Rapid Application Prototyping with GAMS

Steven Dirkse
sDirkse@gams.com

GAMS Development Corp
www.gams.com

Alex Meeraus
AMeeraus@gams.com

GAMS Development Corp
www.gams.com

INFORMS International
Puerto Rico, 10 July, 2007

Welcome/Agenda

GAMS Development / GAMS Software

Working with GAMS – A Guided Tour

Model Development

Model Deployment and Maintenance

Agenda

GAMS Development / GAMS Software

Working with GAMS – A Guided Tour

Model Development

Model Deployment and Maintenance

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

Network of Application Partners

Agenda

GAMS Development / GAMS Software

Working with GAMS – A Guided Tour

Model Development

Model Deployment and Maintenance

GAMS at a Glance

General **A**lgebraic **M**odeling **S**ystem:
Algebraic Modeling Language,
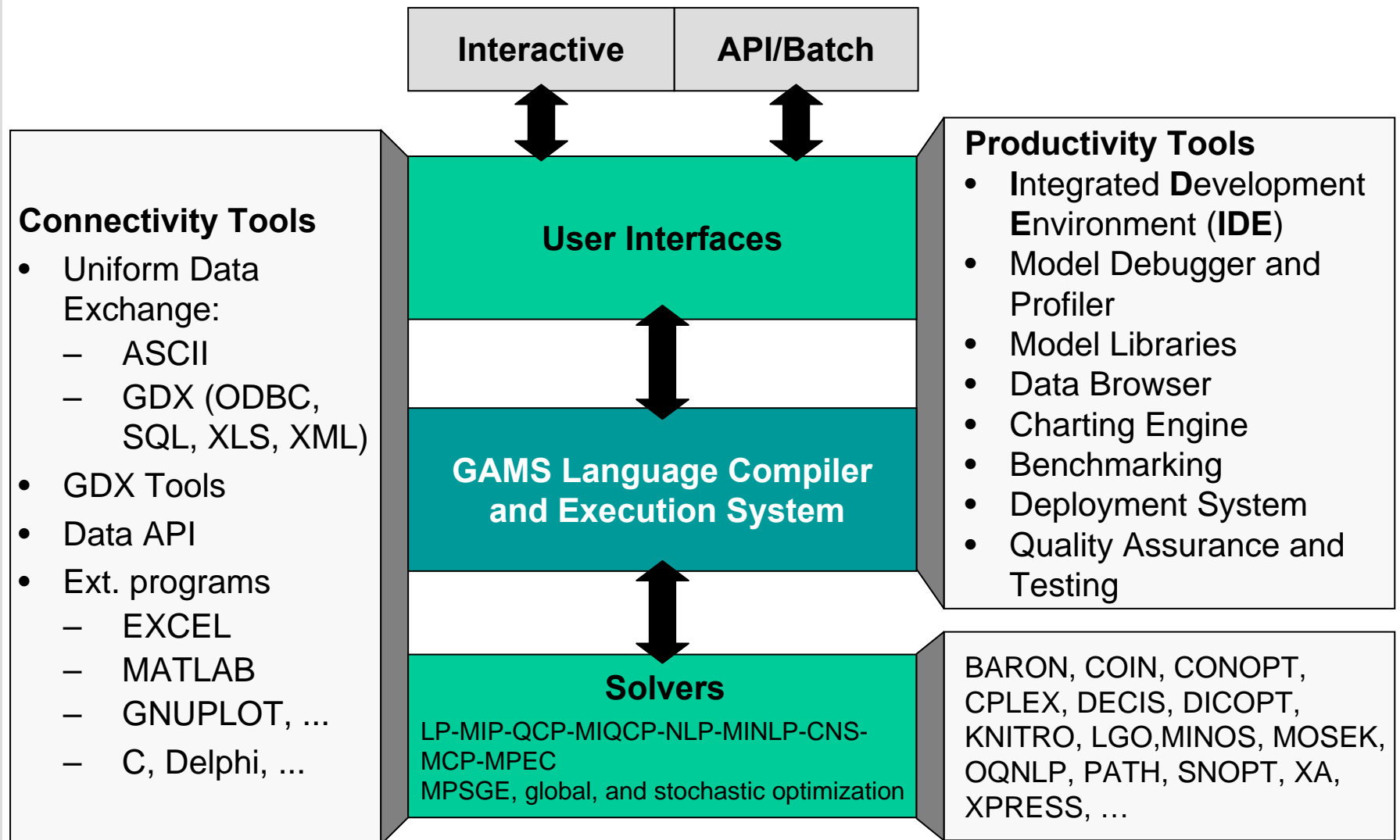Integrated Solver, Model
Libraries, Connectivity- &
Productivity Tools

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

Interactive | **API/Batch**

User Interfaces

GAMS Language Compiler and Execution System

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

Connectivity Tools

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

Productivity Tools

- **I**ntegrated **D**evelopment **E**nvironment (**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

Hands-on! Testing the installation

Hands-on! Testing the installation


```
$gamslib indus89
Model indus89.gms retrieved
$gams indus89
--- Job indus89 Start 06/29/06 05:01:20
GAMS Rev 145  Copyright (C) 1987-2006 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 wsisn
--- indus89.gms(3621) 7 Mb
---    2,726 rows  6,570 columns  39,489 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 =    2955667.467575
```

A few Words about GAMS Syntax

San Diego — 600

Seattle — 350

325 — New York

275 — Topeka

300 — Chicago

2.5, 1.4, 1.8, 2.5, 1.8, 1.7
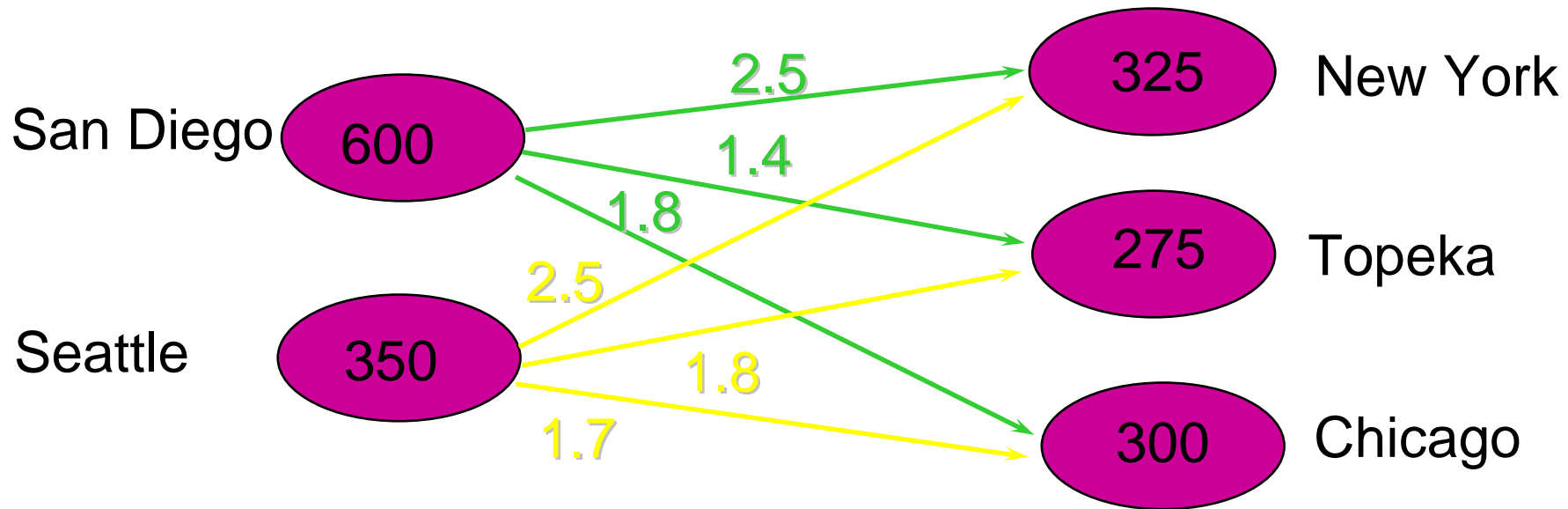
Minimize	Transportation cost
subject to	Demand satisfaction at markets
	Supply constraints

GAMS Syntax – Mathematical Algebra

$$\sum_{\substack{c,p: \\ (c,p)\in\mathcal{N}}} tcost \cdot dist(c,p) \cdot x_p^c \quad \rightarrow \quad \min$$

$$\sum_{\substack{c,p: \\ (c,p)\in\mathcal{N}}} x_p^c \quad \leq \quad sup(c) \quad \forall c$$

$$\sum_{\substack{c,p: \\ (c,p)\in\mathcal{N}}} x_p^c \quad \geq \quad dem(p) \quad \forall p$$

$$x_p^c \quad \geq \quad 0 \qquad \forall c, p : (c,p) \in \mathcal{N}$$

GAMS Syntax – GAMS Algebra


```
gamside: C:\Documents and Settings\bussieck\My Documents\gamsdir\project.gpr - [c:\documents an...

File   Edit   Search   Windows   Utilities   Help

call          {a}

trnsport.gms

    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 ;

    cost ..          z   =e=  sum((i,j), c(i,j)*x(i,j)) ;

    supply(i) ..    sum(j, x(i,j))   =l=  a(i) ;

    demand(j) ..    sum(i, x(i,j))   =g=  b(j) ;

    Model transport /all/ ;
```

1: 1   Insert

GAMS Syntax – cont.

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

```
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 animallife /e, some, more/;

File fx some file / 'c:\t\text.txt' /
```

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

```
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
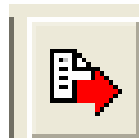
- Unix:

  $ gamslib trnsport
  $ vi trnsport.gms
  $ gams trnsport
  $ vi trnsport.lst

Hands-on! IDE - A Guided Tour

- IDE Project Management
- Documentation
  - User's Guide/McCarl UG, Solver Manual
- Model Library
- Editor
- Solver Selection
- Option Selection
- Listing file/Tree view/Error navigation
- GDX Viewer
  - Data cube
  - Export to Excel
  - Graphs

Sudoku

Address http://www.dailysudoku.com/sudoku/index.shtml

Daily SuDoku

Home

Today's SuDoku

SuDoku Archive

SuDoku for Kids

Draw/Play

Discussion

FAQ

Books

Syndication

Links

Email and News

Contact

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.

Classic   **Monster**   **Kids**   **Squiggly**

							6	1
			7	3	1			4
5					9			
6			2				1	
		8				4		
	1				5			8
			9					3
7			8	6	3			
9		2						

Daily SuDoku: Thu 2-Nov-2006   very hard

19

Christmas tree Sudoku

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

Hands-on! Basic Sudoku (*su1 -> su2*)

- Basic model *su1* computes solution to Sudoku
- Is the solution unique?
- If not, how many solutions exist?
- Edits for *su1 -> su2*:
  - Implement binary cuts to exclude known solutions
  - To cut off xb: sum(i, abs(xb(i)-x(i)) =g= 1;
  - Use loop to find and store solutions
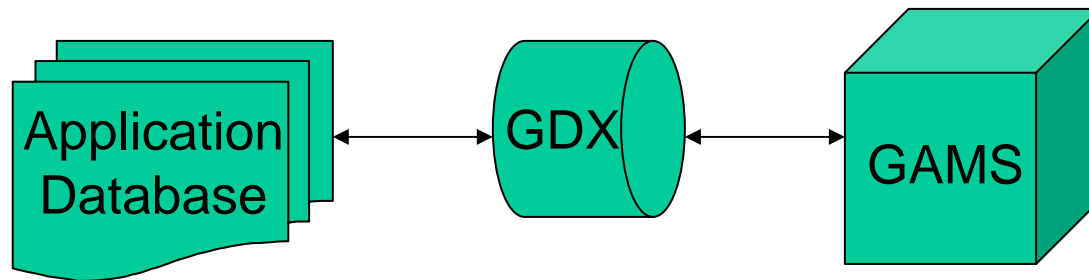 - Use GDX to view model data and solution

Input/Output through ASCII Files

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

- ASCII File Output
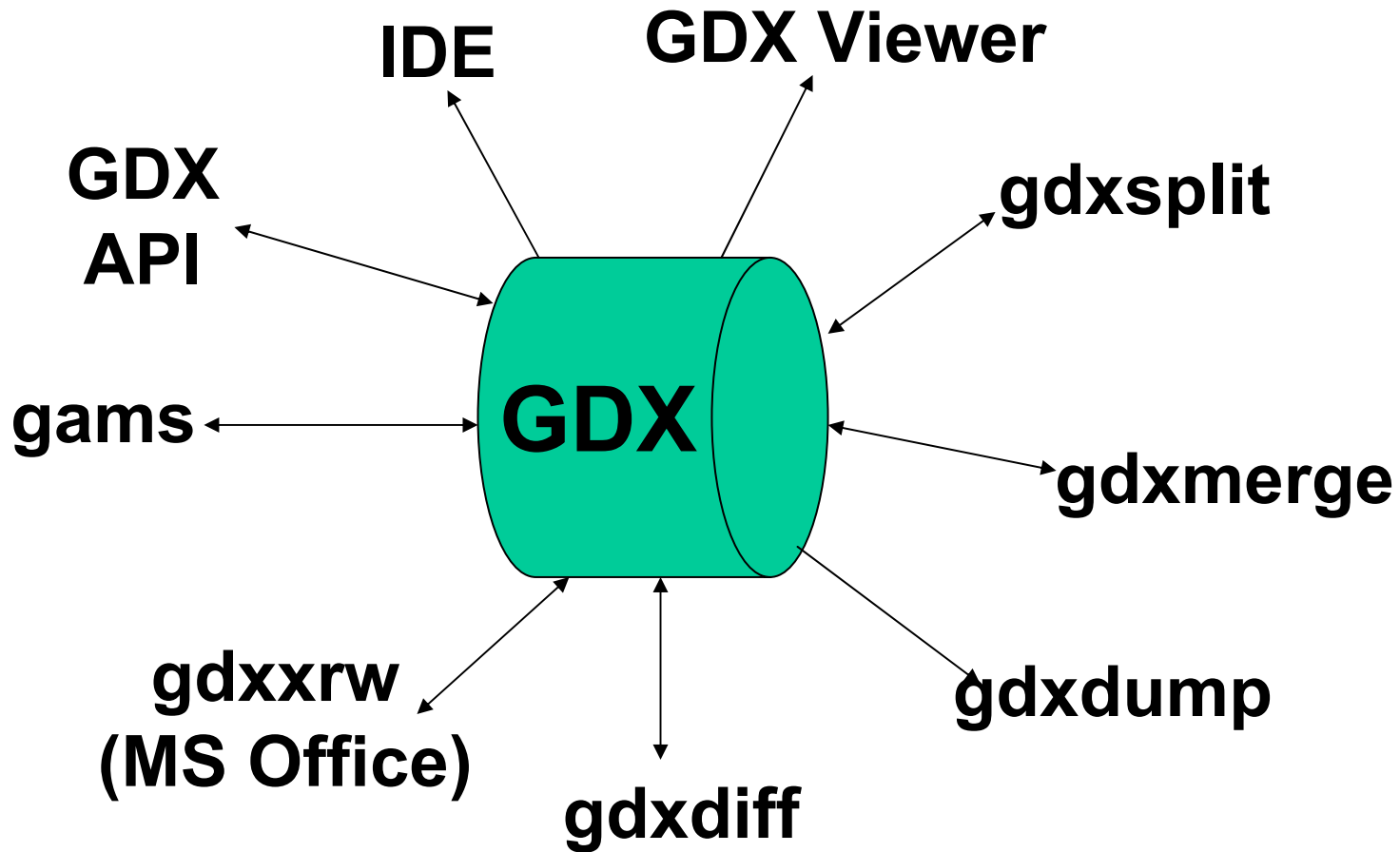 - GAMS Put Facilities

GAMS Data eXchange

- **G**AMS **D**ata e**X**change (GDX):

- 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

GDX Tools

IDE

GDX Viewer

GDX API

gdxsplit

gams

GDX

gdxmerge

gdxxrw (MS Office)

gdxdump

gdxdiff

Hands-on! Report on all solutions (su3)

- Find a "good" cell to fix
  - A good fix is one that leaves few (one?) solutions
  - Compute result of any fix using saved GDX data

Hands-on! Force Uniqueness (*su2 -> su4*)

- Set cell r7.c4 to the value 4 (c.f. *su3*)
- Verify that the resulting solution is unique

Hands-on! Text output (*rep0 - rep3*)

```
+--------+--------+--------+
|  4     |    5   |        |
|        |    3   |        |
|        |  5     |        |
+--------+--------+--------+
|     7  |     1  | 6      |
|     7  |    5 1 |        |
|     5  | 7   2  |     8  |
+--------+--------+--------+
| 2    2 | 4 5 5  |     4  |
|        | 6      |        |
|      6 | 2    5 |     7  |
+--------+--------+--------+
```

Hands-on! Infeasible Sudoku (*su1 -> su5*)

- What should we do with an infeasible Sudoku?
  - Not enough to just report the infeasibility
  - Here, repair the data to make the model feasible
- Edits for going from *su1 -> su5*
  - Add binary variable undo (relaxes fixed cells)
  - Remove x.fx for fixed cells
  - Use random generation to get bogus data

Samurai Sudoku

Hands-on! Mapping data (map1)

- We solve the Samurai as 5 basic puzzles, with linking constraints for the overlapping cells
- Requires mapping 21x21 Samurai puzzle into separate 9x9 puzzles

Hands-on! Samurai model (su5 -> su6)

- Add puzzle index p to all variables/equations
- Add linking constraints
- Use random data to test
- Fix undo variables initially to 0
  - If the model is feasible, it will solve quickly
  - If infeasible, we unfix undo and resolve

Agenda

GAMS Development / GAMS Software

Working with GAMS – A Guided Tour

Model Development

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
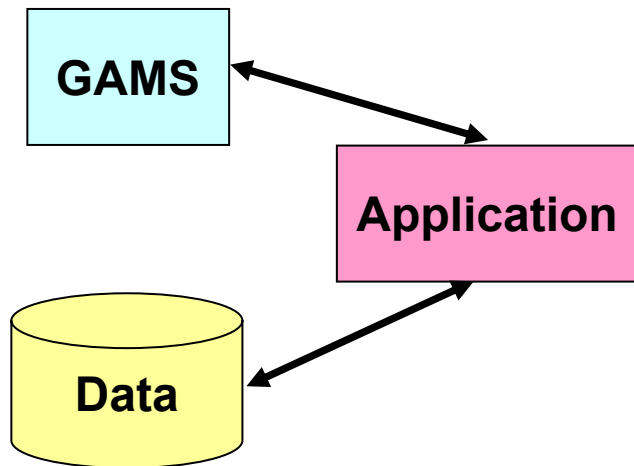
Data Model I

- **Application in control of data processing**

- **No direct data access**
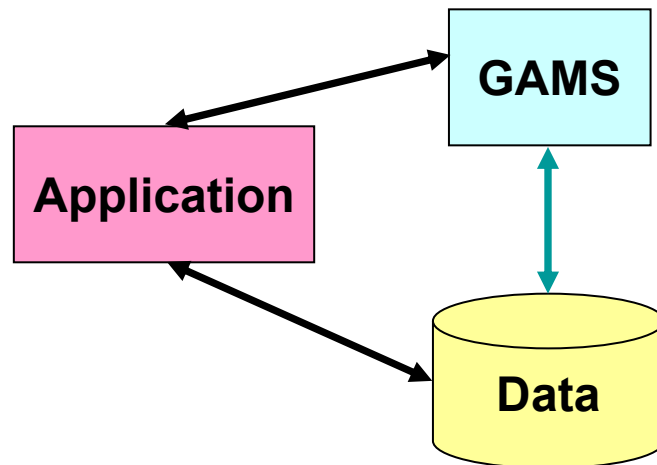
Data Model II

- **Large Scale/Raw data exchange GAMS↔DB**

- **Control Data GAMS↔Application**

Hands-on! Excel in charge (samurai_vb)

- Existing Samurai model with Excel GUI
- Look at data communication between model and GUI

Hands-on! Samurai data input (su6 -> su7)

- Prepare our Samurai model su6 to plug in to spreadsheet
- Import/export 21x21 data from GUI (via GDX)
- Use mappings from map1 to map 21x21 -> 5x9x9
- Validate solution produced via GDXDIFF
  – Compare to solution from old application

Hands-on! Clean up (su7 -> su8)

- Create text file for display in GUI

A few Words about Maintenance

<table>
<tr><td>

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

</td><td>

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

</td></tr>
</table>

- 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

Europe:

GAMS Software GmbH
Eupener Str. 135-137
50933 Cologne
Germany
Phone: +49 221 949 9170
Fax: +49 221 949 9171
http://www.gams.de

USA:

GAMS Development Corp.
1217 Potomac Street, NW
Washington, DC 20007
USA
Phone: +1 202 342 0180
Fax: +1 202 342 0181
http://www.gams.com