OR 2007
GAMS - Workshop

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GAMS Software GmbH  www.gams.de

Saarbrücken, September 4th 2007
Agenda

- GAMS Development / GAMS Software
- Working with GAMS – A Guided Tour
- GAMS Grid Computing
- Compressed and Encrypted Input Files
- 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>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Engineering</td>
<td>Economic Development</td>
</tr>
<tr>
<td>Econometrics</td>
<td>Energy</td>
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<tr>
<td>Environmental Economics</td>
<td>Engineering</td>
</tr>
<tr>
<td>Finance</td>
<td>Forestry</td>
</tr>
<tr>
<td>International Trade</td>
<td>Logistics</td>
</tr>
<tr>
<td>Macro Economics</td>
<td>Military</td>
</tr>
<tr>
<td>Management Science/OR</td>
<td>Mathematics</td>
</tr>
<tr>
<td>Micro Economics</td>
<td>Physics</td>
</tr>
</tbody>
</table>

* 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: 5848

Sorted by Platform:

- 17 AIX
- 20 AXU
- 116 Darwin
- 91 Linux64
- 236 Linux32
- 45 Solaris (x86)
- 35 Solaris (Sparc)
- 4576 Windows32
- 712 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
**GAMS at a Glance**

**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

GAMS Language Compiler and Execution System

Interactive

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

API / Batch

User Interfaces
Hands-on! Installing GAMS

export PATH=/home/jhjagla/gams:$PATH
A few Words about GAMS Syntax

Minimize

subject to

Transportation cost

Demand satisfaction at markets

Supply constraints
\[
\sum_{c,p: (c,p) \in \mathcal{N}} t_{cost} \cdot d_{ist}(c, p) \cdot x_p^c \rightarrow \min \\
\sum_{c,p: (c,p) \in \mathcal{N}} x_p^c \leq \sup(c) \quad \forall c \\
\sum_{c,p: (c,p) \in \mathcal{N}} x_p^c \geq d_{em}(p) \quad \forall p \\
x_p^c \geq 0 \quad \forall c, p : (c, p) \in \mathcal{N}
\]
GAMS Algebra

**Variables**

- \( x(i,j) \): shipment quantities in cases
- \( z \): total transportation costs in thousands of dollars

**Positive Variable** \( x \) ;

**Equations**

- **cost** define objective function
- **supply(i)** observe supply limit at plant \( i \)
- **demand(j)** satisfy demand at market \( j \)

\[
\text{cost .. } \quad z = e = \text{sum}(i,j), c(i,j) \times x(i,j);
\]

\[
\text{supply(i) .. } \quad \text{sum}(j, x(i,j)) = l = a(i);
\]

\[
\text{demand(j) .. } \quad \text{sum}(i, x(i,j)) = g = b(j);
\]

**Model** transport /all/ ;
GAMS Syntax

• Symbols:
  – Sets
  – Parameters
  – Variables
  – Equations
  – Models
  – ASCII Output Files

Sets
  i       canning plants / seattle, san-diego /
Parameters
  a(i)    capacity of plant i in cases
  / seattle 350
  san-diego 600 /
Variables
  x(i,j) shipment quantities in cases;
Equations
  supply(i) observe supply limit at plant i;
Model
  transport /all/ ;
File
  fx some file / 'c:\t\text.txt' /

• Statements
  – Declarations
  – Data Assignments
  – Equation Definition
  – Programming Flow Control
  – Option statement

Parameter c(i,j);
c(i,j) = f * d(i,j) / 1000 ;
supply(i) .. sum(j, x(i,j)) =l= a(i);
loop(i, put fx i.tl);
option reslim=10;
Hands-on! Testing the installation
Hands-on! Testing the installation

```
reagan.gams.com · PuTTY

-bash-3.00$ gamslib transport
Model transport.gms retrieved
-bash-3.00$ gams transport

--- Job transport Start 07/03/07 10:33:00
GAMS Rev 148 Copyright (C) 1987-2007 GAMS Development. All rights reserved
Licensee: GAMS Development Corporation, Washington, DC 20001/00000
Free Demo, 202-342-0180, sales@gams.com, www.gams.com DC0000

--- Starting compilation
--- transport.gms(69) 3 Mb
--- Starting execution
--- transport.gms(45) 4 Mb
--- Generating LP model transport
--- transport.gms(65) 1 Mb
--- 6 rows 7 columns 19 non-zeros
--- Executing CPLEX

GAMS/Cplex Jun 1, 2007 LEX.CF.NA 22.5 034.087.041.LEI For Cplex 10.2
Cplex 10.2.0, GAMS Link 34

Reading data...
Starting Cplex...
Tried aggregator 1 time.
LP Presolve eliminated 1 rows and 1 columns.
Reduced LP has 5 rows, 6 columns, and 12 nonzeros.
Presolve time = 0.00 sec.

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Dual Objective</th>
<th>In Variable</th>
<th>Out Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>79.125000</td>
<td>x(seattle, new-york)</td>
<td>demand(new-york) slack</td>
</tr>
<tr>
<td>2</td>
<td>119.025000</td>
<td>x(seattle, chicago)</td>
<td>demand(chicago) slack</td>
</tr>
<tr>
<td>3</td>
<td>153.675000</td>
<td>x(san-diego, topeka)</td>
<td>demand(topeka) slack</td>
</tr>
<tr>
<td>4</td>
<td>153.675000</td>
<td>x(san-diego, new-york)</td>
<td>supply(seattle) slack</td>
</tr>
</tbody>
</table>
```
Hands-on! IDE - A Guided Tour

• IDE Project Management
• Documentation
  – User’s Guide
  – McCarl User’s Guide
  – Solver Manuals
• Model Library
• Solver Selection
• Option Editor
• Listing file
  – Tree view
  – Error navigation
• Spell checking
Agenda

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- Working with GAMS – A Guided Tour
- Solvers
- GAMS Grid Computing
- Compressed and Encrypted Input Files
- Summary
## Multiple Solvers & Platforms

<table>
<thead>
<tr>
<th>Solver/Platform availability - 22.5</th>
<th>June 1, 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solver</strong></td>
<td>x86 MS Windows</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>ALPHABCP</td>
<td>✔</td>
</tr>
<tr>
<td>BARON 7.8</td>
<td>✔</td>
</tr>
<tr>
<td>BONMIN</td>
<td>✔</td>
</tr>
<tr>
<td>CONOPT 3</td>
<td>✔</td>
</tr>
<tr>
<td>CPLEX 10.2</td>
<td>✔</td>
</tr>
<tr>
<td>DECIS</td>
<td>✔</td>
</tr>
<tr>
<td>DICOPT</td>
<td>✔</td>
</tr>
<tr>
<td>KNITRO 5.1</td>
<td>✔</td>
</tr>
<tr>
<td>LINDO/LINDOS 4.1</td>
<td>✔</td>
</tr>
<tr>
<td>LGO</td>
<td>✔</td>
</tr>
<tr>
<td>MILES</td>
<td>✔</td>
</tr>
<tr>
<td>MINOS</td>
<td>✔</td>
</tr>
<tr>
<td>MCSERK 4</td>
<td>✔</td>
</tr>
<tr>
<td>MPSGE</td>
<td>✔</td>
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<tr>
<td>MSLNLP</td>
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<td>NLPEC</td>
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<tr>
<td>OQNLP</td>
<td>✔</td>
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<tr>
<td>OSL V3</td>
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<tr>
<td>OSL V3E</td>
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<td>SDB</td>
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<td>SNOPT</td>
<td>✔</td>
</tr>
<tr>
<td>XA</td>
<td>✔</td>
</tr>
<tr>
<td>XFRRESS 17.10</td>
<td>✔</td>
</tr>
</tbody>
</table>
## Multiple Model Types

- **LP**  Linear Programs
- **MIP**  Mixed Integer Programs
- **QCP**  Quadratically Constrained Programs
- **MIQCP**  Quadratically Constrained MIPs
- **NLP**  Nonlinear Programs
- **DNLP**  NLP with Discontinuous Derivatives
- **MINLP**  Mixed Integer Nonlinear Programs
- **MCP**  Mixed Complementarity Programs
- **MPEC**  NLP with Complementarity Constraints
- **CNS**  Constrained Nonlinear Systems
- **Stochastic Optimization**
- **Global Optimization**
## Multiple Solver & Model Types

<table>
<thead>
<tr>
<th>Solver/Model Type availability</th>
<th>22.5</th>
<th>June 1, 2007</th>
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<tbody>
<tr>
<td><strong>Solver</strong></td>
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<tr>
<td>ALPHA BCP</td>
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<td>BARON 7.8</td>
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<td>✓</td>
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<tr>
<td>BOMLP</td>
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<td>✓</td>
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<tr>
<td>COIN</td>
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<td>✓</td>
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<td>CONOPT 3</td>
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<td>✓</td>
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<tr>
<td>CPLEX 10.2</td>
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<td>✓</td>
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<tr>
<td>DECIS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>DICOPT</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>KNITRO 5.1</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>LINDO/GLOBAL 4.1</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>LGO</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>MILES</td>
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<td>✓</td>
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<td>MINOS</td>
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<td>✓</td>
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<td>MOSEK 4</td>
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<tr>
<td>MPSGE</td>
<td>✓</td>
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<td>XA</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>XPRESS 17.10</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td><strong>Contributed Plug&amp;Play solvers</strong></td>
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<tr>
<td>AMPL/Idiom</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>DAE</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Kestrel</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Solvers that do not solve the problem:

- **CONVERT**
  - Converts the model into different formats

- **BENCH**
  - Benchmarking solvers

- **EXAMINER**
  - Checks quality of solutions found by different solver
Hands-on! “Solver” Convert
Hands-on! "Solver" Bench
Solver Option Files

• Pass solver specific options
  – e.g. tolerances, limits, algorithm selection

• Solver option file solver.opt e.g. cplex.opt with solver specific options (one per line)

• Activate solver option file
  – optfile=1 on command line/parameter window
  – <modelname>.optfile=1; before solve

• Multiple option files:
  – solver.opt optfile=1
  – solver.op2 optfile=2
  – ...
  – solver.999 optfile=999
PAVER - GAMS Model Translation Web Submission Tool (GMS2XX)

The PAVER GAMS model translation web submission tool uses the GAMS/CONVERT "solver" to translate GAMS models into the following supported languages:

- AlphaECP
- AMPL
- AMPSolver
- BARON
- ConMin
- CplexLP
- CplexMPS
- Dcot
- FixedMPS
- GAMS (scalar)
- Jacobian
- Lago
- Lingo
- LindoMPI
- LINGO
- MINOPT
- NLP2MCP
- VermaDasgupta
- ALL (this creates scalar versions of all supported languages listed above)

The service requires that all models be self-contained. Upon submission, the resulting translated models will be sent via e-mail.

Creating a Self Contained Model:

The translation service requires a self contained model with no include orincludefile. The GAMS system provides an easy way to produce such a model even if it contains nested include and full statements. Run your model in the usual way but add the GAMS parameter dmpout=11:

```gams
model mymodel.dmpout=11
```

This will create a file mymodel.dmp which represents a self contained version of the original model.
Benchmark online - [www.gamsworld.org](http://www.gamsworld.org)

PAVER – Server
Performance Analysis and Visualization for Efficient Reproducibility
Excursus: Solver Links

• Standardized Solver Interface
  – Return Codes, Limits, Interrupts, …
  – Common attributes (e.g. time) through GAMS options
  – Specific options through option file

à allows “hassle free” replacement of solvers:

```plaintext
option nlp=conopt;
```

• Open architecture assures seamless communication
  – IO Library (C, Fortran, Delphi) provides access to
    Matrix, Function/Derivative Evaluator, …

à S. Vigerske: “Interfacing COIN-OR solvers with GAMS”
Wednesday 11.45am-12.15pm, Room B3 1 3.18
Agenda

- GAMS Development / GAMS Software
- Working with GAMS – A Guided Tour
  - Interfaces
- GAMS Grid Computing
- Compressed and Encrypted Input Files
- Summary
Input/Output through ASCII Files

- ASCII Input Data
  - Part of model input ($\text{include file.txt}$)
  - Posix Utilities are part of GAMS Windows System
    - Platform independent data file preparation
    - sed, awk, grep, cut, ...

```bash
$\text{call cut -d, -f1,3- file.txt > filenew.txt}
```

- ASCII File Output
  - GAMS Put Facilities

```gams
file fx / result.txt /;
fx.pc=5; fx.lw=0; fx.nw=10; fx.nd=4;
loop((i,j)$\text{x.l(i,j)>0)},
  put fx i.tl j.tl x.l(i,j) /;
);
```
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 Model
  - Text Files
  - Direct Interface (Office Appl.)
- Visualization Tools

Import

Export
Application in Control

External Application

Call GAMS

GAMS

Call external program (including GAMS)

External Application

Programming Language or other Application

Application
Hands-on! GDX and Tools

- Create GDX file
  - execute_unload
  - Gdx=filename

- GDX Viewer
  - Data cube
  - Export to Excel

- GDXdiff

- Charting Engine
<table>
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<tr>
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<td>Maintenance</td>
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<td>GAMS Grid Computing</td>
</tr>
<tr>
<td>Compressed and Encrypted Input Files</td>
</tr>
<tr>
<td>Summary</td>
</tr>
</tbody>
</table>
Model Support & Maintenance

**Implementation**
- It will be incorrect
- It will be inefficient
- It will be confusing (at least for others)
- …

**Optimization**
- Takes Longer than one is willing to wait
- It will eventually fail
- …

**Application**
- Real Time
- Always need a *Solution* to Problem
- …
Keys for Support & Maintenance

- Implement Data Error checks
- Use reference files: rf=filename a=c
- Get hold of Instance: dumpopt=11/21
- Use Profiler: profile / profiletol
- Get scalar Model using solver: Convert
- Use Deployment System
Hands-on! Reference file
Hands-on! Deployment

GAMS Deployment Model (DEPLOY,SEQ=300)

This model creates a GAMS deployment system.

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


* Add extra new GAMS files to your deployment system and '
  do echo & "ziplist"

gams.exe.lic

* There is no need to change anything.

* We always need the GAMS BASE system.

GAMS Deployment Model (DEPLOY,SEQ=300)

This model creates a GAMS deployment system.
Agenda

GAMS Development / GAMS Software

Working with GAMS – A Guided Tour

GAMS Grid Computing

Compressed and Encrypted Input Files

Summary
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

Improvements

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

à L. Westermann: “Global Optimization with GAMS”
Wednesday 2-2.30pm, Room B3 1 3.18

Further progress using Multiple Threads / Grid Computing
Multiple Threads / SMP

• CPLEX
  – parallel extension for B&B and interior point solver
  – concurrent optimizer
  – academic license includes 4 threads

• MOSEK
  – parallel extension for the interior solver comes free of charge
  – concurrent optimizer

• XPRESS
  – parallel extension for B&B and interior point solver
  – 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...

Grid Computing
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

```gams
Loop(p(pp),
    v.fx = vmin + (vmax-vmin)/(card(pp)+1)*ord(pp) ;
    Solve var1 maximizing m using nlp ;
    xres(i,p) = x.l(i);
    xres('mean',p) = m.l;
    xres('var',p) = v.l;
    xres('status',p) = var1.modelstat;
);
```

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
Hands-on! GAMS Grid Computing

```gams
Solve varl maximizing m using nlp;
xres('i',p) = x.l(i);
xres('mean',p) = m.l;
xres('var',p) = v.l;
xres('status',p) = varl.modelstat;

display xres;
```

```gams
if not %grid%
loop(p;pp),
v.fx = vmin + (vmax-vmin)/(card(pp)+1)*ord(pp); solve varl maximizing m using nlp;
xres('i',p) = x.l(i);
xres('mean',p) = m.l;
xres('var',p) = v.l;
xres('status',p) = varl.modelstat;
else
varl.solveLink(3);
loop(p;pp),
v.fx = vmin + (vmax-vmin)/(card(pp)+1)*ord(pp); solve varl maximizing m using nlp;
handle(p) = varl.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) = varl.modelstat;
    display handleDelete(handle(p))
    display sleep(card(handle)*0.2) 'sleep some time'
    until card(handle) = 0 or timeout > 100;
    xres('i',pp)
    handle(p) = na;
```

```gams
display xres;
execute_unload "portfolio.gdx" xres;
```
**Hands-on! The Mean-Variance Model**

Markowitz (1952), Nobel prize 1990

### Given

- Some investments \( x_i \) with historical data
  - **Rewards** = Expected returns of investments: \( \mu_i \) *(Mean of historical returns)*
  - **Risk** = Variance of investments \( Q_{i,j} \)

### Goal

- Minimize variance \( v \) for a given target return \( r \)
  - Balance risk \( r \) of portfolio against expected returns of portfolio

### Formulation

<table>
<thead>
<tr>
<th>Variance of Portfolio</th>
<th>Minimize ( \sum_{i=1}^{I} \sum_{j=1}^{J} x_i Q_{i,j} x_j )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target return</td>
<td>s.t. ( \sum_{i=1}^{I} \mu_i x_i \geq r )</td>
</tr>
<tr>
<td>Budget constraint</td>
<td>( \sum_{i=1}^{I} x_i = 1 )</td>
</tr>
<tr>
<td>No short sales</td>
<td>( x_i \geq 0 )</td>
</tr>
</tbody>
</table>
* turn on grid option

```gams
var1.solvelink=3;
Loop(p(pp),
  v.fx = vmin + (vmax-vmin)/(card(pp)+1)*ord(pp);
  Solve var1 maximizing m using nlp ;
* save instance handle
  handle(p) = var1.handle );
```

LOG
... 
--- LOOPS pp = p1 
--- 3 rows 9 columns 23 non-zeroes 
--- 538 nl-code 7 nl-non-zeroes 
--- meanvar_edited.gms(174) 3 Mb 
--- Submitting model var1 with handle grid133000004 
...
@echo off
: gams grid submission script
: arg1 solver executable
:    2 control file
:    3 scratch directory
: gmscr_nx.exe processes the solution and produces 'gmsgrid.gdx'
: note: %3 will be the short name, this is needed because
:       the START command cannot handle spaces or "..."
:       before we use %~3 will strip surrounding "...
:       makes the name short
: gmsrerun.cmd will resubmit runit.cmd

echo @echo off              > %3runit.cmd
echo %1 %2                 >> %3runit.cmd
echo gmscr_nx.exe %2       >> %3runit.cmd
echo                      >> %3runit.cmd
echo exit                  >> %3runit.cmd
echo @start /b %3runit.cmd ^> nul
start /b %3runit.cmd > nul
exit
Solution Collection Loop

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) = var1.modelstat;
  display$handledelete(handle(p)) 'trouble deleting handles';
  handle(p) = 0 ;
  display$sleep(card(handle)*0.2) 'sleep some time';

  until card(handle) = 0 or timeelapsed > 100;
  xres(i,p(pp))$handle(p) = na;

LOG

...  
--- meanvar_editeds(161) 3 Mb
--- GDXin=C:\..\225a\grid133000004\gmsgrid.gdx
--- meanvar_editeds(161) 3 Mb
--- Removed handle grid13300004
...
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

www.network.com

- 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 Distribution 22.5 available
- 250 free CPU hours to new users

www.gams.com/sungrid

F. Nelissen: “Grid Computing in Finance using an Algebraic Modeling System”, Thursday 2:30-3pm, Room A2 4 1.32
Agenda

- GAMS Development / GAMS Software
- Working with GAMS – A Guided Tour
- GAMS Grid Computing
- Compressed and Encrypted Input Files
- Summary
Distribution of models to users/customers

- $\text{Compress}$
  - compresses into a GAMS system file
- $\text{Decompress}$
  - decompresses a GAMS system file

Issues of privacy, security, data integrity and ownership

- $\text{Encrypt}$
  - encrypts into a GAMS system file
  - requires special licensing
Hands-on! Compression & Encryption
• Robust and scalable state-of-the-art modeling technology
• Tailored for complex, large-scale modeling applications. Less than 5% of modeling/optimization projects do not fit the GAMS way
• 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
## Sources of GAMS Information

<table>
<thead>
<tr>
<th>Category</th>
<th>URL</th>
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</thead>
<tbody>
<tr>
<td>Download</td>
<td><a href="http://download.gams-software.com/">http://download.gams-software.com/</a></td>
</tr>
<tr>
<td>Contributed Documentation</td>
<td><a href="http://www.gams.com/docs/contributed">http://www.gams.com/docs/contributed</a></td>
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<th>Other Resources</th>
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<tr>
<td>GAMS User Group</td>
<td><a href="http://www.gams.com/maillist/gams_l.htm">http://www.gams.com/ maillist/gams_ l.htm</a></td>
</tr>
<tr>
<td>GAMS Google Group</td>
<td>[<a href="http://groups.google.de/group/gams">http://groups.google.de/group/gams</a> world](<a href="http://groups.google.de/group/gams">http://groups.google.de/group/gams</a> world)</td>
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<th>URL</th>
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<tr>
<td>Other relevant sites on the Web</td>
<td><a href="http://www.gams.com/hotlinks.htm">http://www.gams.com/hotlinks.htm</a></td>
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</table>
Contacting GAMS

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Fax: +1 202 342 0181
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sales@gams.com
support@gams.com
## Benefits for Different User Groups

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