GAMS
Productivity - Performance - Reliability

Jan-H. Jagla, Lutz Westermann
GAMS Software GmbH

Annual Review Meeting CAPD,
CMU Pittsburgh, PA, March 12 – 13, 2007
Agenda

GAMS

- Productivity
- Performance
- Reliability
• Roots: Research project World Bank 1976
• Pioneer in Algebraic Modeling Systems used for economic modeling
• Went commercial in 1987
• Offices in Washington, D.C and Cologne

• Professional software tool provider, not a consulting company
• Operating in a segmented niche market
• Broad academic & commercial user base and network
Typical Application Areas *

- Agricultural Economics
- Chemical Engineering
- Econometrics
- Environmental Economics
- Finance
- International Trade
- Macro Economics
- Management Science/OR
- Micro Economics
  - Applied General Equilibrium
  - Economic Development
  - Energy
  - Engineering
  - Forestry
  - Logistics
  - Military
  - Mathematics
  - Physics

* Illustrative examples in the GAMS Model Library
GAMS at a Glance


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
# Multiple Solvers & Platforms

## Solver/Platform availability - 22.4  February 14, 2007

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<th>x86_64 MS Windows</th>
<th>x86 Linux</th>
<th>x86_64 Linux</th>
<th>Sun Spare SOLARIS</th>
<th>HP 9000 HP-UX 11.1</th>
<th>DEC Alpha Digital Unix 4.0</th>
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1. GAMS distribution for HP 9000/HP-UX is 22.1.
2. GAMS distribution for SGI IRIX is 22.3.

### Contributed Plug&Play solvers

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For backward compatibility we maintain older versions of operating systems and solvers. Please call.
Downloads 2007-02-12 to 2007-03-11

- 9 aix
- 13 axu
- 47 dar
- 6 hp7
- 46 lex
- 100 lnx
- 4 sgi
- 17 sol
- 321 wex
- 1400 win

Total: 1963

~ 500 downloads a week
System Overview

**Connectivity Tools**
- Uniform Data Exchange:
  - ASCII
  - GDX (ODBC, SQL, XLS, XML)
- GDX Tools
- Data API
- Ext. programs
  - EXCEL
  - MATLAB
  - GNUPLLOT, ...
  - C, Delphi, ...

**GAMS Language Compiler and Execution System**

**Interactive**

**API / Batch**

**User Interfaces**

**Productivity Tools**
- Integrated Development Environment
- Model Debugger and Profiler
- Model Libraries
- Data Browser
- Charting Engine
- Benchmarking
- Deployment System
- Quality Assurance and Testing

**Solvers**
- LP-MIP-QCP-MIQCP-NLP-MINLP-CNS-MCP-MPEC
- MPSGE, global, and stochastic optimization

**BARON, COIN, CONOPT, CPLEX, DECIS, DICOPT, KNITRO, LGO,MINOS, MOSEK, OQNLP, PATH, SNOPT, XA, XPRESS, …**
Who are the GAMS Users?

- (Academic) Researcher
  - One time use (Research Paper)
- Model Expert
  - Model Results used for Consulting
- Black Box User
  - Model integrated in (Optimization) Application

à Each Category has its own needs
What are their Risks?

... Relevant new features for productivity increase...

... Performance gains...

... Long term reliability...

User’s Risks
Agenda

GAMS

Productivity

Performance

Reliability
Integrated Development Environment
"Solver" Convert
Integrated Development Environment

è DEMO
Gams Data eXchange

Binary Data Exchange

- Complements ASCII data exchange
- Data exchange at any stage
  - Supports ODBC and XML
  - Direct Excel connectivity
  - General API
- Visual Inspection
- Scenario Management Support
- Full Support of Batch Runs

GDX Tools

- GDX Viewer
- GDXRank
- GDXMerge
- GDXDiff
- GDXDump
- IDE
- GDX API

GAMS

GDXxrw (MS Office)
GAMS in Control

External Database

Text Files

Direct Interface (Office Appl.)

GAMS

Visualization Tools

Import

Export
U.S. Energy Model

Goal:
- Single annual model
- Unique detail level
- Long term energy outlook

Size:
- MIP, 7.5 million var., 3.5 million con.
- Reduction of almost 80%, while optimal solution changed by only 0.5%
How Clients want to use our interfaces

Energy Model
GAMS in Control

è DEMO
Application in Control

External Application

Call GAMS

GAMS

Call external program (including GAMS)

External Application

Programming Language or other Application

Application
Samurai Sudoku
è DEMO
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 GNUPLOT

Investment
Ramsey Growth Model

Asset Balances with Borrowing
Lifecycle Consumption-Savings Model

Fan Plot of Output Distribution
Ramsey Growth Model

Investment
Capital Tax Impacts with Structural Uncertainty
Interfacing with Web Applications

![Image of software interface with tables and data]

### Cadet Schedules with Constraint Violations, AYT 2001-1

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**Details**

- **Names**: BASS, WILLY C., BROWN, JAMIE A., BUNTING, ERIC M., UHRUMSEY, DAVID M., COWDER, CRAIG W., CULLUM, CRAIG M., DONEL, TYLER R., EDOAR, BENJAMIN T.

**Schedule**

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**Notes**
- **Hours A to L**
- **Courses and Activities Listed**
- **Software Interface Features**

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Annual Review Meeting 2007
Individual Front Ends

SAT-PROPHET
Deployment

GAMS Deployment Model (DEPLOY,SEQ=305)

This model creates a GAMS deployment system.

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

1. Add the solvers and other products to the set DeployProducts.
   Display p to inspect all possible products.
2. Add names of files that usually do not come with your GAMS system but you want in your deployment system between on/offecho.

Set p GAMS Products / system.SolverNames /
   DeployProducts.zip / CONOPT /

* Add extra non GAMS files to your dir
  If not set zipfile last zipfile "gamscomplete.txt"
  gamscomplete.txt

* There is no need to change anything.
  * We always need the GAMS BASE system
  DeployProducts('GAMS') = yes;

If not set zipfile last zipfile "gams.workdir\gamsdeploy.zip"
  gams.workdir\gamsworkdir

1G: 81
Deployment

è DEMO
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<td><strong>Performance</strong></td>
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Performance Analysis

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

à Cross comparison of solver resource times
• Cone World
• Global World
• MINLP World
• MPEC World
• MPSGE World
• Performance World \à PAVER
• Translation World \à Convert
PAVER

- Performance Analysis and Visualization for Effortless Reproducibility

www.gamsworld.org/performance/paver

- Online server to facilitate performance testing and analysis/visualization

- Results sent via e-mail in HTML format
  - System independent
Open Testing Architecture

I. Models

GAMS Models

Translate: GAMS/Convert

Solve with "other" systems

II. Data Collection

Solve with GAMS

Web

PAVER Server

Web

III. Analysis & Visualization
Analysis / Visualization
è DEMO
Agenda

- GAMS
- Productivity
- Performance
  - Grid Computing
- Reliability
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
Grid Facilities

è DEMO
- **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**
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Example

Oil Pipeline Design Problem

J. Brimberg, P. Hansen, K.-W. Lih, N. Mladenovic, M. Breton 2003.
An Oil Pipeline Design Problem.
Operations Research,
Vol 51, No. 2 228-239

http://www.gams.com/modlib/libhtml/bchoil.htm
Convergence – Pipeline Design
• Cut Generator and Heuristic
  – Represented in terms of original GAMS problem formulation
  – Independent of the specific MIP solver
  – Use any other model type and solver available in GAMS

• Design Principle:
BCH Facility

è DEMO
Agenda

GAMS
Productivity
Performance
Reliability
Long Term Commitment

- Backward compatibility
- Performance comparison tools: Bench / Paver
- Model converter and “encryption“ tool: Convert
- Solution verification tool: Examiner
- Software Quality Assurance (SQA)
  - Software configuration management
  - Quality control and tests of the product
  - Client model testing

à SQA becomes more and more important for MP industry
Software configuration management

- Audit strings
  KNITRO  Nov 27, 2006  WIN.KN.NA  22.3  009.035.041.VIS  KNITRO 5.0
  KNITRO  ALFA  5Mar07  WIN.KN.NA  22.5  010.036.041.VIS  KNITRO 5.1.0

- Build automation tools: Automatic build of the whole system every week - build early and build often

- Simple source management system (automatic version and audit string checks)
Quality control and tests of the product

- **Goal:** Continuous quality improvement using automated and reproducible tests
- **Test libraries (available online):**
  - GAMS Model Library (solver tests)
  - GAMS Quality Test Models Library (modeling system test)
- **Continuous addition of new test models**
- **Bugtracking System**
SQA at GAMS
Client Model Testing

• Clients with complex application
• Need assurance that application will work with new GAMS releases
• Only limited resources to do major testing themselves
• Confidentiality issues
SQA at GAMS
Client Model Testing

• Includes:
  – Ability to solve (= no bugs)
  – Returns the “same” solution back
  – Similar or better performance

• Improves communication between development team and clients

à Benefits both for solver developers, for clients and for GAMS
Summary

• GAMS increases **productivity**

• Continuous gain in **performance**

• Proven **reliability** (+30)

• Opens doors to a large network of GAMS developers and clients with modeling needs
Thank you!

Performance of bchoil example:

• Cplex/BCH: 17 seconds
• Regular Xpress: 124 seconds
• Regular Cplex: 311 seconds
• Regular Coincbc: > 10,000 seconds

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