Rapid Application Prototyping using GAMS

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Welcome/Agenda

- GAMS Development / GAMS Software
- Working with GAMS – A Guided Tour
- Model Development
- Model Deployment and Maintenance
Agenda

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GAMS Development / GAMS Software

- 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
- Operating in a segmented niche market
- Broad academic & commercial user base and network
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
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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
More GAMS Features

- State of art professional modeling technology
- Increased productivity
- Robust and scalable
- Rapid development
- Broad Network
- Large model libraries with templates
- Multiple Model Types
- Platform / Solver independence:
  - Maintainable models
  - Protection of investments
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

User Interfaces

Interactive

API/Batch

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

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

BARON, COIN, CONOPT, CPLEX, DECIS, DICOPT, KNITRO, LGO, MINOS, MOSEK, OQNLP, PATH, SNOPT, XA, XPRESS, ...
Hands-on! Installing GAMS

```
s1s
euroO6lnx.zip
$unzip neuroO6lnx.zip
Archive: euroO6lnx.zip
    inflating: lx3gams_sfx.exe
    inflating: gamslice.txt
$./lx3gams_sfx.exe
UnZipSFX 5.41 of 16 April 2000, by Info-ZIP (Zip-Bugs@lists.wku.edu).
    extracting: gams.zip
    inflating: gamsinst
    inflating: gamsunpack
    inflating: gamsunzip
$rm euroO6lnx.zip lx3gams_sfx.exe
$./gamsinst -a

gamsinst version 034
---------------------
Installation of GAMS distribution 22.2

Unpacking GAMS ...
    estimated disk blocks needed : 20480, available : 923184
executing--> ./gamsunpack

$export PATH=/home/susanne/euro2006/::PATH
```
Hands-on! Testing the installation

This file contains the basic data and definition of the surface water system. Data is complete for year 1988. Some parameters could be computed for future years using growth rates provided in this file, others had to be estimated and entered. Enter the year for which the setup is desired in set irst (set irst should have only one entry).


changes for year 2000 runs
growth of crop yields set to a maximum of 3 & insert this line after growthcy parameter

--- 0.0183 0.0183 (growthcy); at 1 = 3.0;

--- Iteration: 4085 Dual objective = 113074.076725
--- Iteration: 4183 Dual objective = 114925.604909
--- Iterating new solution found.
--- Objective : 114073.655552
--- Restarting execution
--- indus89.gms (3621) 0 Mb
--- Reading solution for model waism
--- indus89.gms (3621) 4 Mb
--- Status: Normal completion
--- Job indus89.gms Stop 06/29/06 04:59:12 elapsed 0:00:02.724
---
Hands-on! Testing the installation

lewis.gams.com - PuTTY

$gamslib indus89
Model indus89.gms retrieved
$gams indus89
--- Job indus89 Start 06/29/06 05:01:20
GAMS Rev 145 Copyright (C) 1997-2006 GAMS Development. All rights reserved
Licensee: EURO 2006 GAMS Workshop G060626/0001CB-LNX
GAMS Software GmbH DC5946
--- Starting compilation
--- indus89.gms(3622) 4 Mb
--- Starting execution
--- indus89.gms(3618) 5 Mb
--- Generating LP model vsin
--- indus89.gms(3621) 7 Mb
--- 2,726 rows 6,570 columns 39,409 non-zeroes
--- Executing CPLEX

GAMS/Cplex  Apr  21, 2006 LNX.CP.CP 22.2 031.034.041.LX3 For Cplex 10.0
Cplex 10.0.1, GAMS Link 31
Cplex licensed for 1 use of lp, qp, mip and barrier, with 4 parallel threads.

Reading data...
Starting Cplex...
Tried aggregator 1 time.
LP Presolve eliminated 280 rows and 805 columns.
Aggregator did 652 substitutions.
Reduced LP has 1794 rows, 5113 columns, and 33006 nonzeros.
Presolve time = 0.04 sec.
Initializing dual steep norms . . .

Iteration log . . .
Iteration: 1 Scaled dual infeas = 2955567.467575
A few Words about GAMS Syntax

Minimize Transportation cost
subject to Demand satisfaction at markets
Supply constraints
GAMS Syntax – Mathematical Algebra

\[ \sum_{(c,p) \in \mathcal{N}} t_{\text{cost}} \cdot d_{\text{ist}}(c, p) \cdot x_{p}^{c} \rightarrow \min \]

\[ \sum_{(c,p) \in \mathcal{N}} x_{p}^{c} \leq sup(c) \quad \forall c \]

\[ \sum_{(c,p) \in \mathcal{N}} x_{p}^{c} \geq dem(p) \quad \forall p \]

\[ x_{p}^{c} \geq 0 \quad \forall c, p : (c, p) \in \mathcal{N} \]
GAMS Syntax – 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 \( j \);

\[
\text{cost} \quad \quad z = \epsilon \quad \sum\{(i,j), c(i,j)x(i,j)\};
\]
\[
\text{supply(i)} \quad \quad \sum\{j, x(i,j)\} = l = a(i);
\]
\[
\text{demand(j)} \quad \quad \sum\{i, x(i,j)\} = g = b(j);
\]

Model transport /all/ ;
GAMS Syntax – cont.

- **Symbols:**
  - Sets
  - Parameters
  - Variables
  - Equations
  - Models
  - ASCII Output Files

```plaintext
Set I some stuff /cat,dog,ding1*ding10/
Parameter life(I) life count / cat 7 /
Integer Variable x(I) number to purchase;
Equation e(I) relate something;
Model animal life / e, some, more/;
File fx some file / 'c:\t\text.txt' /
```

- **Statements**
  - Declaration+Data statement
  - Data Assignments
  - Equation Definition
  - Programming Flow Control
  - Option statement

```plaintext
Set I /cat,dog/;
life('dog')=life('cat')-1; x.lo(I)=1;
e(I).. Sqr(x(I)) =l= log(life(I));
loop(I, put fx I.tl);
Option reslim=10;
```
Hands-On! Inspect trnsport.gms

• IDE:
  File→Model Library
  trnsport
  Hit F9 or Click

• Unix:
  $ gamslib trnsport
  $ vi trnsport.gms
  $ gams trnsport
  $ vi trnsport.lst
Hands-on! IDE - A Guided Tour

- IDE Project Management
- Documentation
- Model Library
- Editor
- Solver Selection
- Option Selection
- Listing file/Tree view/Error navigation
- GDX Viewer
  - Data cube
  - Export to Excel
  - Graphs
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`
Special Solvers

- **Solvers** that do not *solve* the problem:
  - **CONVERT**
    - Converts the model into different formats
  - **AMPL/LINGO**
    - Converts model into AMPL/LINGO syntax and calls the other system to solve the problem
  - **EXAMINER**
    - Checks the quality of a solution found by a different solver
  - **BENCH**
    - Benchmarking solver
Model Translation

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)
Model Translation – Cont.

• Translation of MP Model into *Scalar Model*
  – List of Variables/Equations
• Advantages:
  – Syntax for Scalar Models almost identical for different Modeling Languages (easy Translation)
  – Hides proprietary Information
• Seamless Modeling System Connection
  – For example: GAMS/AMPL with Kestrel (NEOS)
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 trimlosstrimloss /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;
Welcome to the Daily SuDoku!

Today’s SuDoku is shown on the right. Click the grid to download a printable version of the puzzle. Visit the archive for previous daily puzzles and solutions. Play online, print a SuDoku, solve and get hints using the new improved Draw/Play function.

But how do I do it?

The object is to insert the numbers in the boxes to satisfy only one condition: each row, column and 3x3 box must contain the digits 1 through 9 exactly once. What could be simpler?

The rules of the new Monster SuDokus are exactly the same, but more numbers and letters are needed.
Christmas tree Sudoku

Daily SuDoku

Daily Seasonal Sudoku: Fri 23-Dec-2005  [instructions]

3 2 9
1 7 3
7 4 9 2
6 2 8 3

3 8 4 5

Christmas tree Sudoku: Fri 23-Dec-2005  very hard
Agenda

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- Model Deployment and Maintenance
Important Principles

• Deployed models have often 15+ years lifecycle
  – Changing environment:
    • hardware, operating system, interface (GUI/data)

• Backward compatibility
• Platform/Solver/Interface Independence
  – Model benefits from
    • Advanced hardware
    • Advanced solver technology

• Reduced Total Cost of Ownership (TCO)
Flow of Data

Data Model I
- Application in control of data processing
- No direct data access

Data Model II
- Large Scale/Raw data exchange GAMS↔DB
- Control Data GAMS↔Application
Input/Output through ASCII Files

• ASCII Input Data
  – Part of model input ($\texttt{include file.txt}$)
  – Posix Utilities are part of GAMS Windows System
    • Platform independent data file preparation
    • sed, awk, grep, cut, ...
      $\texttt{call cut -d, -f1,3- file.txt > filenew.txt}$

• ASCII File Output
  – GAMS Put Facilities
GAMS Data eXchange

- **GAMS Data eXchange (GDX):**

  ![Diagram of data exchange between Application Database, GDX, and GAMS]

  - Complements the ASCII text data input
  - Advantages:
    - Fast exchange of data (factor >20)
    - Syntactical check on data before model starts
    - Compile-time and Run-time Data Exchange
    - Platform Independent

- Hands-on! IDE GDX browser
GDX Tools

- IDE
- GDX Viewer
- GDX API
- gams
- gdxxxrw (MS Office)
- gdxdiff
- gdxsplits
- gdxmerge
- gdxdump

GDX
Samurai Sudoku

Top Notch Free Samurai #33
(Easy)

Get the solution to this puzzle from our solver.
Registered users can view, save or print the Samurai in Adobe PDF format.

The classic five merged grid Samurai Sudoku. We have one free puzzle each week and three additional weekly puzzles for registered users. See below for previous puzzles.

We also have a printable blank Gattai-5 grid for those of you who want to print out some copies to work on.

Free Samurai #33 (Easy)

Access key:

To access the premium Samurais, you will need to enter an access key in the box above. The same key will also let you access our Samuraz, Shogun, Sudo and Weebooku puzzles and use both the Samurai and standard solvers as many times as you like.

To obtain an access key:
Click the "Buy Now" button below to use secure PayPal pages to purchase an access key. Each key costs £3.00 and is valid for 14 days. The key will be sent to you by email. We will only use your email address to administer this service, and will not pass your details to any third party.

Buy Now

Address: http://sudoku.top-notch.co.uk/gattai5.asp
Data in Excel and GAMS in Control

- GAMS is the driving program
- Data is stored in Excel (database)
- Use gdxxrw to import data from Excel
- Use gdxxrw to export data to Excel

- Hands-on: samurai_mrb, samurai_xls
Calling GAMS from an Application

Creating Input for GAMS Model
Callout to a GAMS Process/Executable
Reading Output from GAMS Model

• Works from basically every environment
  – Web application (server side)
  – Application Builder
    • Oracle, Eclipse, .NET, …
    • Regular Programming language C++, Java, VB, …
  – MS Office Application / VBA

• Hands-on! samurai_vb.xls
A few Words about Maintenance

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

**Application**
- Real Time
- Always need a *Solution* to Problem

- Key for support/maintenance
  - Catch problems before a model is solved
    - Implement Data Error checks
  - Reproduce the problem offline
    - Get hold of Instance (*dumpopt=11*)
  - Solver related problems in confidential models
    - Get scalar Model using solver **CONVERT**
Summary

• 30+ Years Experience in Modeling
  – Strong views on modeling process (The GAMS Way)
    • Development
    • Deployment
    • Maintenance
  – Less than 5% of modeling/optimization projects do not fit the GAMS way
  – Use of GAMS and its productivity tools (after potentially steep learning curve)
    • Increases productivity of model building
    • Reduces total cost of ownership for model client
    • Opens doors to a large network of GAMS developers and clients with modeling needs
Contacting GAMS

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