



GAMS

General Algebraic Modeling System

Michael Bussieck mbussieck@gams.com

Jan-Hendrik Jagla jhjagla@gams.com

GAMS Software GmbH

www.gams.de

GAMS Development Corporation

www.gams.com



EURO 2009 Bonn



GAMS at a Glance

The screenshot displays the GAMS software interface with several components:

- Code Editor:** Contains GAMS code for creating an example GDY file for charting. The code includes comments and parameters for data sets.
- Data Table:** A table listing model elements with columns for Entry, Symbol, Type, Dim, and Nr Elem. The selected entry is 12 StockData.
- StockData Plot:** A line graph showing the values of four stocks (IBM, DELL, HP, SUN) over time. The y-axis ranges from 102 to 104, and the x-axis ranges from 38,780 to 38,840.
- Surface Plot:** A 3D surface plot showing a sharp peak. The y-axis ranges from -0.2 to 0.6, and the x-axis ranges from s2 to s49.
- Log Window:** Shows the execution status of the job, including start and stop times and elapsed time.

Algebraic Modeling System

- Facilitates to formulate mathematical optimization problems similar to algebraic notation
 - ➔ Simplified model building
- Provides links to appropriate state-of-the-art external algorithms
 - ➔ Efficient solution process



GAMS at a Glance

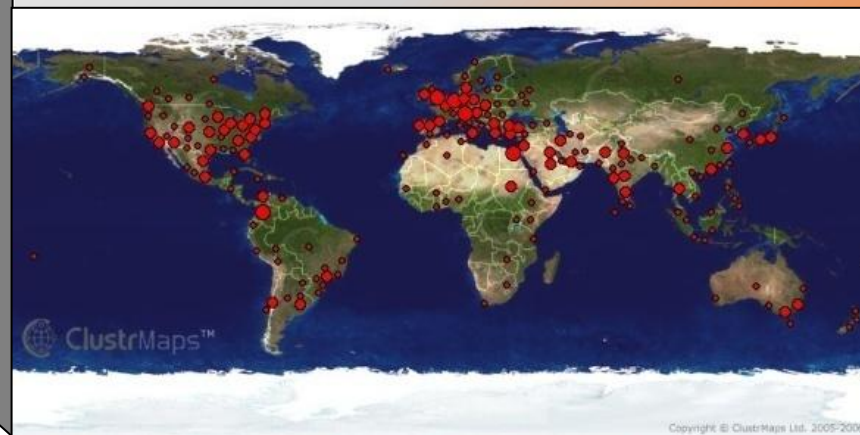
General Algebraic Modeling System

- Roots: World Bank, 1976
- Went commercial in 1987
- GAMS Development Corp.
- GAMS Software GmbH
- Broad academic & commercial user community and network

The screenshot displays the GAMS software interface with the following components:

- Code Editor:** Contains GAMS code for creating an example GDY file for charting, including parameters for years and data sets.
- Data Table:** A table listing various data sets and their properties. The 'StockData' entry is highlighted.
- StockData Chart:** A line chart showing the stock prices of IBM, DELL, HP, and SUN over time.
- Surface Chart:** A 3D surface plot showing a sharp peak.
- Log Window:** Shows the execution status of the job, including start and stop times and file paths.

| Entry | Symbol | Type | Dim | Nr Elem |
|-------|--------------|------|-----|---------|
| 10 | GanttData | Par | 3 | 14 |
| 4 | Points | Par | 2 | 200 |
| 8 | Scatter2D | Par | 2 | 40 |
| 9 | Scatter3D | Par | 2 | 60 |
| 13 | ScenarioData | Par | 2 | 136,000 |
| 12 | StockData | Par | 3 | 800 |
| 11 | Surface | Par | 2 | 2,500 |
| 5 | Vector2D | Par | 2 | 80 |
| 6 | Vector2Db | Par | 2 | 80 |
| 7 | Vector3D | Par | 2 | 120 |
| 1 | YearDataA | Par | 1 | 8 |
| 2 | YearDataB | Par | 1 | 8 |
| 3 | YearDataC | Par | 1 | 8 |





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
 - ...

The screenshot displays the GAMS IDE interface. On the left, a code editor shows the following code:

```

* Create an example GDX file for the
* Create gdx file for charting demo
* The generated gdx file can be used to fo
*
* GAMS Development Corporation, Formulation
$settitle data for single lines: bars, pie
set years /y1998:y2005 /
parameter YearDataA(years), YearDataB(years);
YearDataA(y1998)=100;
YearDataA(y1999)=105;
YearDataA(y2000)=110;
YearDataA(y2001)=115;
YearDataA(y2002)=120;
YearDataA(y2003)=125;
YearDataA(y2004)=130;
YearDataA(y2005)=135;
YearDataB(y1998)=100;
YearDataB(y1999)=105;
YearDataB(y2000)=110;
YearDataB(y2001)=115;
YearDataB(y2002)=120;
YearDataB(y2003)=125;
YearDataB(y2004)=130;
YearDataB(y2005)=135;
YearDataC(y1998)=100;
YearDataC(y1999)=105;
YearDataC(y2000)=110;
YearDataC(y2001)=115;
YearDataC(y2002)=120;
YearDataC(y2003)=125;
YearDataC(y2004)=130;
YearDataC(y2005)=135;

```

In the center, a table lists model elements:

| Entry | Symbol | Type | Dim | Nr Elem |
|-------|--------------|------|-----|---------|
| 10 | GanttData | Par | 3 | 14 |
| 4 | Points | Par | 2 | 200 |
| 8 | Scatter2D | Par | 2 | 40 |
| 9 | Scatter3D | Par | 2 | 60 |
| 13 | ScenarioData | Par | 2 | 136,000 |
| 12 | StockData | Par | 3 | 800 |
| 11 | Surface | Par | 2 | 2,500 |
| 5 | Vector2D | Par | 2 | 80 |
| 6 | Vector2Db | Par | 2 | 80 |
| 7 | Vector3D | Par | 2 | 120 |
| 1 | YearDataA | Par | 1 | 8 |
| 2 | YearDataB | Par | 1 | 8 |
| 3 | YearDataC | Par | 1 | 8 |

On the right, two plots are shown. The top plot, titled 'StockData', is a line graph with four series: IBM (red), DELL (green), HP (yellow), and SUN (blue). The x-axis ranges from 38,780 to 38,840, and the y-axis ranges from 102 to 104. The bottom plot, titled 'Surface', is a 3D surface plot showing a sharp peak. The x-axis is labeled with 's2 s5 s8 s12 s16 s20 s24 s28 s32 s36 s40 s45 s49' and the y-axis ranges from -0.2 to 0.6.

At the bottom, a log window shows the following output:

```

--- Job chartdat.gms Start 05/05/06 13:08:00
GAMS Rev 145 Copyright (C) 1987-2006 GAMS Development. All rights
License: Franz Weltschen 5051012/
--- Starting compilation
--- chartdat.gms(133) 3 Mb
--- Starting execution
--- chartdat.gms(126) 7 Mb
--- Putfile F:\D:\support\testchart.gch
*** Status: Normal completion
--- Job chartdat.gms Stop 05/05/06 13:08:01 elapsed 0:00:01.422

```

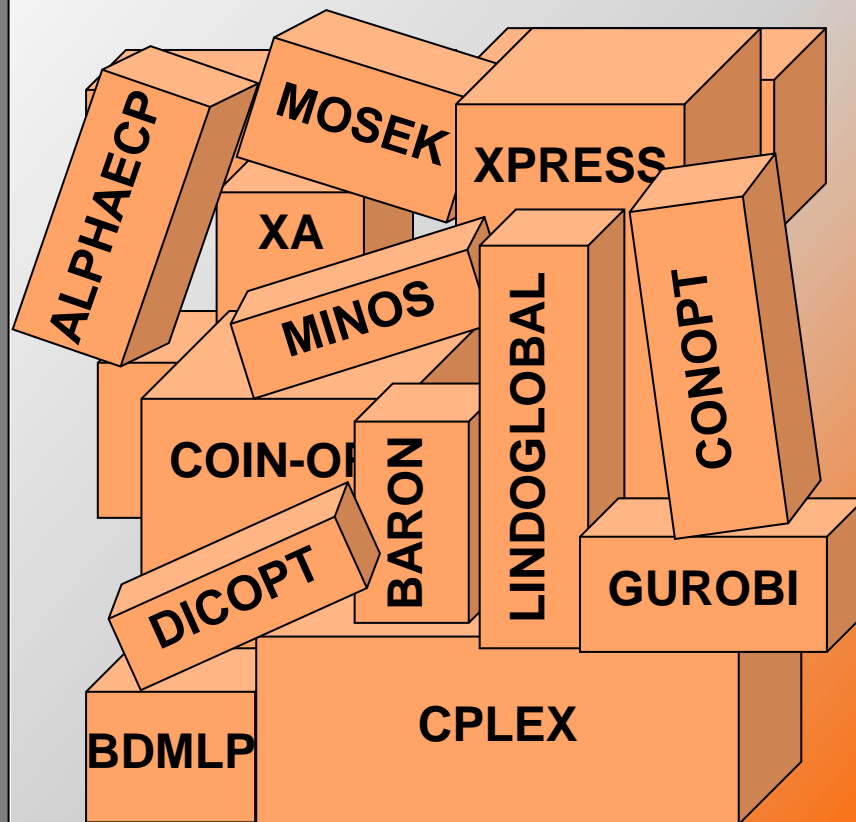


GAMS at a Glance

The screenshot displays the GAMS software environment with several windows open:

- Code Editor:** Shows GAMS code for creating an example GDx file for charting. The code includes comments and commands like `set years = y1998:y2005 /;` and `parameter YearDataA(years), YearDataB(years);`.
- StockData Chart:** A line chart showing stock prices for IBM, DELL, HP, and SUN from 1998 to 2005. The y-axis ranges from 102 to 104, and the x-axis shows years.
- Table:** A table listing model elements with columns for Entry, Symbol, Type, Dim, and Nr Elem. The selected entry is 12 StockData, Par, 3, 800.
- Surface Plot:** A 3D surface plot showing a sharp peak. The z-axis ranges from -0.2 to 0.6, and the x and y axes are labeled with indices.
- Log Window:** Shows the execution log for job chartdat.gms, including start and stop times and status messages.

25+ Integrated Solvers





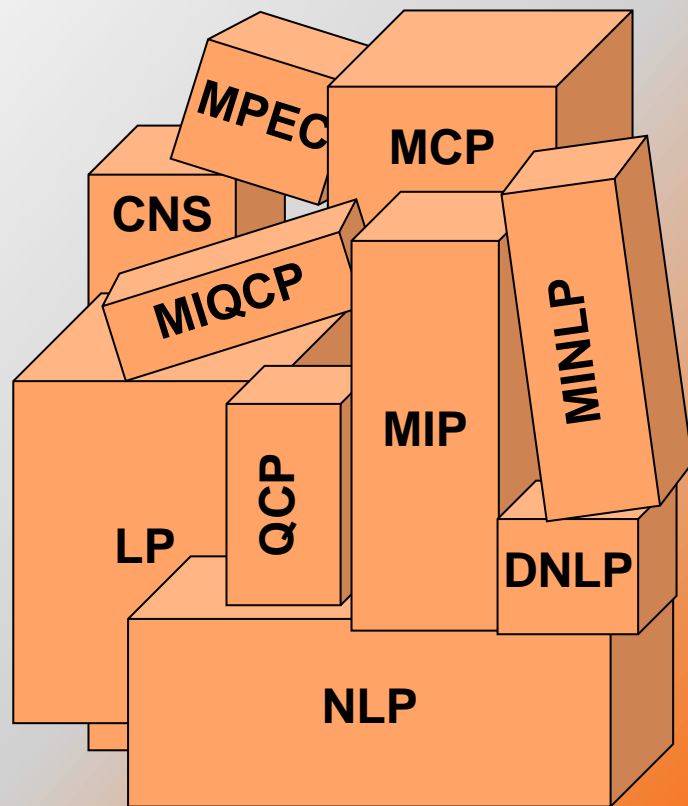
GAMS at a Glance

The screenshot shows the GAMS software interface with the following components:

- Code Editor:** Contains GAMS code for creating an example GDY file and defining data for single lines, bars, and pie charts. It includes parameters for years and data sets.
- Data Table:** A table listing model elements:

| Entry | Symbol | Type | Dim | Nr Elem |
|-------|--------------|------|-----|---------|
| 10 | GanttData | Par | 3 | 14 |
| 4 | Points | Par | 2 | 200 |
| 8 | Scatter2D | Par | 2 | 40 |
| 9 | Scatter3D | Par | 2 | 60 |
| 13 | ScenarioData | Par | 2 | 136,000 |
| 12 | StockData | Par | 3 | 800 |
| 11 | Surface | Par | 2 | 2,500 |
| 5 | Vector2D | Par | 2 | 80 |
| 6 | Vector2Db | Par | 2 | 80 |
| 7 | Vector3D | Par | 2 | 120 |
| 1 | YearDataA | Par | 1 | 8 |
| 2 | YearDataB | Par | 1 | 8 |
| 3 | YearDataC | Par | 1 | 8 |
- StockData Plot:** A line graph showing stock prices for IBM, DELL, HP, and SUN over time. The y-axis ranges from 102 to 104, and the x-axis ranges from 38,780 to 38,840.
- Surface Plot:** A 3D surface plot showing a sharp peak. The y-axis ranges from -0.2 to 0.6, and the x-axis ranges from s2 to s49.
- Log Window:** Shows the execution status of the job, including start and stop times and elapsed time.

10+ Supported MP classes





GAMS at a Glance

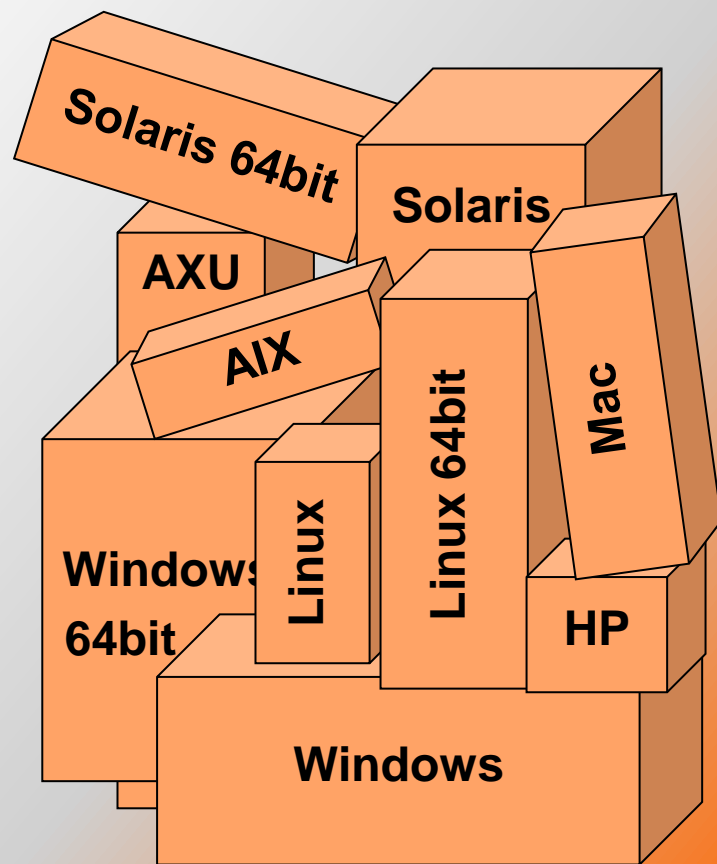
The screenshot displays the GAMS software interface with the following components:

- Code Editor:** Contains GAMS code for creating an example GDX file for charting. The code includes comments and commands like `set years = y1998:y2005 /;` and `parameter YearDataA(years), YearDataB(years);`.
- Parameter Table:** A table listing model parameters. The selected entry is 'StockData'.

| Entry | Symbol | Type | Dim | Nr Elem |
|-------|--------------|------|-----|---------|
| 10 | GanttData | Par | 3 | 14 |
| 4 | Points | Par | 2 | 200 |
| 8 | Scatter2D | Par | 2 | 40 |
| 9 | Scatter3D | Par | 2 | 60 |
| 13 | ScenarioData | Par | 2 | 136,000 |
| 12 | StockData | Par | 3 | 800 |
| 11 | Surface | Par | 2 | 2,500 |
| 5 | Vector2D | Par | 2 | 80 |
| 6 | Vector2Db | Par | 2 | 80 |
| 7 | Vector3D | Par | 2 | 120 |
| 1 | YearDataA | Par | 1 | 8 |
| 2 | YearDataB | Par | 1 | 8 |
| 3 | YearDataC | Par | 1 | 8 |

- StockData Chart:** A line chart showing the values of four parameters (IBM, DELL, HP, SUN) over time. The x-axis represents years from 1998 to 2005, and the y-axis represents values from 102 to 104.
- Surface Chart:** A 3D surface plot showing a sharp peak. The x-axis is labeled with 's2' through 's49', and the y-axis ranges from -0.2 to 0.6.
- Log Window:** Shows the execution log for 'chartdat.gms', including start and stop times, memory usage, and status messages.

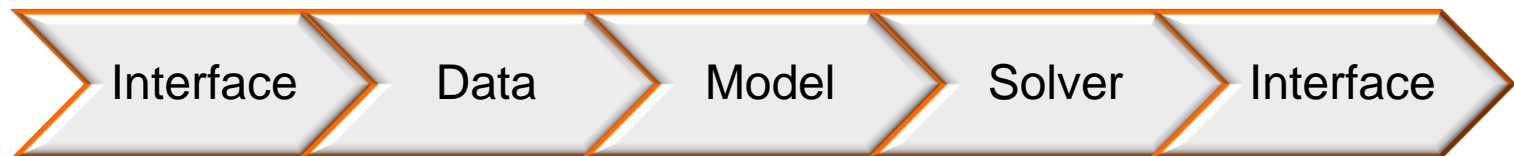
10+ Supported Platforms





GAMS' Fundamental concepts

- **Platform independence**
- **Open architecture and interfaces to other systems**
- **Balanced mix of declarative and procedural elements**
 - Declaration of Sets, Parameters, Variables, Equations, Models,
 - Procedural Elements like loops, if-then-else, ...
- **Layers of separation**





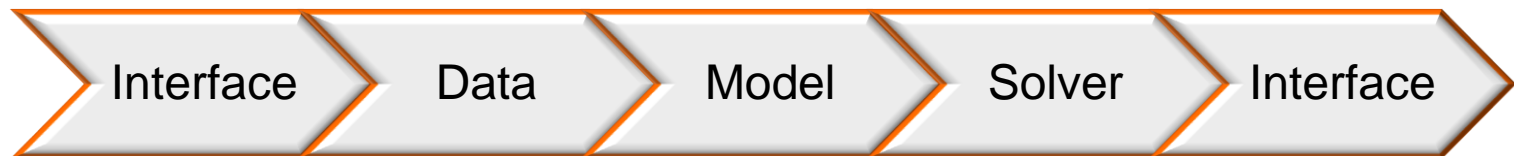
GAMS' Fundamental concepts

- **Different layers with separation of**

- model and data
- model and solution methods
- model and operating system
- model and interface

→ **Models benefit from**

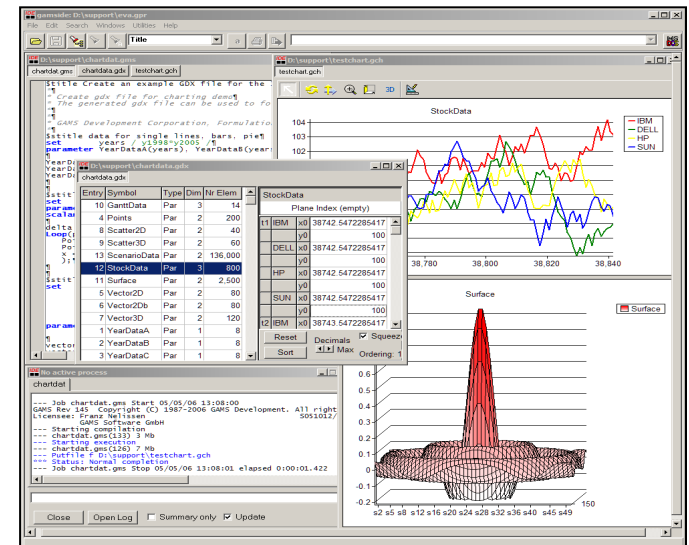
- advancing hardware
- enhanced / new solver technology
- improved / upcoming interfaces to other systems





Integrated Development Environment

- Project management
- Editor / Syntax coloring / Spell checking
- Launching and monitoring of (multiple) GAMS processes
- Listing file / Tree view / Syntax-error navigation
- Solver selection / Option selection
- GDX viewer
 - Data cube
 - Data export (e.g. to MS Excel)
 - Charting facilities
- Model libraries
- Documentation





Documentation

- **Distributed Documentation**
 - GAMS Users Guide
 - Expanded GAMS Users Guide (McCarl)
 - Solver Manuals
 - GAMS Utility Manuals
- **Wikis**
 - Support Wiki <http://support.gams-software.com>
 - Interfaces Wiki <http://interfaces.gams-software.com>



Documentation

- **Groups**
 - User Group http://www.gams.com/maillist/gams_l.htm
 - Google Group <http://groups.google.de/group/gamsworld>
- **Newsletter**
 - McCarl's News
<http://www.gams.com/maillist/newsletter.htm>
 - Release List
- **Search all GAMS Websites**
<http://www.gams.com/search.htm>



Distributed Model Libraries

- **GAMS Model Library**

- Example and user-contributed models
- Very often used as templates
- Tests for
 - Solver robustness and correctness
 - Backward compatibility

| Model Libraries | Help |
|---|------|
| GAMS Model Library | |
| GAMS Test Library | |
| GAMS Data Utilities Models | |
| Practical Financial Optimization Models | |

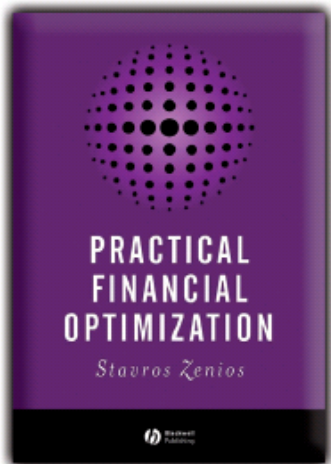
- **GAMS Test Library**

- Transparent and reproducible Quality Assurance Tests
- Tests for
 - Solver correctness
 - Special functions
 - GAMS utilities



Distributed Model Libraries

- **GAMS Data Utilities Library**
 - Demonstration of the various utilities interfacing GAMS with other applications
 - E.g. gdxxrw, mdb2gms, sql2gms
- **GAMS EMP Library**
 - Examples for the use of Extended Mathematical Programming



- **Practical Financial Optimization Models**
Models of the book

*“PRACTICAL FINANCIAL OPTIMIZATION –
A Library of GAMS Models”*

by Consiglio, Nielsen and Zenios



GAMSworld Model Libraries



GAMS World

Maintained libraries of established and varied set of both theoretical and practical test models:

The Worlds

CONE

GLOBAL

MINLP

MPEC

MPSGE

Performance

Translation

Search

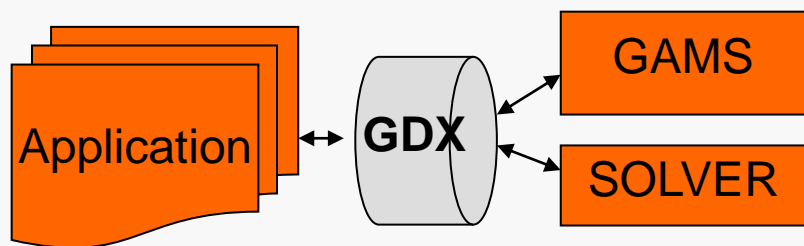
Contact

- CONELib
- GLOBALLib
- LinLib
- MINLPLib
- MPECLib
- MPSGELib
- PrincetonLib
- XPRESSLib
- ...



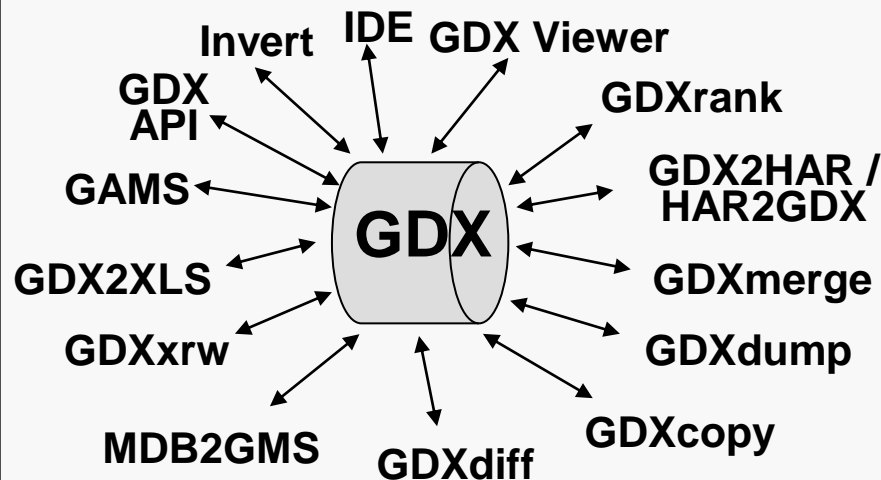
Gams Data eXchange

Binary Data Exchange



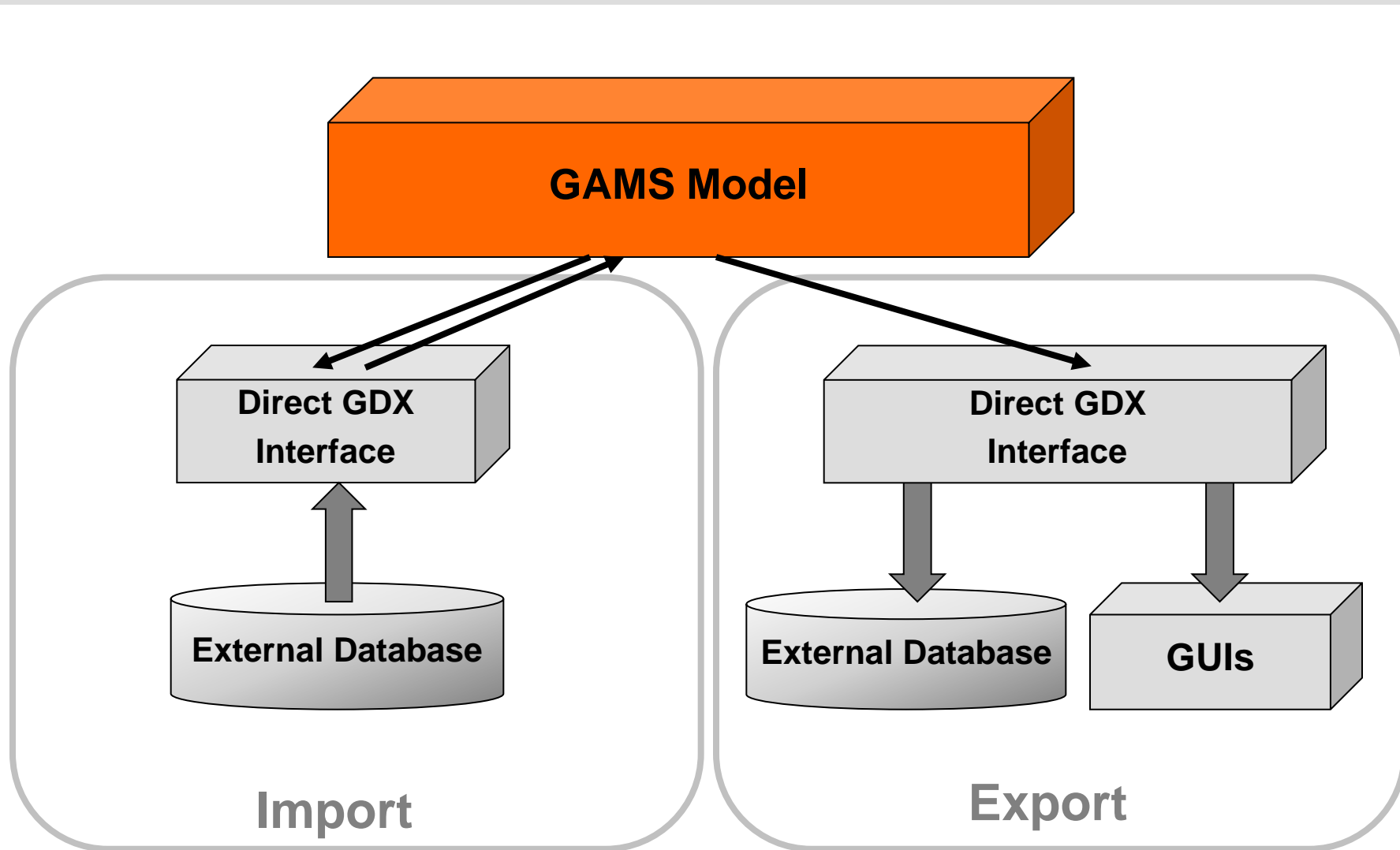
- Fast exchange of data
- Syntactical check on data before model starts
- Data Exchange at any stage (Compile and Run-time)
- Platform Independent
- Direct GDX interfaces and general API
- Scenario Management Support
- Full Support of Batch Runs

GDX Tools



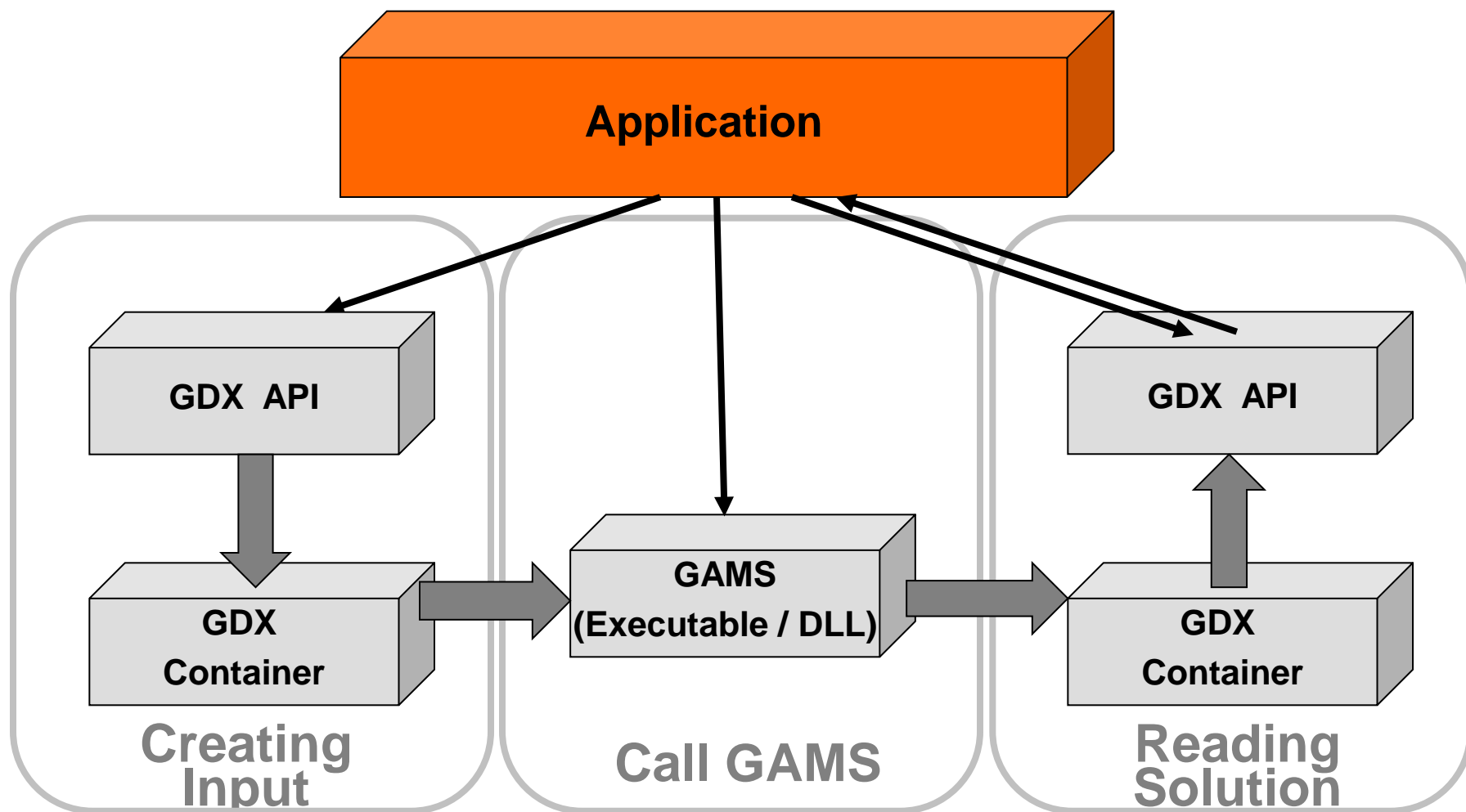


GAMS in Control



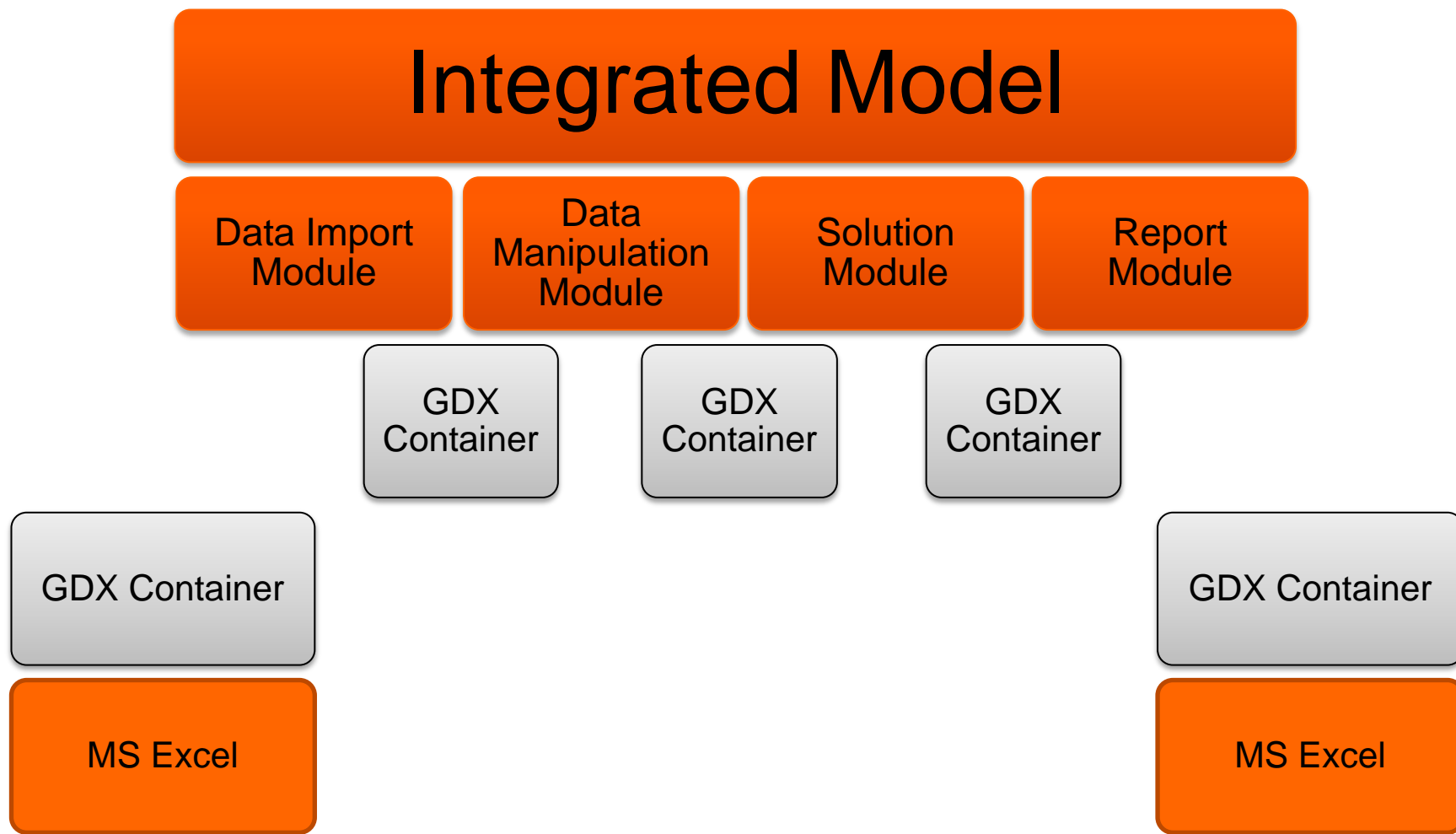


Application in Control





Layout of an Integrated Model





GAMS at a Glance

The screenshot displays the GAMS software interface. The main window shows a code editor with the following code:

```

* Create an example GDX file for the
* Create gdx file for charting demo
* The generated gdx file can be used to fo
*
* GAMS Development Corporation, Formulation
$stitle data for single lines: bars, pie
set years / y1998:y2005 /
parameter YearDataA(years), YearDataB(years);
YearDataA = 1;
YearDataB = 2;
YearDataC = 3;
$gdxin chardata.gdx
$load chardata.gdx
$gdxout testchart.gch
$load testchart.gch
$gdxout testchart.gch

```

Below the code editor is a table of parameters:

| Entry | Symbol | Type | Dim | Nr Elem |
|-------|--------------|------|-----|---------|
| 10 | GanttData | Par | 3 | 14 |
| 4 | Points | Par | 2 | 200 |
| 8 | Scatter2D | Par | 2 | 40 |
| 9 | Scatter3D | Par | 2 | 60 |
| 13 | ScenarioData | Par | 2 | 136,000 |
| 12 | StockData | Par | 3 | 800 |
| 11 | Surface | Par | 2 | 2,500 |
| 5 | Vector2D | Par | 2 | 80 |
| 6 | Vector2Db | Par | 2 | 80 |
| 7 | Vector3D | Par | 2 | 120 |
| 1 | YearDataA | Par | 1 | 8 |
| 2 | YearDataB | Par | 1 | 8 |
| 3 | YearDataC | Par | 1 | 8 |

Two plots are visible: a line graph titled 'StockData' showing the performance of IBM, DELL, HP, and SUN from 1998 to 2005, and a 3D surface plot titled 'Surface' showing a complex surface structure.

At the bottom, a log window shows the execution status:

```

--- Job chardat.gms Start 05/05/06 13:08:00
GAMS Rev 145 Copyright (C) 1987-2006 GAMS Development. All right
License: Franz Weltsch 505102/
GAMS Software GmbH
--- Starting compilation
--- chardat.gms(133) 3 Mb
--- Starting execution
--- chardat.gms(126) 7 Mb
--- Putfile F:\D:\support\testchart.gch
*** Status: Normal completion
--- Job chardat.gms Stop 05/05/06 13:08:01 elapsed 0:00:01.422

```

The GAMS/BASE Module

Free Solvers

- Convert (convert model to different formats)
- EMP, LOGMIP, NLPEC
- BENCH, EXAMINER, GAMSCHK
- BDMLP, LS, and MILES
- COIN-OR
Cbc, IpOpt, BonMin, Couenne
- Glpk, Scip (academic only)



GAMS/Convert

Model translation tool

- GAMS → other formats/languages
- Algebraic information still available

e.g.

- GAMS
- Jacobian / Hessian
- MPS / MPI
- NLP2MCP
- Chull
- C Evaluation routines

```
gamside: C:\Documents and Settings\Jan\My Documents\cmu\cmu.gpr
File Edit Search Windows Utilities Help
lp=convert optfile=1

c:\documents and settings\jan\my documents\cmu\transport.gms
transport

$title A Transportation Problem (TRANSPORT,SEQ=1)
$ontext

This problem finds a least cost shipping schedule that m
requirements at markets and supplies at factories.

Dantzig, G B, Chapter 3.3. In Linear Programming and Ext.
Princeton University Press, Princeton, New Jersey, 1963.

This formulation is described in detail in:
Rosenthal, R E, Chapter 2: A GAMS Tutorial. In GAMS: A U
The Scientific Press, Redwood City, California, 1988.

The line numbers will not match those in the book becau
comments.
$offtext

Sets
  1  canning plants / seattle, san-diego /
  J  markets / new-york, chicago, topeka /

Parameters
  a(i)  capacity of plant i in cases
        / seattle 350
          san-diego 600 /
  b(j)  demand at market j in cases
        / new-york 325

Reading parameter(s) from "C:\Documents and Settings\Jan\My
>> All
Finished reading from "C:\Documents and Settings\Jan\My Doc
--- Writing Ampl : ampl.mod
--- Writing AmplNLC : amplnlc.c
--- Writing Baron : gams.bar
--- Writing CplexLP : cplex.lp
--- Writing CplexMPS : cplex.mps
--- Writing FixedMPS : fixed.mps
--- Writing Gams : gams.gms
--- Writing Lgo : lgo.gms
--- Writing LindoMPI : lingo.mpi
--- Writing Lingo : lingo.lng
--- Writing AlphaECP : alpha.ecp
--- Writing Minopt : minopt.dat
--- Writing NLP2MCP : gamsnlp2mcp.gms
--- Writing ViennaDag : vienna.dag
--- Writing CoinFML : coinfml.xml
--- Writing Dict : dict.txt
--- Writing Jacobian : jacobian.gdx
--- Writing Lgo : lgo.main.for

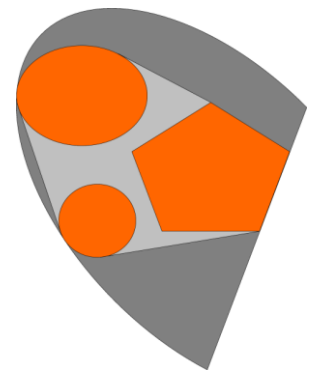
--- Restarting execution
--- transport.gms (66) 0 Mb
--- Resolving solution for model transport
--- Executing after solve
--- transport.gms (68) 3 Mb
*** Status: Normal completion
--- Job transport.gms Stop 03/10/07 22:38:05 elapsed 0:00:00

Close Open Log Summary only Update
```



EMP + LogMIP + NLPEC

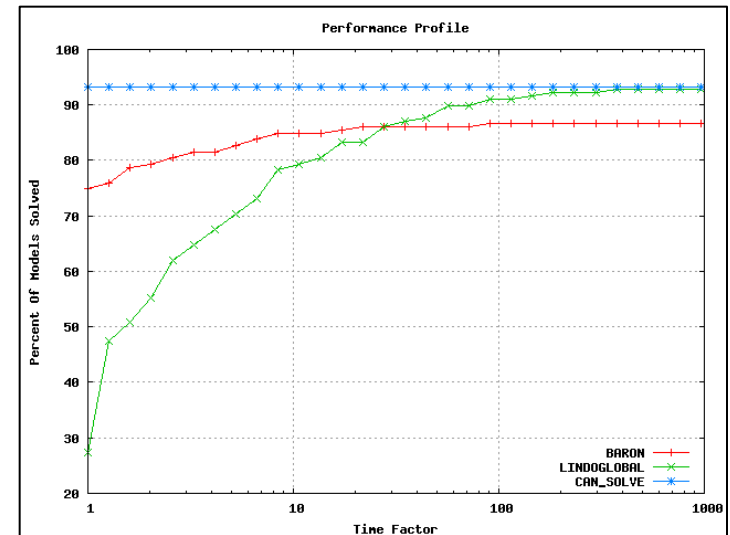
- Extended Mathematical Programming (EMP)
 - Framework for automated mathematical programming reformulations such as
 - Bilevel Programs
 - Disjunctive Programs
 - Extended Nonlinear Programs
 - Embedded Complementarity Systems
 - Variational Inequalities
- Logical Mixed Integer Programming (LogMIP)
 - Reformulation and logic-based methods on Generalized Disjunctive Programs (GDP)
- GAMS/NLPEC
 - Solves MPECs as NLPs
 - 20+ different reformulation strategies





GAMS/Bench + Examiner

- Bench
 - Benchmarks GAMS solvers
 - Creates problem matrix once and gives it to all solvers
 - Creates trace files for visualization
 - Can call GAMS/Examiner to verify correctness of solutions
- Examiner
 - produces an unbiased, independent report on the merit of points
 - Points may come from GAMS or a solver
 - tolerances can be adjusted, default is tight





Coin-OR

An initiative to spur the development of open-source software for the OR community

<http://www.coin-or.org/>



- A repository of currently ~30 open-source projects
 - Solvers
 - Interfaces
 - Tools
- An active OR community
 - Mailing lists
 - Google group
 - Wikis



The Coin-OR / GAMSLinks Project

<https://projects.coin-or.org/GAMSlinks>

Stefan Vigerske (Humboldt-University Berlin)



Goals

- easy access to COIN-OR solvers via GAMS
- broadening the audience of COIN-OR
- broadening the audience of GAMS
- help developers to connect their solvers to GAMS
- provide access to GAMS benchmarking and quality assurance tools



The Coin-OR / GAMSLinks Project

GAMS interfaces to open-source Solvers

- COIN-OR Linear Programming (**CLP**) and Branch and Cut (**CBC**)
 - state of the art LP and MIP solver from J. Forrest
- Gnu Linear Programming Kit (**GLPK**)
 - LP and MIP solver from A. Makhorin
- Interior Point Optimizer (**IPOPT**)
 - large scale NLP solver from A. Wächter
- Solving Constraint Integer Programs (**SCIP**)
 - LP/MIP solver developed at Zuse Institute Berlin (ZIB)





The Coin-OR / GAMSLinks Project

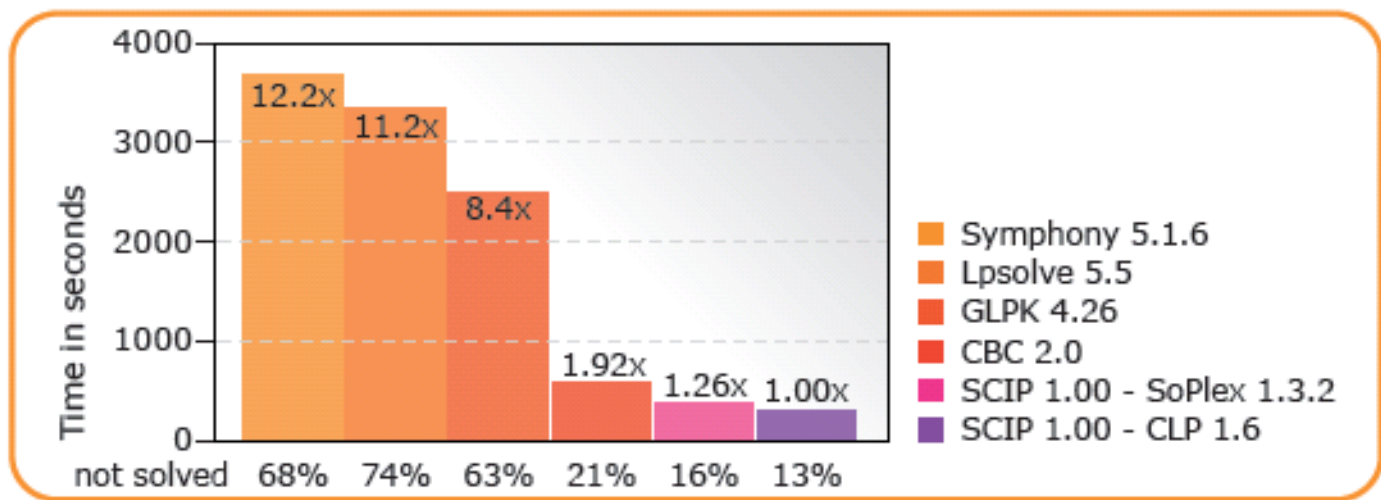
GAMS interfaces to open-source Solvers

- Basic Open-source Nonlinear Mixed Integer programming (**BONMIN**)
 - Branch and Cut based MINLP solver from P. Bonami et.al.
- Convex Over and Under Envelopes for Nonlinear Estimation (**COUENNE**)
 - Branch and Bound MINLP solver
- Lagrangian Global Optimizer (**LaGO**)
 - Convexification and Branch and Cut based MINLP solver from I. Nowak and S. Vigerske





The Coin-OR / GAMSLinks Project



Performance Benchmark of MIP codes free for academic use by H. Mittelmann. Solution times are geometric means where unsolved instances were assigned a 2 hours solution time (time limit). Details at scip.zib.de



GAMS QA and testing supports maturing of COIN-OR solvers!

Coin-OR solvers enable GAMS to offer dependable free solvers!





GAMS

Download

www.gams.de www.gams.com

Free Euro 2009 Evaluation License

www.gams.com/evals/e09



GAMS Talks at EURO 2009 – Monday

Session: Optimization Modeling in Practice I (MA-22)

- **Using utility computing to provide mathematical programming resources**
Franz Nelissen
- **GAMS - features you might not know about**
Alex Meeraus (08:00-09:20)

Session: Stochastic programming II (MD-13)

- **Stochastic optimization: recent enhancements in algebraic modeling systems**
Michael Bussieck (13:35-14:55)



GAMS Talks at EURO 2009 - Tuesday

Session: Software for OR/MS II (TE-42)

- **Rapid application prototyping with GAMS**
Lutz Westermann

(14:30-15:50)

Session: Parallel Nonlinear Programming Algorithms

- **Formulating and solving non-standard model types using gams/emp**
Jan-Hendrik Jagla

(16:05-17:25)