS Server Version 4.0

    Job#    : 180054
    Solver  : MINLP (AMPL input)
    Start   : 08/26/2002 17:31:32
    End     : 08/26/2002 17:31:35
    Host    : pergamon.iems.northwestern.edu

**************************************************************



***minlp***


10 variables, all nonlinear
10 constraints, all nonlinear; 100 linear nonzeros
1 nonlinear objective; 10 nonzeros.

MINLP-B?B (20020703): □□□□□□□□□□□□□□□□□□□□□□□□MINLP-B?B (20020703): Optimal solution found
113 subproblems, objective = -1033.2
Evals: obj = 385, constr = 386, grad = 386, Hes = 387
```



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	*					date	direction	eqnum	varnum	dvarnum	nz	nlnz	optfile	modelstat	solvesta	obj	objest	res	iter	dom	nodes
2	NVS01		MINLPBB				0	4	4	2	10	7		8	1	12.4697		2.00E+01			
3	NVS02		MINLPBB				0	4	9	5	20	16		8	1	5.9642		2.00E+01			
4	NVS03		MINLPBB				0	3	3	2	7	3		8	4	16.0000		2.00E+01			
5	NVS04		MINLPBB				0	1	3	2	3	2		8	1	0.7200		2.00E+01			
6	NVS05		MINLPBB				0	10	9	2	31	24		8	1	5.4709		2.00E+01			
7	NVS06		MINLPBB				0	1	3	2	3	2		8	1	1.7703		2.00E+01			
8	NVS07		MINLPBB				0	3	4	3	9	3		8	1	4.0000		2.00E+01			
9	NVS08		MINLPBB				0	4	4	2	13	7		8	1	23.4497		2.00E+01			
10	NVS09		MINLPBB				0	1	11	10	11	10		8	1	-43.1343		2.00E+01			
11	NVS10		MINLPBB				0	3	3	2	7	6		8	1	-310.8000		2.00E+01			
12	NVS11		MINLPBB				0	4	4	3	13	12		8	1	-431.0000		2.00E+01			
13	NVS12		MINLPBB				0	5	5	4	21	20		8	1	-481.2000		2.00E+01			
14	NVS13		MINLPBB				0	6	6	5	31	30		8	1	-585.2000		2.00E+01			
15	NVS14		MINLPBB				0	4	9	5	20	16		8	1	-40358.1548		2.00E+01			
16	NVS15		MINLPBB				0	2	4	3	7	3		8	1	1.0000		2.00E+01			
17	NVS16		MINLPBB				0	1	3	2	3	2		8	1	0.7031		2.00E+01			
18	NVS17		MINLPBB				0	8	8	7	57	56		8	1	-1100.4000		2.00E+01			
19	NVS18		MINLPBB				0	7	7	6	43	42		8	1	-778.4000		2.00E+01			
20	NVS19		MINLPBB				0	9	9	8	73	72		8	1	-1098.4000		2.00E+01			
21	NVS20		MINLPBB				0	9	17	5	70	16		8	1	230.9222		2.00E+01			
22	NVS21		MINLPBB				0	3	4	2	8	7		8	1	-5.6848		2.00E+01			
23	NVS22		MINLPBB				0	10	9	4	31	24		8	1	6.0582		2.00E+01			
24	NVS23		MINLPBB				0	10	10	9	91	90		8	1	-1125.2000		2.00E+01			
25	NVS24		MINLPBB				0	11	11	10	111	110		8	1	-1033.2000		2.00E+01			
26																					

Analysis Program

```
*=== Read in trace table
Table tracedata(*,*,col)
$ondelim
modelname,solvername,%col%
$offlisting
$call cat trace.trc minlpbb.csv | cut -d, -f1,3,6- > trace.tmp
$include trace.tmp
$onlisting
$offdelim
;

*=== Extract driving sets
Set modelname, solvername;
loop((u1,u2)$tracedata(u1,u2,'julian'),
  modelname(u1)  = yes;
  solvername(u2) = yes;
);

parameter srep(u1,u2,col)
          mstat(u1,u2);

* Load Reference solution
$gdxin minlpstat
$load mstat

*=== Select columns
srep(modelname,solvername,c)       = tracedata(modelname,solvername,c);
srep(modelname,'Reference','obj') = mstat(modelname,'BestInt');

Parameter gap;
gap(modelname,solvername,'agap') = round(srep(modelname,solvername,'obj') - srep(modelname,'Reference','obj'),3);
gap(modelname,solvername,'agap')$( srep(modelname,solvername,'modelstat')<>1 and
                                  srep(modelname,solvername,'modelstat')<>2 and
                                  srep(modelname,solvername,'modelstat')<>8) = inf;
gap(modelname,solvername,'rgap') = gap(modelname,solvername,'agap')/abs(srep(modelname,'Reference','obj'));
gap(modelname,solvername,'obj')  = srep(modelname,solvername,'obj');
gap(modelname,solvername,'cpu')  = srep(modelname,solvername,'res');

display srep, gap;
```

Results

```
----    167 PARAMETER gap

                      obj         agap         rgap          cpu

NVS01.OQMS         15.806        3.336        0.268        2.218
NVS01.BARON        12.470                                  0.110
NVS01.SBB          12.470                                  0.410
NVS01.DICOPT       12.470                                  0.035
NVS01.MINLPBB      12.470                                 20.000
NVS02.OQMS          6.575        0.611        0.102       20.046
NVS02.BARON         5.964                                  0.080
NVS02.SBB           5.964                                  0.437
NVS02.DICOPT        5.964                                  0.346
NVS02.MINLPBB       5.964                                 20.000
NVS03.OQMS         16.000                                 20.015
NVS03.BARON        16.000                                  0.060
NVS03.SBB          16.000                                  0.305
NVS03.DICOPT       16.000                                  0.069
NVS03.MINLPBB      16.000                                 20.000
NVS04.OQMS          0.720                                  0.265
NVS04.BARON         0.720                                  0.050
NVS04.SBB           0.720                                  0.195
NVS04.DICOPT        2.120        1.400        1.944        0.227
NVS04.MINLPBB       0.720                                 20.000
```

Example 2

- 50 instances of NLP model LMP1 from *H. Konno and T. Kuno, "Linear multiplicative programming" Mathematical Programming, 56(51-64), 1992.*
- Run BARON in default mode and with 5 different option files (time limit 300 seconds).
- Compare Performance using PAVER.

lmp1.gms : Linear Multiplicative Model - Type 1

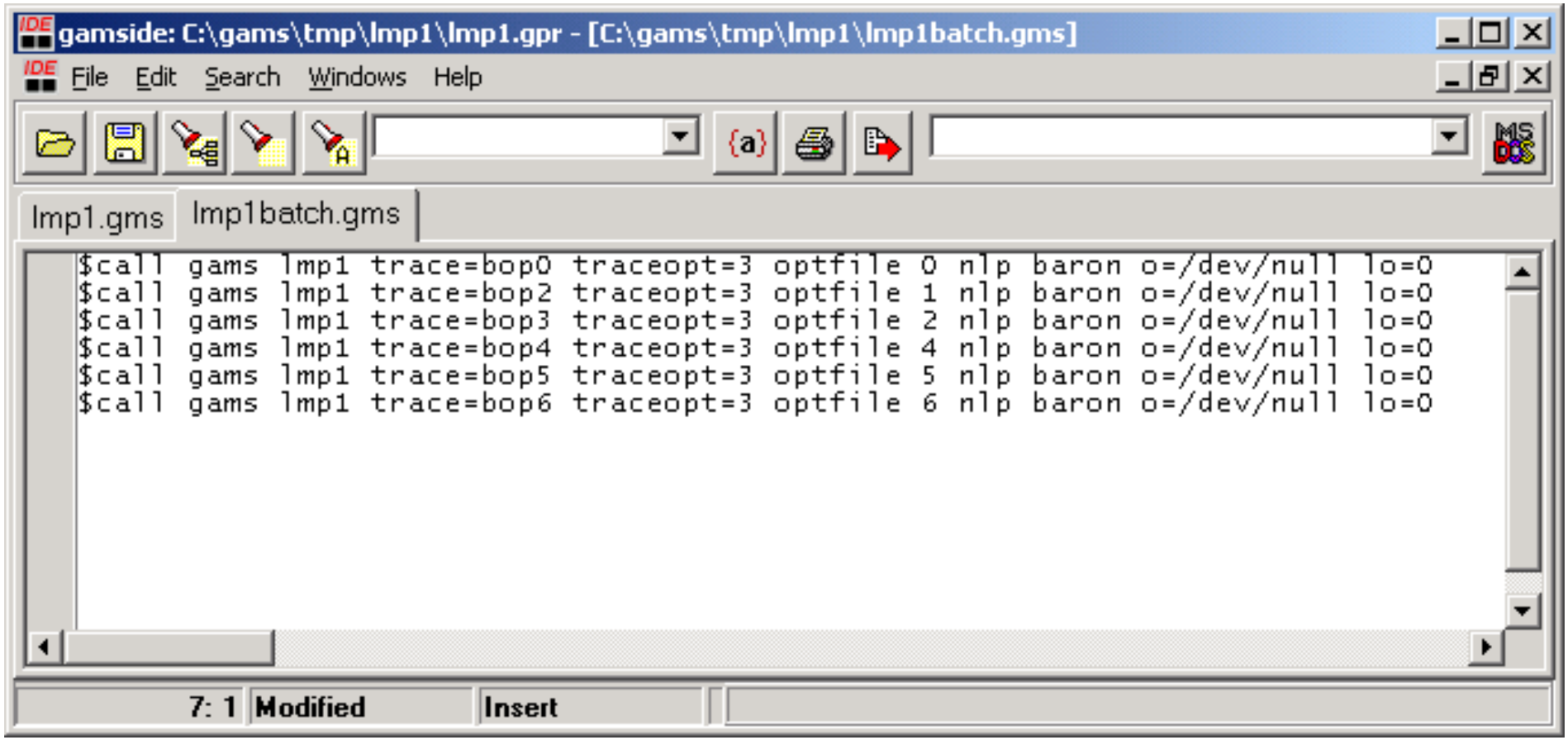
```
Generates and solves random linear multiplicative models of
"Type 1."  Problem instances are generated as proposed by
Konno and Kuno. Model developed by N. Sahinidis.
```

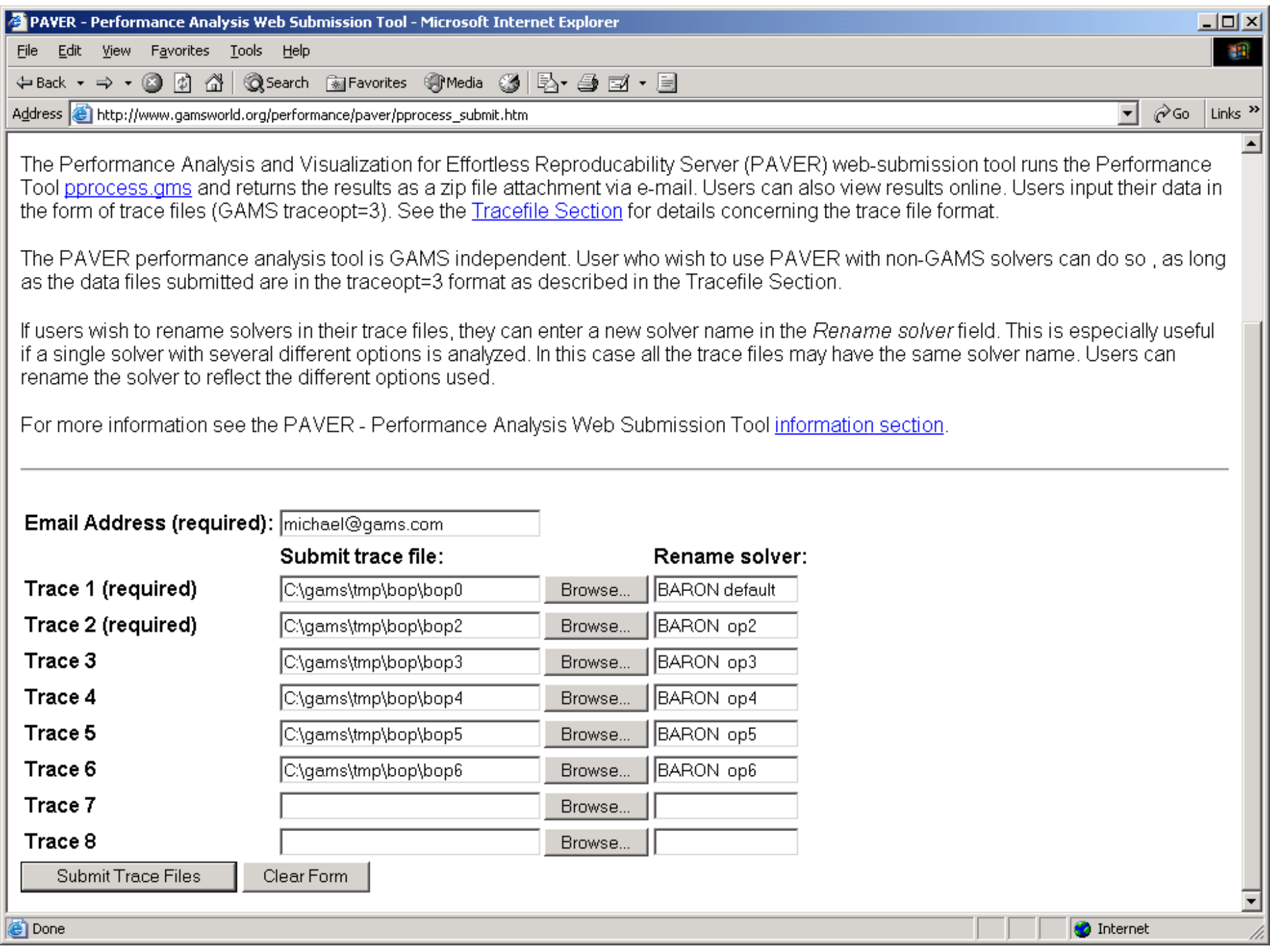
References:

- Konno, H, and Kuno, T, Linear multiplicative programming. Mathematical Programming 56 (1992), 51-64.
- Tawarmalani, M, and Sahinidis, N, Convexification and Global Optimization in Continuous and Mixed-Integer Nonlinear Programming: Theory, Algorithms, Software, and Applications. Kluwer, 2002.

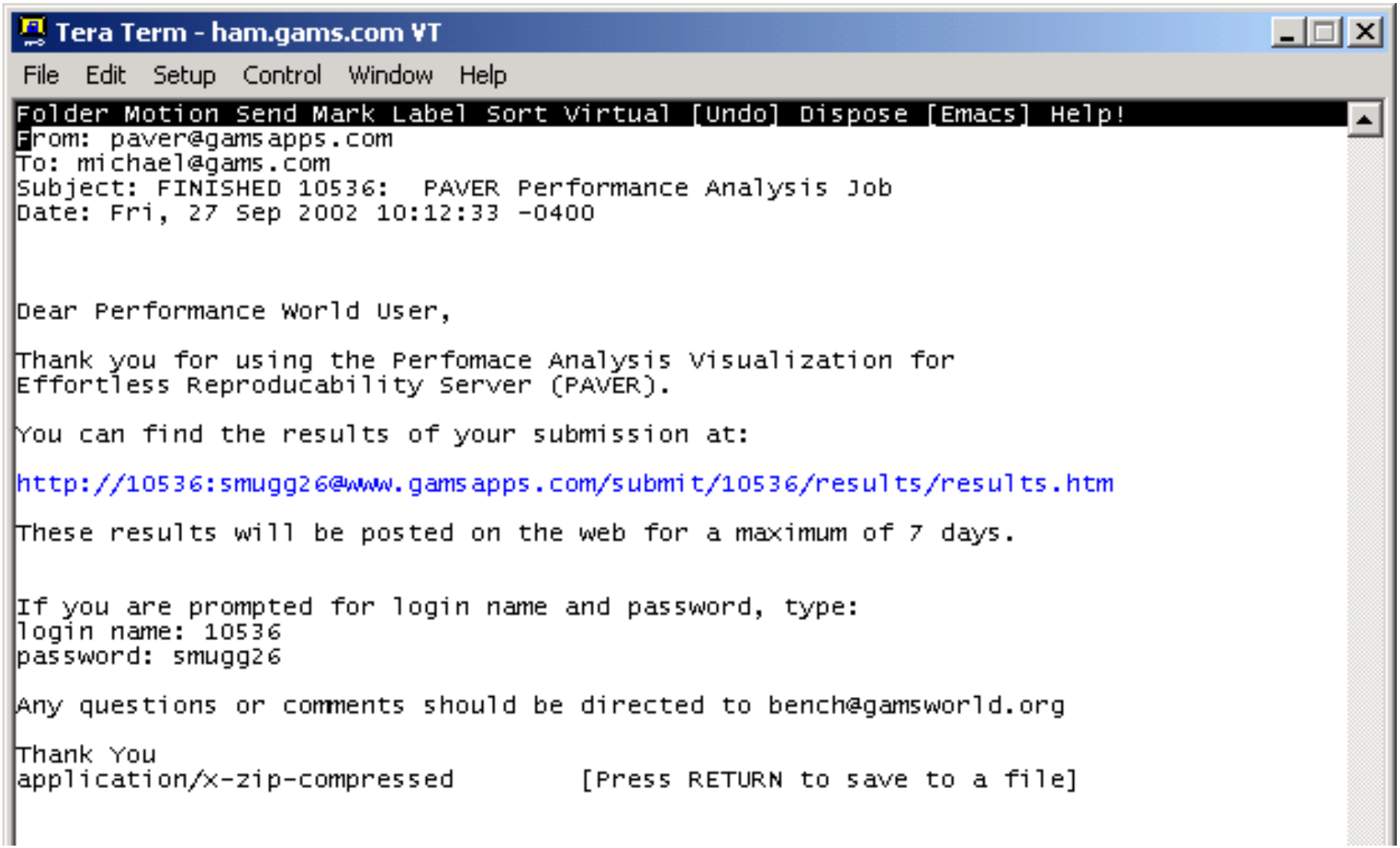
Large Model of Type: NLP

LMP1 Trace Generation




PAVER - Performance Analysis Web Submission Tool - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites Media
Address http://www.gamsworld.org/performance/paver/pprocess_submit.htm
Go Links
The Performance Analysis and Visualization for Effortless Reproducability Server (PAVER) web-submission tool runs the Performance Tool pprocess.gms and returns the results as a zip file attachment via e-mail. Users can also view results online. Users input their data in the form of trace files (GAMS traceopt=3). See the Tracefile Section for details concerning the trace file format.
The PAVER performance analysis tool is GAMS independent. User who wish to use PAVER with non-GAMS solvers can do so , as long as the data files submitted are in the traceopt=3 format as described in the Tracefile Section.
If users wish to rename solvers in their trace files, they can enter a new solver name in the Rename solver field. This is especially useful if a single solver with several different options is analyzed. In this case all the trace files may have the same solver name. Users can rename the solver to reflect the different options used.
For more information see the PAVER - Performance Analysis Web Submission Tool information section.
Email Address (required): michael@gams.com
Submit trace file:
Rename solver:
Trace 1 (required) C:\gams\tmp\bop\bop0 Browse... BARON default
Trace 2 (required) C:\gams\tmp\bop\bop2 Browse... BARON op2
Trace 3 C:\gams\tmp\bop\bop3 Browse... BARON op3
Trace 4 C:\gams\tmp\bop\bop4 Browse... BARON op4
Trace 5 C:\gams\tmp\bop\bop5 Browse... BARON op5
Trace 6 C:\gams\tmp\bop\bop6 Browse... BARON op6
Trace 7 Browse...
Trace 8 Browse...
Submit Trace Files
Clear Form
Done
Internet

PAVER Results by Email



Conclusions

- Framework for reliability and performance testing of (global) optimization codes.
- Open architecture for using this framework with models, modeling languages and solvers that are not necessarily connected with GAMS.
- Commitment to quality assurance in the optimization world (critical for success in the commercial environment).
- Presentation with all examples (will be) available at `http://www.gams.com/presentations`