GAMS

Rapid Development of Optimization-based Decision Support Applications

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www.gams.de

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Agenda

- GAMS Development / GAMS Software
- GAMS at a Glance
- Recent Enhancements
- Summary
Agenda

GAMS Development / GAMS Software

GAMS at a Glance

Recent Enhancements

Summary
GAMS

- Roots: Research project
  World Bank, 1976
- Pioneer in
  Algebraic Modeling Systems
- Went commercial in 1987
- GAMS Development Corp.
  (Washington, D.C)
- GAMS Software GmbH
  (Cologne)

- Used for economic modeling
- Professional software tool
  provider, not a consulting
  company
- Operating in a segmented
  niche market
- Broad academic & commercial
  user base and network
## Typical Application Areas *

<table>
<thead>
<tr>
<th>Agricultural Economics</th>
<th>Applied General Equilibrium</th>
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<tr>
<td>Chemical Engineering</td>
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<td>Logistics</td>
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<td>Macro Economics</td>
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<tr>
<td>Management Science/OR</td>
<td>Mathematics</td>
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<tr>
<td>Micro Economics</td>
<td>Physics</td>
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* Illustrative examples in the GAMS Model Library
Companies with wide experience in GAMS modeling

Details at: http://www.gams.com/specialists/
Academic + Commercial Users Worldwide
Downloads

Total Downloads of Distribution 22.5 since 2007-06-01: 2308

Sorted by Platform:

- 2 AIX
- 6 AXU
- 51 Darwin
- 39 Linux64
- 107 Linux32
- 16 Solaris (x86)
- 13 Solaris (Sparc)
- 1821 Windows32
- 253 Windows64

~ 500 downloads per Week
Algebraic Modeling Languages

- High-level programming languages for large scale mathematical optimization problems
- Algebraic formulation
  - Syntax similar to mathematical notation
  - Does not contain any hints how to process it
- Do not solve optimization problems directly, but call appropriate external algorithms (solvers)

Goals

- Support of decision making process
- Efficient handling of mathematical optimization problems
- Simplify model building and solution process
- Increase productivity and support maintainable models
Agenda

- GAMS Development / GAMS Software
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- Recent Enhancements
- Summary
General Algebraic Modeling System:

Design Principles:
• Balanced mix of declarative and procedural elements
• Open architecture and interfaces to other systems
• Different layers with separation of:
  – model and data
  – model and solution methods
  – model and operating system
  – model and interface
System Overview

Connectivity Tools
• Uniform Data Exchange:
  • ASCII
  • GDX (ODBC, SQL, XLS, XML)
• GDX Tools
• Component Library with Interfaces to C++, Java, .NET, ...
• Distributed Execution (Grid Computing)
• Ext. programs
  • EXCEL
  • MATLAB
  • GNUPLOT, ...
• CONVERT

Productivity Tools
• Integrated Development Environment (IDE)
• Integrated Data Browser and Charting Engine
• Model Libraries
• Benchmarking and Deployment
• Model Debugger and Profiler
• Transparent and reproducible Quality Assurance and Testing System
• Data and Model Encryption
• Grid Computing
• Scenario Reduction
• MPSGE for general equilibrium modeling

Interactive API / Batch

User Interfaces

GAMS Language Compiler and Execution System

Solvers
LP/MIP-QCP-MIQCP-NLP/DNLP-MINLP-CNS-MCP-MPEC, global, and stochastic

ALPHAEC, BARON, COIN, CONOPT, CPLEX, DECIS, DICOPT, KNITRO, LGO, LINDO, MINOS, MOSEK, OQNLP, PATH, SNOPT, XA, XPRESS, ...
# Multiple Solvers & Platforms

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**Notes:**
- GAMs distribution for HP-UX/HP-UX is 22.1.
- GAMs distribution for SGI IRIS is 22.3.
- For backward compatibility we maintain older versions of operating systems and solvers. Please call.

## Contributed Plug&Play Solvers

- AMPL
- CPLEX
- DRA
- Keil
- MATLAB
Multiple Model Types

<table>
<thead>
<tr>
<th>Model Type</th>
<th>Description</th>
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<td>Mixed Integer Programs</td>
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<td>QCP</td>
<td>Quadratically Constrained Programs</td>
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*Contributed Plug & Play solvers*
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GAMS Language Compiler and Execution System

User Interfaces

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Interactive API / Batch

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- MPSGE for general equilibrium modeling

ALPHAEC, BARON, COIN, CONOPT, CPLEX, DECIS, DICOPT, KNITRO, LGO, LINDO, MINOS, MOSEK, OQNLP, PATH, SNOPT, XA, XPRESS, ...
Gams Data eXchange

Binary Data Exchange

- Fast exchange of data
- Syntactical check on data before model starts
- Data Exchange at any stage (Compile and Run-time)
- Platform Independent
- Direct Excel connectivity
- General API
- Scenario Management Support
- Full Support of Batch Runs
GAMS in Control

External Database

Text Files

Direct Interface (Office Appl.)

GAMS

Text Files

Direct Interface (Office Appl.)

Visualization Tools

Import

Export
Interfacing with GIS Applications

Increase in Ktons Per Year
- Less Than 0
- 0 - 199
- 200 - 1000
- 1000 - 3000
Interfacing with MATLAB

**Figure 1: US dollar short rate scenarios**

**Figure 2: Short vs. long rates**
Interfacing with GNUPLLOT
Interfacing with Web Applications
Interfacing with Individual Front Ends
Application in Control

External Application

Call GAMS

GAMS

Call external program (including GAMS)

External Application

Programming Language or other Application

Application
Samurai Sudoku
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GAMS Integrated Development Environment
### GAMS Model Libraries

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<th>Model Name</th>
<th>Application Area</th>
<th>Type</th>
<th>Contributor</th>
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<td>Management Science and OR</td>
<td>LP</td>
<td>Dantzig, G B</td>
<td>A Transportation Problem</td>
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**A Transportation Problem (TRANSPORT, SE201)**
Transparent Software Quality Assurance (SQA)

Elements:
1. Software configuration management (SCM)
2. Test libraries (available online):
   - GAMS Model Library
   - GAMS Quality Test Models Library
     - Solved for all relevant solvers: More than 5,000 tests for each platform
3. (Automated) Client Model Testing

Goal: Continuous quality improvement using automated and reproducible tests
Deployment

This model creates a GAMS deployment system

Complete two steps and run this model and pick up gmadeply.hlp in your project/current directory

1. Add the solvers and other products to the set Deployproducts.
2. Set up the deployment system between on/off/echo

Set p, GAMS Products / system.SolverNames / DeployProducts[p] ;

* ADD extra new GAMS files to your deployment system
if not set ziplist then ziplist gamslicerr.txt
sometext

- There is no need to change anything
- We always need the GAMS base system
  DeployProducts('GAMS') = yes;

If not set zipline then zipline gamslicerr.txt
set gmadeply to gamslicerr.txt

Agenda

- GAMS Development / GAMS Software
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Release Notes

New Solvers

- COIN-OR Solvers (http://www.coin-or.org/)
  - MINLP solver: CoinBonmin
- AlphaECP
  - MINLP solver
  - Extended Cutting Plane method by T. Westerlund and T. Lastusilta (Abo Akademi University, Finland)
- LINDOGLOBAL
  - finds proven optimal solutions to non-convex MINLP
  - Global Optimization Solver from Lindo Systems, Inc.

New solver binaries

- BARON, CONOPT, CPLEX, MOSEK, XPRESS,...
Performance Analysis

- Solver robustness and correctness
- Solver efficiency
- Quality of solution (nonconvex and discrete models)

Cross comparison of solver resource requirements and quality of solution
Benchmarking

• BENCH -”solver”

--- BENCH SUMMARY:

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<th>Modstat</th>
<th>Solstat</th>
<th>Objective</th>
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• PAVER – Server
Performance Analysis and Visualization for Efficient Reproducibility

http://www.gamsworld.org/performance/paver/
Paver: Visualization

Performance Profiles (Dolan and More, 2002):

- **Performance metric**: ratio of current solver time over best time of all solvers

\[ \rho(p, s) := \frac{t_{p,s}}{\min_{s' \in S} t_{p,s'}} \]

- **Cumulative distribution function** for performance metric: probability of success if given \( \tau \) times fastest time (\( \tau \)=ratio)

\[ P_s(\tau) := \frac{|\{p \in P : \rho(p, s) \leq \tau\}|}{|P|} \]
PAVER: AlphaECP vs. Dicopt

![Performance Profile Graph](image)
PAVER: Lindoglobal vs. Baron

Performance Profile

Percent of Models Solved

Time Factor
Solver Technology

- Tremendous algorithmic and computational progress
  - **LP** in fact only restricted by available memory
  - **MIP**
    - Some small (academic) problems still unsolvable
    - Commercial problems in most case docile
  - **NLP/MINLP**
    - Predictions are problem and data specific, global vs. local solutions
- Further progress using Multiple Threads / Grid Computing
Multiple Threads / SMP

- **CPLEX**
  - parallel extension for B&B and interior point solver
  - options threads, barthreads, mipthreads, strongthreadlim
  - concurrent optimizer options lpmethod, qpmethod, startalg
  - academic license includes 4 threads

- **MOSEK**
  - parallel extension for the interior solver comes free of charge
  - option MSK_IPAR_INTPNT_NUM_THREADS
  - concurrent optimizer options MSK_IPAR_CONCURRENT_*

- **XPRESS**
  - parallel extension for B&B and interior point solver
  - options threads, barThreads, mipThreads, sbThreads
  - academic license includes 4 threads

- **XA (XAPAR)**
Imagine...

.. you have to solve 1,000’s of independent scenarios...
.. and you can do this very rapidly for little additional money...
.. without having to do lots of cumbersome programming work...
What is Grid Computing?

A pool of connected computers managed and available as a common computing resource

- Effective sharing of CPU power
- Massive parallel task execution
- Scheduler handles management tasks
- E.g. Condor, Sun Grid Engine, Globus
- Can be rented or owned in common
- Licensing & security issues
Simple Serial Solve Loop

Loop (p(pp),
     ret.fx = rmin + (rmax - rmin) /
     (card(pp)+1)*ord(pp) ;
     Solve minvar min var using miqcp;
     xres(i,p) = x.l(i);
     report(p,i,'inc') = xi.l(i);
     report(p,i,'dec') = xd.l(i)
);

How do we get to parallel and distributed computing?
GRID Specific Enhancements

1. Submission of jobs
2. “Grid Middleware”
   - Distribution of jobs
   - Job execution
3. Collection of solutions
4. Processing of results
Minor Changes to Model

```plaintext
Loop (p | pp),
  v.fx = vmin + (vmax-vmin)/(card(pp)+1)*ord(pp);
  Solve vara maximizing m using nlp;
  xres('i',p) = x.l(i);
  xres('mean',p) = m.l;
  xres('var',p) = v.l;
  xres('status',p) = vara.modelstat;
Display xres;

//
var1.solveLink=3;
Loop (p | pp),
  v.fx = vmin + (vmax-vmin)/(card(pp)+1)*ord(pp);
  Solve vara maximizing m using nlp;
  handle(p) = vara.handle();
  Repeat loop (p | pp) $ handleCollect(handle(p)),
    xres('i',p) = x.l(i);
    xres('mean',p) = m.l;
    xres('var',p) = v.l;
    xres('status',p) = vara.modelstat;
    display$handleDelete(handle(p)) 'trouble delel handle(p) = 0 ';
  display$sleep(card(handle)*0.2) 'sleep some time until card(handle) = 0 or timeelapsed > 100;
  xres('i',p | pp) $ handle(p) = na;

Display xres;

execute_unload "portfolio.gdx" xres;
```
GAMS & Grid Computing

- **Scalable:**
  - support of massive grids, **but also**
  - multi-cpu / multiple cores desktop machines
  - “1 CPU - Grid”

- **Platform independent**

- **Only minor changes to model required**

- **Separation of model and solution method**
  à Model stays **maintainable**
SUNgrid

- On-demand grid computing service operated by Sun Microsystems
- Access to enormous computing power over Internet
- Opteron-based servers with 4 GB of RAM per CPU
- Solaris 10 OS, and Sun Grid Engine 6 software.
- $1 per CPU-hour

**GAMS on the SUN Grid**
- GAMS distribution 22.5 for Solaris 10
- COIN-OR solvers will be available
Agenda

- GAMS Development / GAMS Software
- GAMS at a Glance
- Recent Enhancements
- Summary
Benefits for Users

- Robust and scalable state-of-the-art modeling technology
- Tailored for complex, large-scale modeling applications
- Productivity gains through rapid development environment
- Broad academic and commercial network
- Proven reliability (30+ years of experience)
- Protection of investments through platform and solver independency
# Benefits for Different User Groups

<table>
<thead>
<tr>
<th>User Group</th>
<th>Benefits</th>
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</thead>
<tbody>
<tr>
<td><strong>Researcher</strong></td>
<td>• Projects</td>
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<tr>
<td></td>
<td>• Product maintenance</td>
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<tr>
<td></td>
<td>• Commercial network</td>
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<td></td>
<td>• Quality assurance</td>
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<td><strong>Model Developer</strong></td>
<td>• Rapid prototyping</td>
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<td></td>
<td>• Higher productivity</td>
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<td></td>
<td>• Robust &amp; scalable solution</td>
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<tr>
<td></td>
<td>• Academic network</td>
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<tr>
<td><strong>Consultants &amp; Solution Provider</strong></td>
<td>• Rapid prototyping</td>
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<tr>
<td></td>
<td>• Tailored solutions</td>
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<td></td>
<td>• Benchmarking</td>
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<tr>
<td></td>
<td>• Extended support</td>
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<tr>
<td><strong>Innocent User</strong></td>
<td>• Works in different environments</td>
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<td></td>
<td>• Lots of different interfaces</td>
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<tr>
<td></td>
<td>• Robust and reliable system</td>
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<tr>
<td><strong>Management</strong></td>
<td>• Protection of investments</td>
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<td>• Low cost</td>
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<td>• Maintainable applications</td>
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<tr>
<td></td>
<td>• Independence:</td>
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<td></td>
<td>- Solver</td>
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<tr>
<td></td>
<td>- Platform</td>
</tr>
<tr>
<td></td>
<td>- Interface</td>
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