Recent enhancements in GAMS

Lutz Westermann LWestermann@gams.com

GAMS Software GmbH

GAMS Development Corporation

www.gams.com

OR 2013 IMPACT

GAMS

Rotterdam, September 5, 2013

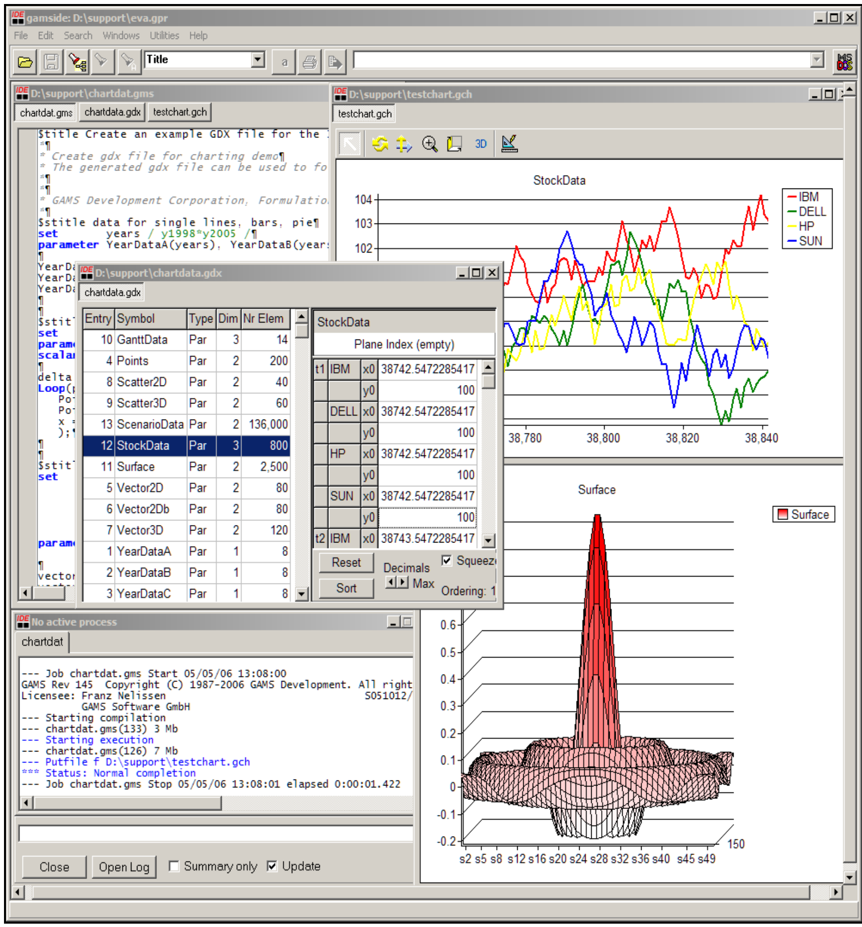
Outline

- GAMS at a Glance
- Recent enhancements
  - MipTrace
  - GDXRRW
  - New Solvers / Solver Updates
  - Stochastic Programming in GAMS

Outline

- GAMS at a Glance
- Recent enhancements
  - MipTrace
  - GDXRRW
  - New Solvers / Solver Updates
  - Stochastic Programming in GAMS

GAMS at a Glance



Algebraic Modeling System

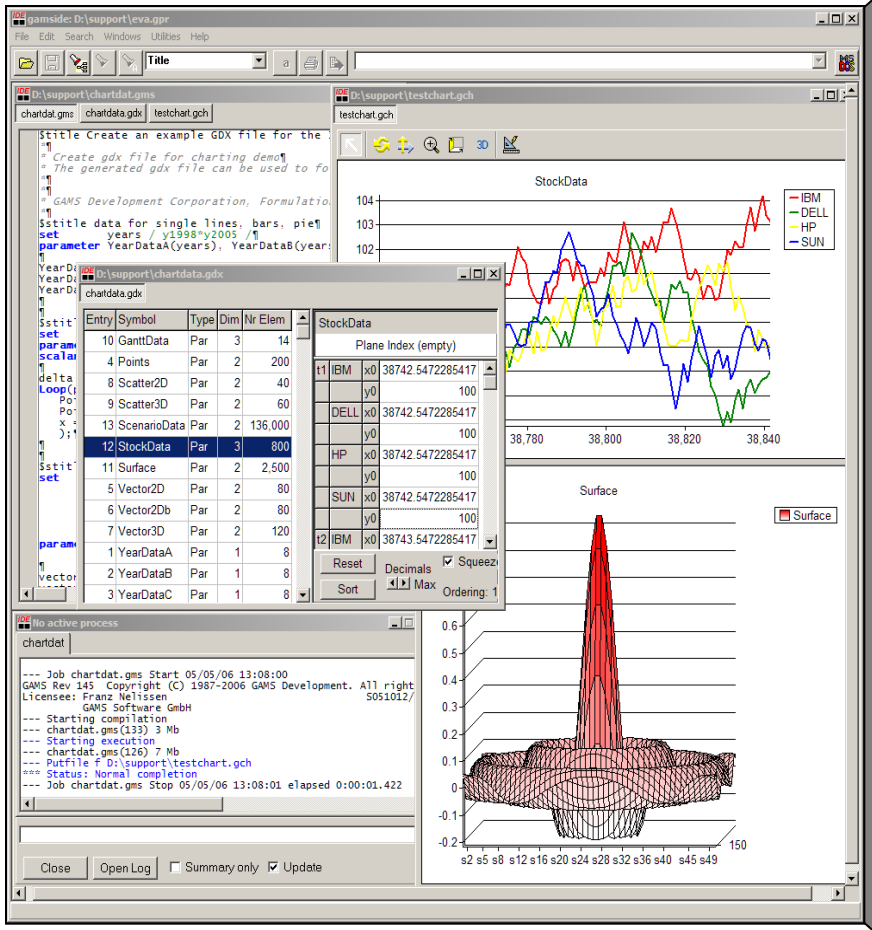
- Facilitates to formulate mathematical optimization problems similar to algebraic notation

  ➔ Simplified model building

- Provides links to appropriate state-of-the-art external algorithms

  ➔ Efficient solution process

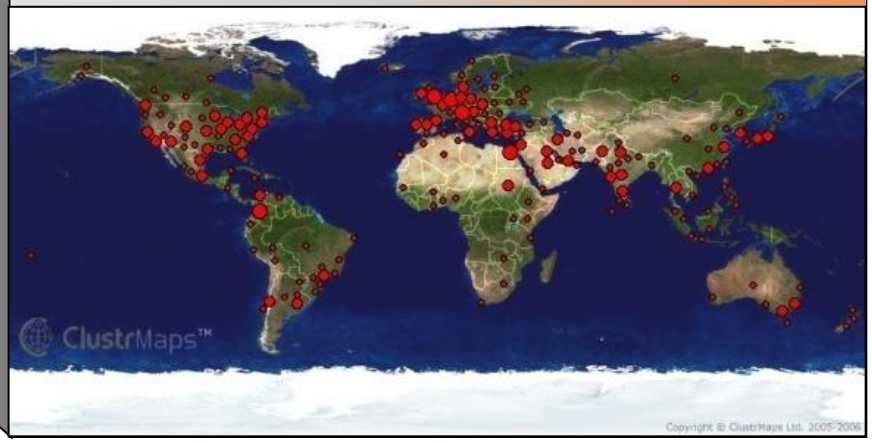
GAMS at a Glance



General **A**lgebraic **M**odeling **S**ystem

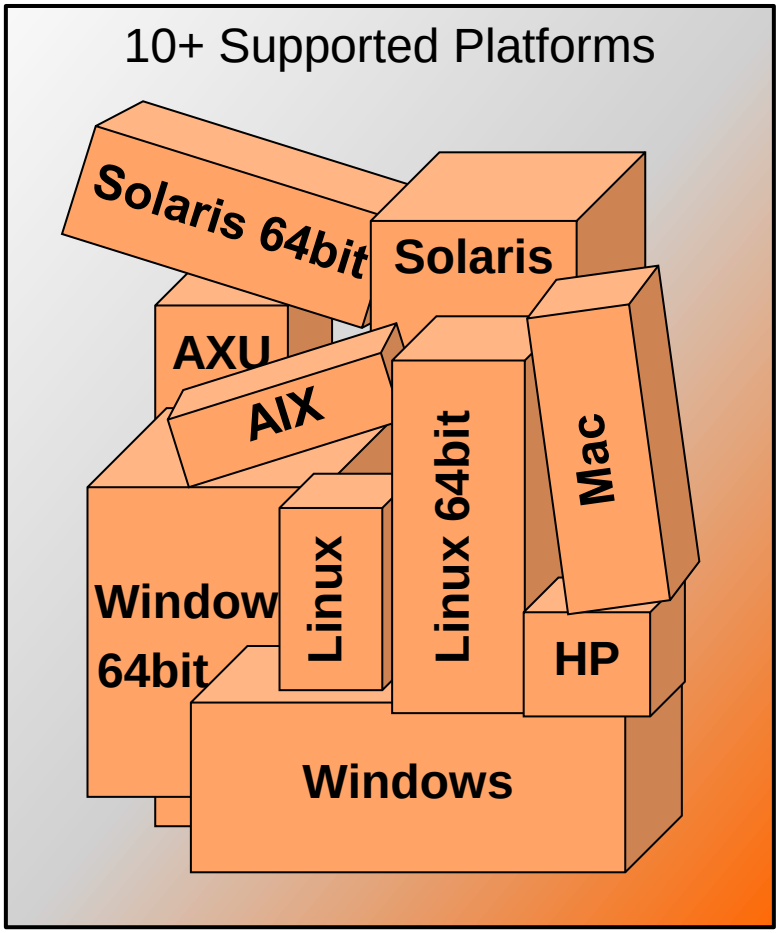
- Roots: World Bank, 1976
- Went commercial in 1987
- GAMS Development Corp.
- GAMS Software GmbH

- Broad academic & commercial user community and network



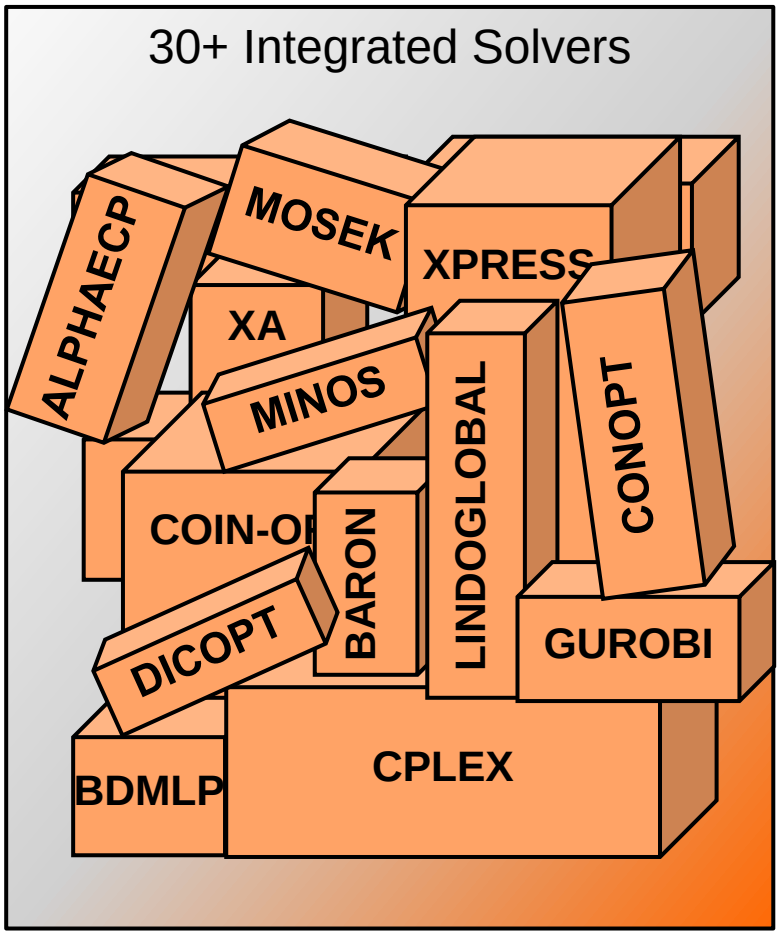
GAMS' Fundamental concepts

- **Platform independence**
- Hassle-free switch of solution methods
- Open architecture and interfaces to other systems
- Balanced mix of declarative and procedural elements



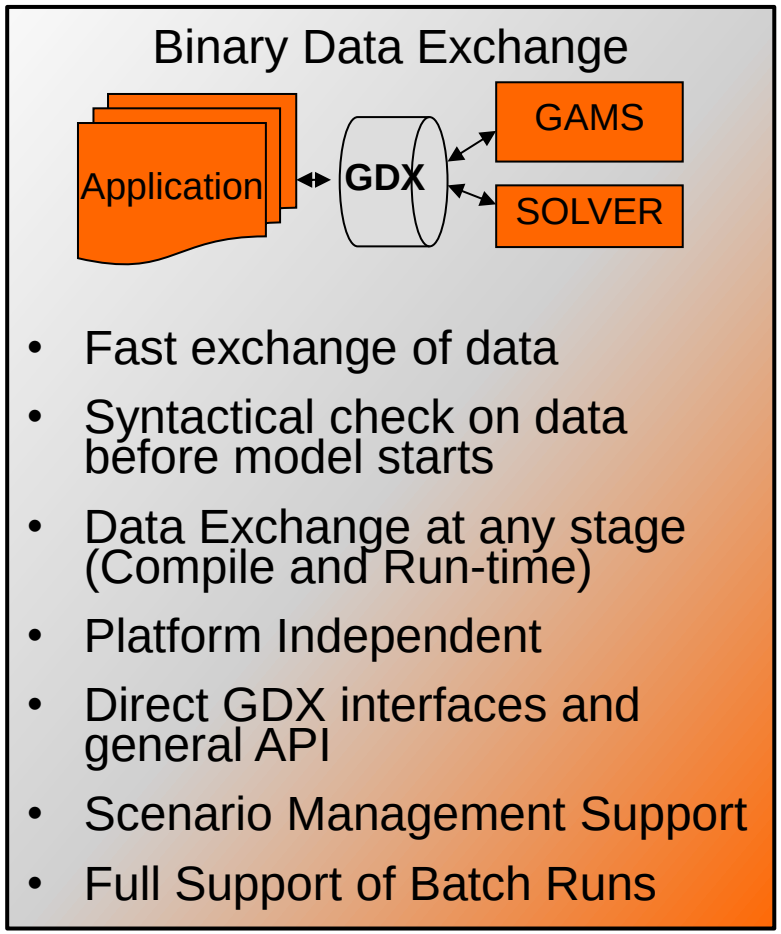
GAMS' Fundamental concepts

- Platform independence
- **Hassle-free switch of solution methods**
- Open architecture and interfaces to other systems
- Balanced mix of declarative and procedural elements



GAMS' Fundamental concepts

- Platform independence
- Hassle-free switch of solution methods
- **Open architecture and interfaces to other systems**
- Balanced mix of declarative and procedural elements



GAMS' Fundamental concepts

- Platform independence
- Hassle-free switch of solution methods
- Open architecture and interfaces to other systems
- **Balanced mix of declarative and procedural elements**

Declaration of..

- **Sets**
- **Parameters**
- **Variables**
- **Equations**
- **Models**
- **…**

Procedural Elements like…

- **loops**
- **if-then-else**
- **…**

Outline

- GAMS at a Glance
- Recent enhancements
  - MipTrace
  - GDXRRW
  - New Solvers / Solver Updates
  - Stochastic Programming in GAMS

Tracing Solve Process

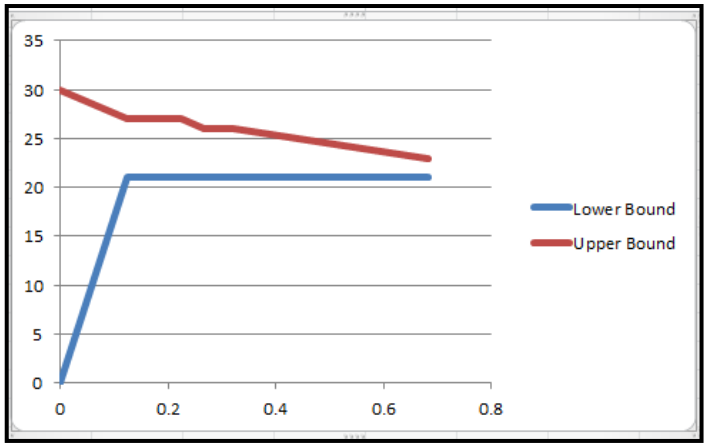
Solver Options (e.g. Cplex, Gurobi, Xpress):

- **`MipTrace`**
  - Writes a file that records the best integer and best bound values every *`miptracenode`* nodes and at *`miptracetime`*-second intervals
- **`MipTraceNode`**
  - Specifies the node interval between entries to the *`MipTrace`* file [Default: 100]
- **`MipTraceTime`**
  - Specifies the time interval, in seconds, between entries to the *`MipTrace`* file [Default: 5]

Tracing Solve Process – cont.

Generates a Trace file during solve:

```
* miptrace file gurobi.trc: ID = Gurobi
* fields are lineNum, seriesID, node, seconds, bestFound, bestBound
1, S, 0, 0, 0, 30
2, N, 100, 0.113, 21, 27
3, N, 200, 0.169, 21, 27
4, N, 300, 0.212, 21, 27
5, N, 400, 0.255, 21, 26
6, N, 500, 0.31, 21, 26
7, E, 683, 0.668, 21, 23
* miptrace file gurobi.trc closed
```



- Common format among all solvers that support this option
- Available with: ANTIGONE, BONMIN, CBC, CPLEX, COUENNE, GloMIQO, Gurobi, SBB, SCIP, Sulum, Xpress (Partly using different option names)

Outline

- GAMS at a Glance
- Recent enhancements
  - MipTrace
  - GDXRRW
  - New Solvers / Solver Updates
  - Stochastic Programming in GAMS

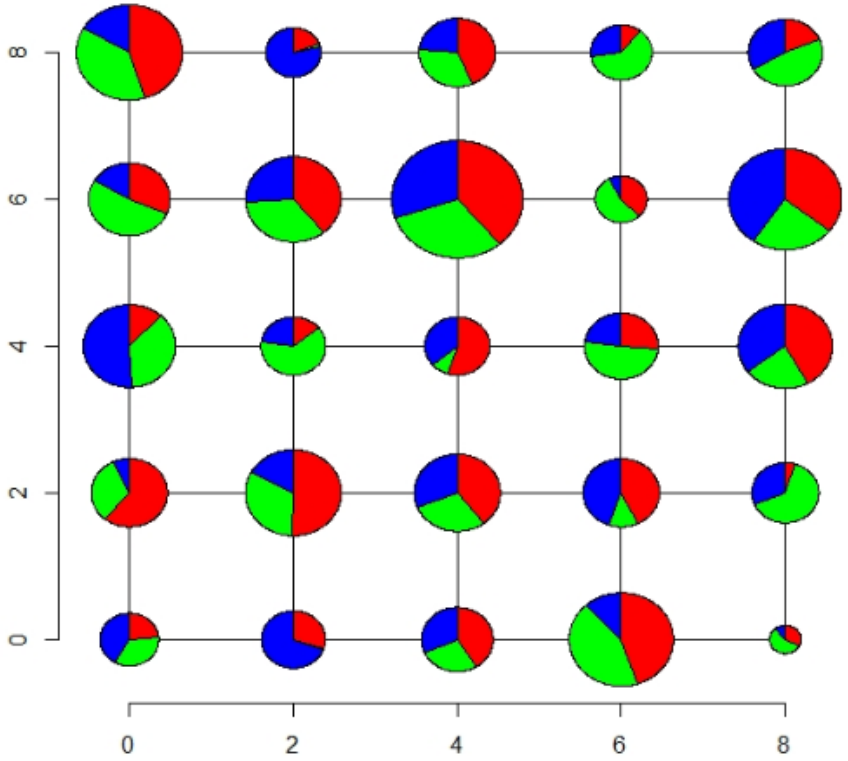
What is R

- Powerful, feature-packed software package
  - Statistics
  - Data analysis, manipulation, and visualization
  - Programming - prototyping and development
  - Thousands of application-specific packages available:
    - More statistics
    - Finance
    - Computational biology / bioinformatics (Bioconductor)

- R is free and easy to install, update, and augment

GDXRRW

- GDXRRW bridges the gap between R and GAMS (import/export data between GAMS and R)
- Fits into the ecosystem of existing GDX utilities
- Presents data in a natural form for R users



Source: http://blog.modelworks.ch

- More information: http://support.gams.com/doku.php?id=gdxrrw:interfacing_gams_and_r

Outline

- GAMS at a Glance
- Recent enhancements
  - MipTrace
  - GDXRRW
  - New Solvers / Solver Updates
  - Stochastic Programming in GAMS

New Solvers / Solver Updates

- Solver Updates
  - AlphaECP v2.10.02
  - Baron 12.3.3
  - CBC 2.8
  - Conopt 3.15L
  - Cplex 12.5.1
  - GloMIQO 2.3
  - Guropi 5.5
  - Knitro 8.1.1
  - Lindo 8.0.385
  - Mosek 7.0.0.75
  - SCIP 3.0 #0b46aef
  - Xpress 24.01.04
  - …
- New Solvers
  - ANTIGONE
  - Sulum
  - IpoptH
  - Kestrel
  - Gather-Update-Solve-Scatter (GUSS)
  - Deterministic Equivalent (DE)

GAMS/ANTIGONE

ANTIGONE

Algorithms for coNTinuous / Integer Global Optimization of Nonlinear Equations

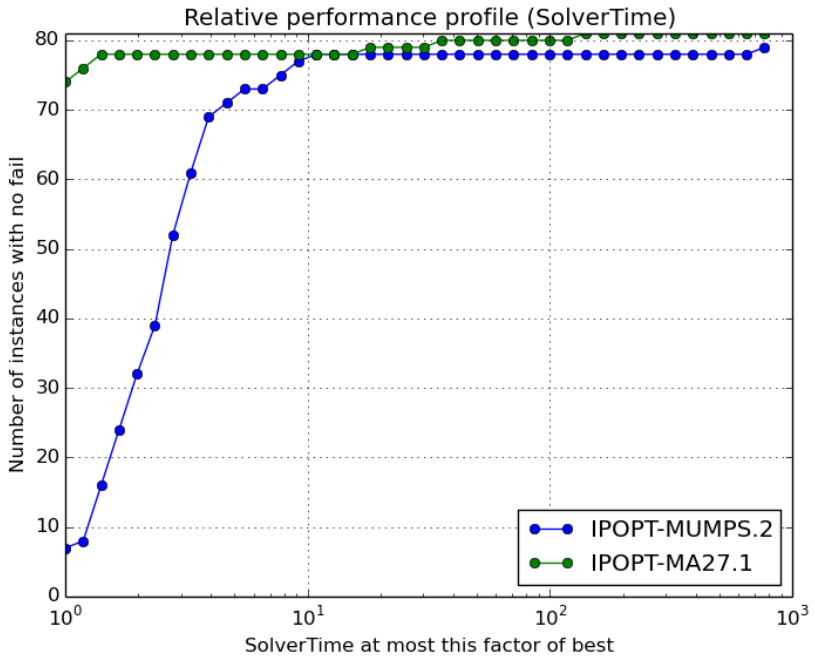
- Developed at Princeton University and Imperial College London by C. A. Floudas and R. Misener
- Computational framework for deterministic global optimization of non-convex MINLP
- Exploits special structure within a MINLP
- Generates and solves convex relaxations of a non-convex MINLP
- Finds feasible solutions via local optimization
- Divides and conquers the feasible set to generate a sequence of convex relaxations converging to the global optimum
- Requires a Cplex and either Conopt or Snopt

GAMS/Sulum

- LP and MIP Solver
- From Sulum Optimization ApS
- Offers a good cost-benefit ratio for LP and MIP solution technology
- Advanced LP and MIP presolve
- Highly optimized sparse vector and matrix implementation
- Advanced crash of initial basis
- Fast reoptimize from a previous found solution
- Various branching and node selection methods
- Cutting plane generation and filtering
- Heuristics to either find an initial solution or improve the current incumbent

GAMS/IpoptH

- Commercial Extension of the free NLP solver Ipopt (**I**nterior **P**oint **Opt**imizer)
- Solver for large-scale nonlinear programming



- Using high performance linear algebra routines from the Harwell Subroutines Library (MA27, MA57, HSL_MA86, and HSL_MA97)

GAMS/Kestrel

- Remote Solver Execution on NEOS Servers
- From within your usual GAMS modeling environment
- Receiving results that can be processed as with any local solver


```
Model transport /all/;

Option lp=kestrel;
transport.optfile=1;

$onecho > kestrel.opt
kestrel_solver xpress
neos_server www.neos-server.org
socket_timeout 10
$offecho

Solve transport using lp minimizing z;
```

```
--- Executing KESTREL: elapsed 0:00:00.005
Connecting to: http://www.neos-server.org:3332

NEOS job#=956988, pass=LXBsrGJe
Check the following URL for progress report :
http://www.neos-server.org/neos/cgi-bin/nph-neos-solver.cgi?admin=results&jobnumber=956988&pass=LXBsrGJe

FICO-Xpress      24.1.2 r40979 Released Jun 16, 2013 LEG x86_64/Linux

Xpress Optimizer 24.01
Xpress Optimizer 64-bit v24.01.04 (Hyper capacity)
```

GUSS Detour – Solvelink Option

```
Model transport /all/ ;
Option solvelink = {%Solvelink.ChainScript%,
                    %Solvelink.CallScript%,
                    %Solvelink.CallModule%,
                    %Solvelink.AsyncGrid%,
                    %Solvelink.AsyncSimulate%,
                    %Solvelink.LoadLibrary%};
solve transport using lp minimizing z;
```

- ChainScript [0]: Solver process, GAMS vacates memory
  - \+ Maximum memory available to solver
  - \+ protection against solver failure (*hostile* link)
  - \- swap to disk

Solvelink Option – cont.

- Call{Script [1]/Module [2]}: Solver process, GAMS stays live
  - + protection against solver failure (*hostile* link)
  - + no swap of GAMS database
  - - file based model communication

- LoadLibrary [5]: Solver DLL in GAMS process
  - + fast memory based model communication
  - + update of model object inside the solver (hot start)
  - - not supported by all solvers

Solving Scenarios

trnsport.gms (LP) solved 500 times with CPLEX:

```
Loop(s,
     d(i,j) = dd(s,i,j);
     f = ff(s);
     solve transport using lp minimizing z;
     rep(s) = transport.objval;
);
```

Setting	Solve time (secs)
Solvelink=%Solvelink.ChainScript%	52.221
Solvelink=%Solvelink.CallModule%	37.366
Solvelink=%Solvelink.LoadLibrary%	03.252

GAMS/GUSS

Setting	Solve time (secs)
Solvelink=%Solvelink.ChainScript%	52.221
Solvelink=%Solvelink.CallModule%	37.366
Solvelink=%Solvelink.LoadLibrary%	03.252
GUSS	01.046

- Update model data instead of matrix coefficients/rhs
- Hot start (keep the model hot inside the solver and use solver's best update mechanism)
- Save model generation and solver setup time
- Model rim unchanged from scenario to scenario
- Apriori knowledge of all scenario data

GAMS/DE

- Accepts EMP models that have been annotated with information about uncertainty

$$\begin{aligned} \text{Max}_{x,y} \quad & -c^T x + \textstyle\sum_i p_{\zeta_i} q_{\zeta_i}^T y \\ \text{s.t.} \quad & \begin{pmatrix} A & & & & \\ T_{\zeta_1} & W_{\zeta_1} & & & \\ T_{\zeta_2} & & W_{\zeta_2} & & \\ \vdots & & & \ddots & \\ T_{\zeta_m} & & & & W_{\zeta_m} \end{pmatrix} \begin{pmatrix} x \\ y_{\zeta_1} \\ y_{\zeta_2} \\ \vdots \\ y_{\zeta_m} \end{pmatrix} = \begin{pmatrix} b \\ h_{\zeta_1} \\ h_{\zeta_2} \\ \vdots \\ h_{\zeta_m} \end{pmatrix} \end{aligned}$$

- Reformulates the stochastic model into the extensive form equivalent with implicit non-anticipativity constraints
- The reformulated model is solved with any of the regular GAMS solvers
- All optimization model types (LP, MIP, QCP, MIQCP, NLP, DNLP, and MINLP) are accepted
- Comes free with the GAMS/Base system

Outline

- GAMS at a Glance
- Recent enhancements
  - MipTrace
  - GDXRRW
  - New Solvers / Solver Updates
  - Stochastic Programming in GAMS

Stochastic Programming in GAMS

- The Extended Mathematical Programming (EMP) framework is used to replace parameters in the model by random variables
- Support for Multi-stage recourse problems and chance constraint models
- Easy to add uncertainty to existing deterministic models, to either use specialized algorithms or create Deterministic Equivalent (new free solver DE)
- More information: http://www.gams.com/dd/docs/solvers/empsp.pdf

Simple Example: Newsboy (NB) Problem

- A newsboy faces an uncertain demand for newspapers
- He can buy newspapers for fixed costs per unit
- He can sell newspapers for a fixed price
- For hold units he has to pay a disposal fee
- He has to satisfy his customers demand or has to pay a penalty

- Decisions to make:
  - How much newspaper should he buy “here and now” (without knowing the outcome of the uncertain demand)?
    → *First-stage decision*
  - How many customers are lost after the outcome becomes known?
    → *Second-stage* or *recourse decision*
  - Recourse decisions can be seen as
    - penalties for bad first-stage decisions
    - variables to keep the problem feasible

Simple NB Problem – GAMS Formulation

```
*            LostSales = demand - UnitsSold
lSales..     L =e= d - S;
*            Inventory = UnitsBought - UnitsSold
Inv..        I =e= X - S;
*            Profit, to be maximized
Profit..     Z =e= r*S - c*X - h*I - p*L;

$onEcho > %emp.info%
* Make d uncertain
randvar d normal 45 10
* Define nondefault stages
stage 2 d I L S
stage 2 lSales Inv
$offEcho

Model nb / all /;
Solve nb max z use emp scenario dict;
```

```
Set scen       / s1*s6 /;
Parameter
     s_d(scen) Demand
     s_x(scen) Units bought;
Set
 dict / scen.scenario.''
        d    .randvar .s_d
        x    .level   .s_x /;
```

How to stay Up To Date

- Sign up for a mailing list
  - http://www.gams.com/maillist/
- Find the last release on our website
  - Latest version: GAMS 24.1.3
  - Released July, 26th
  - http://www.gams.com/download/

Please visit us at our booth in the exhibit area!

Contacting GAMS

Europe

GAMS Software GmbH
P.O. Box 40 59
50216 Frechen
Germany

Phone: +49 221 949 9170
Fax: +49 221 949 9171

info@gams.de

USA

GAMS Development Corp.
1217 Potomac Street, NW
Washington, DC 20007
USA

Phone: +1 202 342 0180
Fax: +1 202 342 0181

sales@gams.com
support@gams.com

http://www.gams.com