GAMS –
Striving for Innovation
and Compatibility

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Then ...

In Table 17.1 we list sizes and attributes of representative models that are “large” in the sense that they are near the limit of what is practical on a personal computer, along with the model generation time (GAMS) and solution time (solver), both in minutes. These examples were run on an 8 MHz AT with an 80287 coprocessor and 640K of RAM. The times shown are to give you a rough idea of what is possible: these are not precisely controlled benchmarks, and we have a host of performance improvements in mind for the near future.

Table 17.1: Problem Characteristics

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<thead>
<tr>
<th>Name</th>
<th>Number of Rows</th>
<th>Number of Columns</th>
<th>Number of Nonzeros</th>
<th>Generation Time*</th>
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*Measured in minutes.

The problem is too big for MINOS. ZOOM was used instead.

A nonlinear problem. 63% of the non-zeroes are nonlinear.

A nonlinear problem. 58% of the non-zeroes are nonlinear.

A mixed binary problem, with 55 binary variables (solved with a relative termination criterion of 10%).

A linear problem, solved using XMP which is contained within ZOOM.
... and now

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<tr>
<th>Type</th>
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* MIP 1988 solver ZOOM, 2008 solver CPLEX
Agenda

- General Algebraic Modeling System
- Impact, Compatibility, and Innovation
- Example
Agenda

General Algebraic Modeling System

Impact, Compatibility, and Innovation

Example
GAMS at a Glance

General Algebraic Modeling System

- Roots: World Bank, 1976
- Went commercial in 1987
- GAMS Development Corp.
- GAMS Software GmbH
- GOR Company Award 2010
- Broad academic & commercial user community and network
GAMS at a Glance

General Algebraic Modeling System

- Algebraic Modeling Language
- 25+ Integrated Solvers
- 10+ Supported MP classes
- 10+ Supported Platforms
- Connectivity- & Productivity Tools
  - IDE
  - Model Libraries
  - GDX, Interfaces & Tools
  - Grid Computing
  - Benchmarking
  - Compression & Encryption
  - Deployment System
  - …
System Overview

Connectivity Tools
- Uniform Data Exchange:
  - ASCII
  - GDX (ODBC, SQL, XLS, XML)
- GDX Tools
- Component Library with Interfaces to C++, Java, .NET, ...
- Ext. programs
  - EXCEL
  - MATLAB
  - GNUPLTO, ...
- 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, …
## Supported Model Types

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<th>Solver/Model type availability - 22.7 May 1, 2008</th>
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**Contributed Plug&Play solvers**

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1 GAMS distribution for HP 9000/HP-UX is 22.1
2 GAMS distribution for SGI IRIS is 22.3

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10
Downloads by Platform

GAMS 22.5
~525 downloads/week

GAMS 22.6
~590 downloads/week

GAMS 22.7
~670 downloads a week
Agenda

**General Algebraic Modeling System**

Impact, Compatibility, and Innovation

Example
Impact of AML (like GAMS) to Optimization

Optimization -> OR -> Society

Algebraic modeling systems
- Improve productivity of OR/Optimization specialists
- Opens world of optimization to domain experts
- Adds quickly value
- Extends the reach of OR (methods like optimization) to communities outside classical OR
GAMS Design

• Universal language: Algebra
  – Algebra (Expressions): model equations
  – Relational Algebra (SQL): data manipulation
  – Scalability/Sparsey
  – Necessary procedural elements

• Avoid pitfalls of traditional/imperative languages:
  – Addressing
  – Memory management

• Independence of data, model, and solution technology (platform, data/user interface)
  – Development/debug versus production/stress test
  – Solvers become a commodity
  – No porting work
Backward Compatibility

- Life time of a model: 15+ years:
  - New maintainer, platform, solver, user interface
  - Protection of investment in a model

- Blessing for the user (mostly) – Curse for developers
  - Old concepts in new situations
    - Example GAMS Listing file, OptCR
  - Language additions have to be supported in the future
  - GAMS is extremely conservative when it comes to syntax additions

- Danger of becoming a barrier for innovation
Platform for Innovation

• Reliable, high performance system for developing and deploying optimization applications

• Research tool:
  – new modeling paradigms (e.g. SDP, bilevel, GDP, …)
  – emerging solution technology (e.g. MPEC)
  – new computing environments (e.g. Grid)

• GAMS tries to serve both worlds (synergy)
  – Large user base in industry and academia
  – Dissemination of research ideas
  – Challenging/relevant problems from industry
General Algebraic Modeling System

Impact, Compatibility, and Innovation

Example
User Extensions of GAMS

- GAMS open architecture

- User developed tools complement GAMS system
  - Main contributors: Michael Ferris, Erwin Kalvelagen, Bruce McCarl, Tom Rutherford, …

- Often interaction with GAMS syntax required
  - difficult, GAMS is not context free language
  - MPSGE (Rutherford, early integration into GAMS)
  - NLP2MCP (Ferris), GAMS-F (Ferris, Rutherford, Starkweather), LogMIP (Grossmann, Vecchietti)

- “Solvers” for special models: DEA (Ferris, Voelker)
Generalized Disjunctive Programming

• Generalized Disjunctive Program

• Ignacio Grossmann, CMU Pittsburgh
• Aldo Vecchietti, U. Tecnológica Nacional, Argentinia

• Interest in
  – Applications of GDP
  – Formulations/Reformulations
  – Algorithms (e.g. Logic Based Outer Approximation)

• LogMiP
  – GAMS parser
  – Various solvers (reformulation, algorithms)
Non-linear Discrete/Continuous Optimization: GDP Model


Min \( Z = \sum_{k \in K} c_k + f(x) \)

s.t. \( r(x) \leq 0 \)

\[ \forall j \in J_k \quad g_{jk}(x) \leq 0 \]

\( c_k = y_{jk} \)

\( \forall j \in J_k \quad Y_{jk} \)

\( k \in K \)

\( \Omega(Y) = True \)

\( x^L \leq x \leq x^U \)

\( Y_{jk} \in \{True, False\} \quad j \in J_k, k \in K \)

\( c_k \in \mathbb{R}^1 \quad k \in K \)

Objective function

Common constraints

Disjunctive constraints

Logic constraints

Logical OR operator

Boolean variables

convex functions
Generalized Disjunctive Prog. Example


- Three jobs (A,B,C) must be executed sequentially in three steps, but not all jobs require all the stages. Once a job has started it cannot be interrupted.

- The objective is to obtain the sequence of task, which minimizes the completion time.

<table>
<thead>
<tr>
<th>Stage Job</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>4</td>
<td>-</td>
</tr>
</tbody>
</table>
Data Definition

\begin{verbatim}
table p(j,s) processing time

    1  2  3
  A  5  3
  B  3  2
  C  2  4

alias    (j,jj),(s,ss);

parameter c(j,s) stage completion time
    w(j,jj) maximum pair wise waiting time
    pt(j) total processing time;
set      less(j,jj) upper triangle;

  c(j,s)  = sum(ss$(ord(ss)<=ord(s)), p(j,ss));
  w(j,jj) = smax(s, c(j,s) - c(jj,s-1));
  pt(j)  = sum(s, p(j,s));
less(j,jj)= ord(j) < ord(jj);
\end{verbatim}
Basic Model Definition

variables t completion time
     x(j) job starting time

positive variable x;

equations comp(j) job completion time
     seq(j,jj) job sequencing j before jj;

comp(j).. t =g= x(j) + pt(j);

seq(j,jj)$ (not sameas(j,jj)).. x(j) + w(j,jj) =l= x(jj);

Above equation is incomplete!

If (j,jj) is active then (jj,j) should be relaxed
New Modeling and Solution Concepts

• Breakouts of traditional MP classes
  – Extended Nonlinear Programs
  – Chance Constraints
  – CVaR Constraints
  – Robust Programming
  – Bilevel Programs
  – Generalized Disjunctive Programs
  – …

• Limited support with common model representation
• No conventional syntax
• Incomplete/experimental solution approaches
• Lack of reliable/any software
What now?

Do not:
• overload existing GAMS notation right away!
• attempt to build new solvers right away!

But:
• Use existing language features to specify additional model features, structure, and semantics
• Express extended model in symbolic (source) form and apply existing modeling/solution technology
• Package new tools with the production system

→ Extended Mathematical Programming (EMP)
JAMS: a GAMS EMP Solver

Translation

Mapping Solution Into original space

Viewable

Solving using established Algorithms

Solution

Reformulated Model

Original Model

EMP Information

Mapping Solution Into original space

Viewable

Solving using established Algorithms

Solution

Reformulated Model

Original Model

EMP Information

Mapping Solution Into original space
EMP Library

- Distributed with GAMS
Conclusions

• Algebraic Model Languages/Systems
  – Support the dissemination of optimization into non-classical OR fields
  – Make a scarce resource (*good modelers*) more productive

• Balancing act between
  – backward compatible, reliable, high performance software
  – research tool with open architecture to foster innovative research on new model paradigms, formulations and algorithms
Thank you!

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