Challenges in Bringing Global Optimization to the Marketplace

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Outline

- Background: Global Optimization at GAMS
  - Solver intro, key features
  - Computational tests and comparison
- Creating new markets for GO
- Using GO in existing applications
- Requirements of GAMS made by GO
- Risk avoidance & quality control

GAMS Overview

- Started as a Research Project at the World Bank in 1976, commercial in 1987
- “Modeling for the masses”
  - User provides the model
  - GAMS does the dirty work
- 10,000s of users in over 100 countries
- Unique position between the academic and commercial world

Introducing GO in GAMS

- Availability of general purpose global optimization (GO) codes
- Customer demand: currently, about 3000 GAMS systems with NLP capability
- 2001: Start of collaboration GAMS Dev. Corp. and developers of BARON, LGO, and OQNLP
- Current CD (21.1): all 3, fully supported

GAMS/GLOBAL Solvers

The solvers differ in the methods they use, in whether they find globally optimal solution with proven optimality, in the size of models they can handle, and in the format of models they accept.

- **BARON** Branch-and-Reduce Optimization Navigator
  by The Optimization Firm, USA
- **LGO** Global/nonlinear optimization solver suite
  by Pintér Consulting Services, Canada
- **OQNLP** OptQuest/NLP Multi-start Solver
  by OptTek Systems and Optimal Methods, USA

BARON - Branch And Reduce Optimization Navigator

- BARON is a computational system for solving mixed-integer nonlinear non convex optimization problems to global optimality
- Works with relaxed problems by constructing (convex) under-estimators for objective and constraints
- Combining branch-and-bound with range reduction

LGO – Lipschitz Global Optimizer

- Global/nonlinear optimization solver suite
- Branch-and-bound based global search, enhanced with a stochastic sampling procedure
- Adaptive global random search, enhanced with a statistical bound estimation technique
- Various local search procedures

OQNLP
Multi-Start Search Method

- Intended for nonlinearly constrained, smooth, non-convex NLP's and MINLP's
- It starts any GAMS NLP solver from a set of starting points chosen by the widely used Scatter Search software, OptQuest (Glover, Laguna, Kelly).
- It can also be used to solve any NLP problem where solver failures are common, by automating the process of choosing multiple starting points

OQNLP Algorithm

- While point is evaluated for Scatter Search, NLP solver is called from that point if filter criteria (merit/distance) are satisfied
- User supplied starting point is part of initial reference set which guarantees that OQNLP is at least as good as just the NLP solver

GO Solver Differences

- The three solvers differ in the methods they use
- Results in different:
  - Model requirements
  - Problem size
  - Solution quality metrics/termination criteria
- Contrast with LP/MIP

Difference Matrix

	Model requirements	Problem size	Solution metrics
BARON	**-**	**o**	**+**
LGO	**+**	**o**	**o**
OQNLP	**o**	**+**	**-**

Model Requirements

-	o	+
+	o	o
o	+	-

- BARON
  - Constructs convex under-estimators
  - Knowledge about model algebra
  - No black box evaluators
- LGO
  - Lipschitz-continuity of objective function
  - Black box models
- OQNLP
  - Requirements of local solver used during search
  - Smooth problems (first [and second] order derivatives)

Problem Size

-	o	+
+	o	o
o	+	-

- BARON/LGO
  - Ratio of LP/MIP problem sizes = ratio of local NLP/global NLP sizes
- OQNLP
  - Size of model is limited by size limitation of the local solver

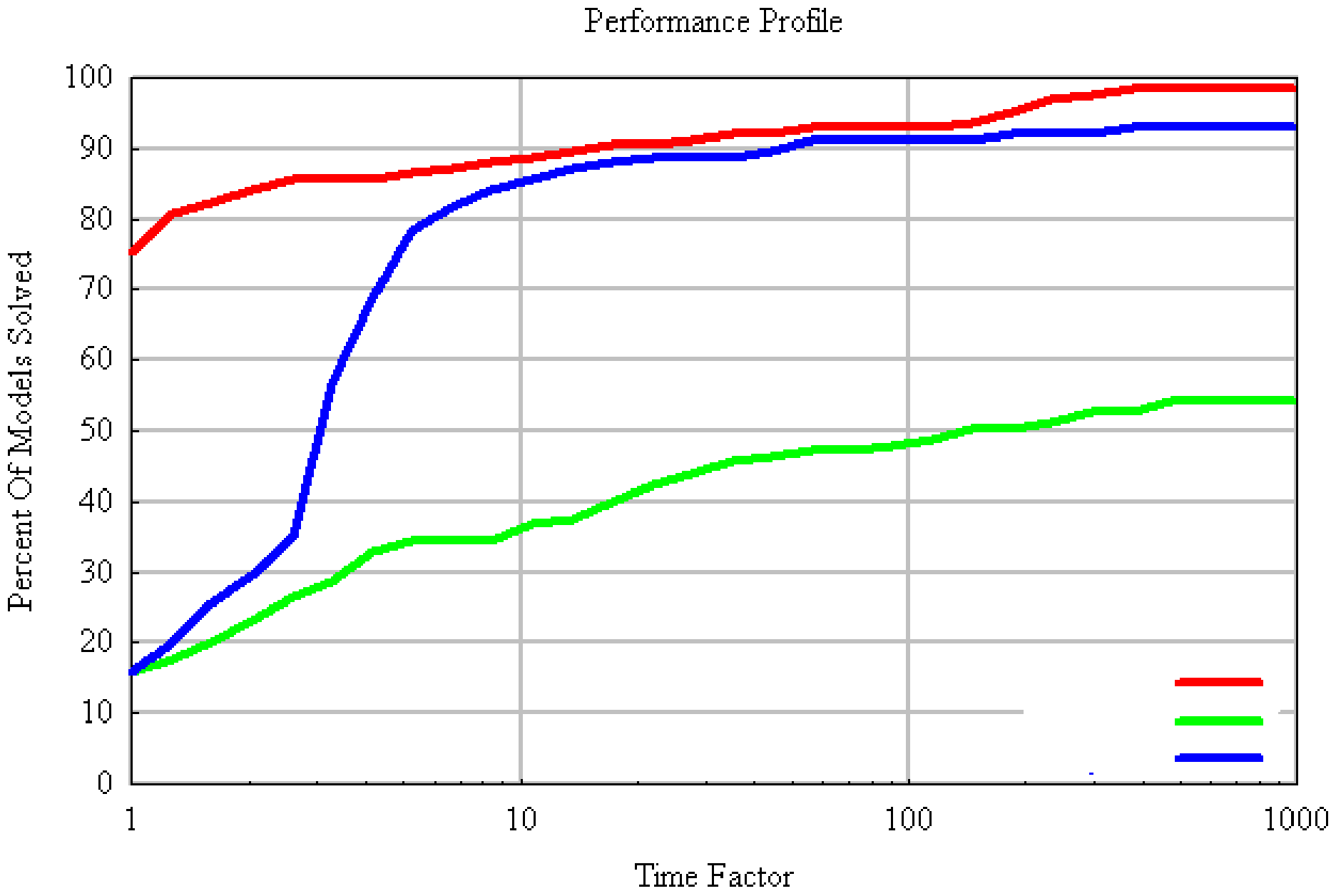
Solution Quality Metrics

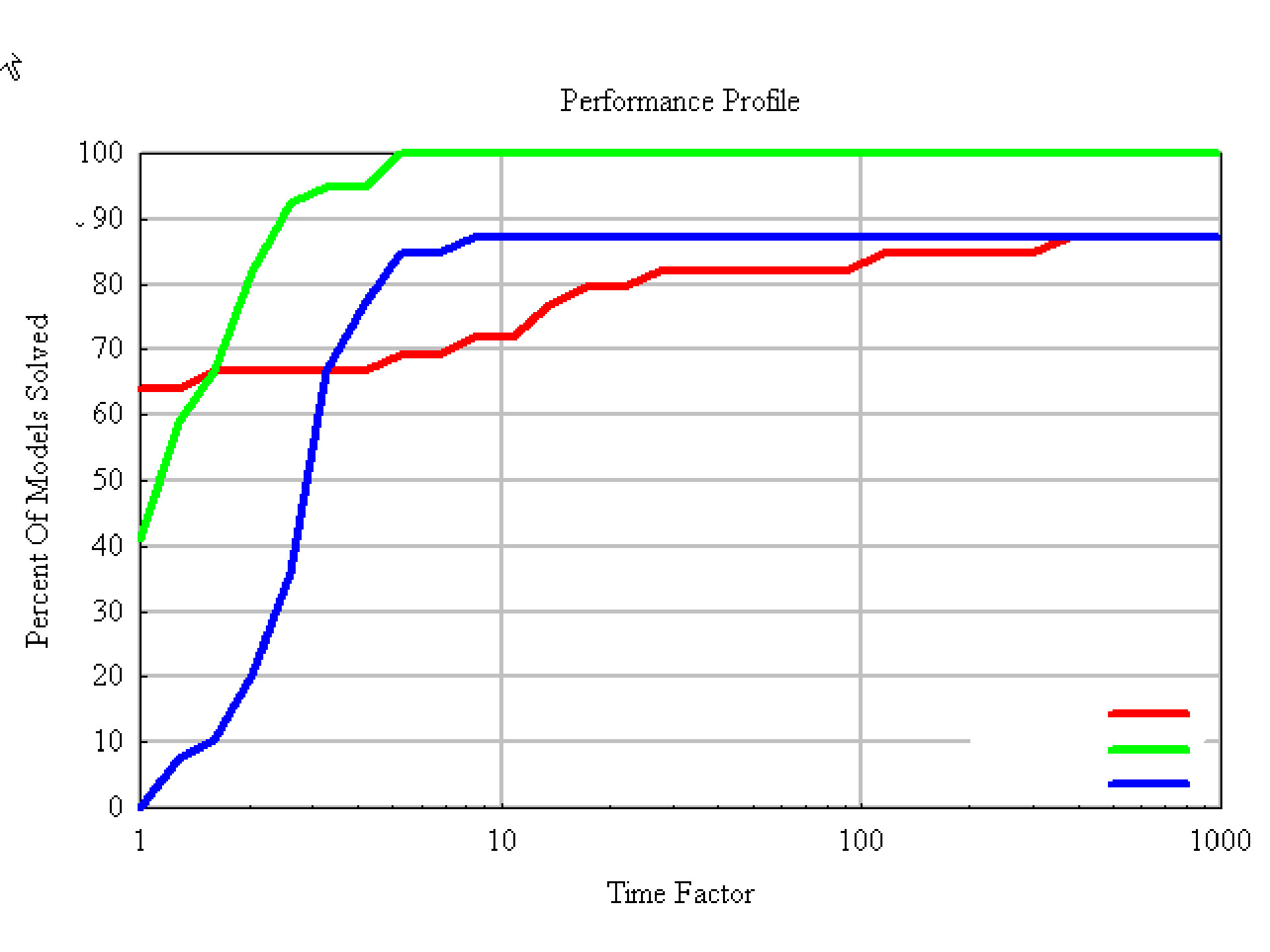
-	o	+
+	o	o
o	+	-

- BARON
  - Deterministic lower bound
  - relative/absolute gap similar to MIP
- LGO
  - Estimated statistical or Lipschitz lower bound
  - Stochastic convergence to global optimum
- OQNLP
  - Scatter Search ensures stochastic convergence towards the global optimum

Which one is the best?

- Models from GlobalLib ($n \leq 500$, $m \leq 500$) (http://www.gamsworld.org/global)
- Performance Profiles (Dolan and More, 2002):
  - Cumulative distribution function for a performance metric
  - Performance metric: ratio of current solver time over best time of all solvers
  - Intuitively: probability of success if given τ times fastest time (τ=ratio)


Performance Profile
Percent Of Models Solved
100
90
80
70
60
50
40
30
20
10
0
1
10
100
1000
Time Factor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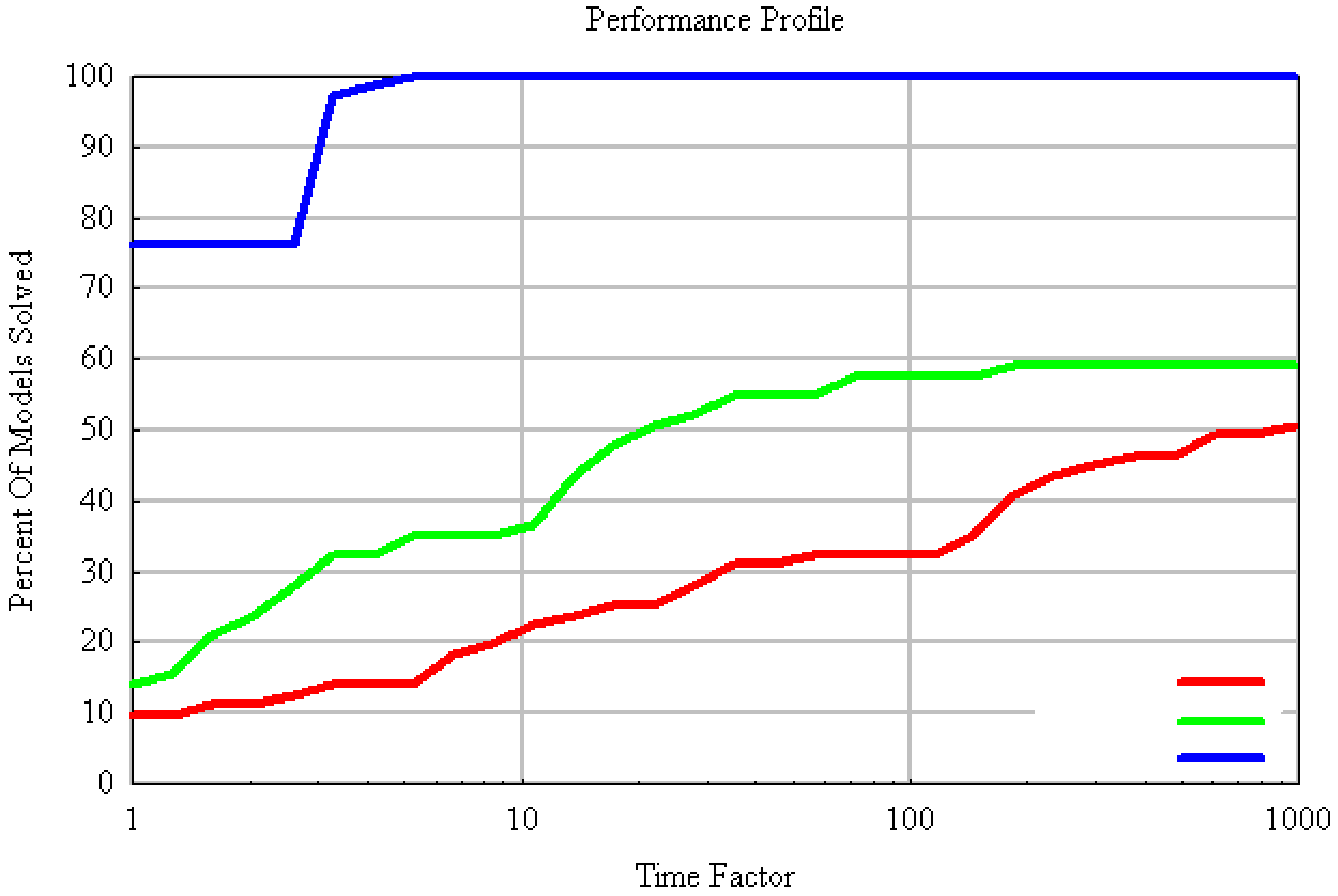
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Comparison Conclusion

- Model selection decides about the “winner”
  - 235 models from GlobalLib (total)
  - Subgroups between 39 and 125 models
- Where each solver “shines”:
  - BARON: Deterministic bounds
  - LGO: Black box models
  - OQNLP: Large models

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Creating Demand: MPSGE

- Complementarity: 10% of solver business
- Most of this involves MPSGE users
- MPSGE user profile:
  - Well versed in the economics of the model
  - Want to duplicate the success of other users
  - Start by reproducing previous published results
  - Extend or modify as appropriate

Factors in Market Creation

- Utility or superiority of the new technique
- Core group of pioneers
  - Create software to model and solve a problem
  - Advocate among the leaders in the field
  - Educate and tutor new users
  - Demonstrate the possibilities of the new technology, apply it creatively
  - Freely share their expertise & tools

Using GO in Existing Apps

- Pull out existing solver, plug in GO solver
- Potential benefits are clear:
  - Independence of starting point
  - Global/improved solutions
  - Solution quality metrics
- Risk involved – raise expectation & fail to deliver
- Many potential hurdles to success

Potential Customer Hurdles

- Generic leading-edge risks – bugs, etc.
- No proof of optimality
- Model too large
- Model not acceptable (plug-compatibility!)
- Bounds required for global solver
- Quality control issues (GAMS solvers should all work similarly)

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Adapting GAMS to GO

- GO solvers: demand much => deliver much
- Example: BARON
  - Special input format, bounds, limited functions
  - Delivers bounds on solution quality
- What else should GAMS provide?
  - Intervals (already done)
  - Suggestions ????

QA Tests for Reducing Risk

- Replication of quality assurance results critical factor for establishing a new solver technology in the commercial world
- Non-reproducible tests damage the reputation of a solver (red flag to users)
- Requirement: low cost replication of such results by an independent auditor (user/tester)

GAMS

Reproducible Tests: case study

Effective Testing

- Test cases
  - Widely available collection of standardized test model instances
- Data collection tools
  - Automatic collection of solution and statistics
  - Capture test environment setting (hardware, software)
- Data analysis tools
  - Standard quality and performance measurements

GAMS World Home Page

GAMS World

The Worlds
- GLOBAL
- MINLP
- MPEC
- MPSGE
- Performance
- Translation

Search

Contact

Welcome to the GAMS World

This is the home page of the GAMS World, a web site aiming to bridge the gap between academia and industry by providing highly focused forums and dissemination services in specialized areas of mathematical programming.

Substantial progress was made in the 1980s and 1990s with the development of algebra based modeling systems, algorithms, and computer codes to solve large and complex mathematical programs. The application of these tools, however, was less than expected. The abstraction, expression, and translation of real world problems into reliable and effective operational systems requires highly specialized and domains specific knowledge. The process of acquisition and dissemination of this knowledge is complex and poorly understood and the number of "good modelers" is much less than we all hoped for. Similarly, the process of transforming a new algorithm into a reliable and effective solution system is a slow and expensive process and there are few "good implementers". This web site hopes to address some of these problems by helping with the collection and dissemination of domain specific information and knowledge that is outside the established channels because of its content or form.

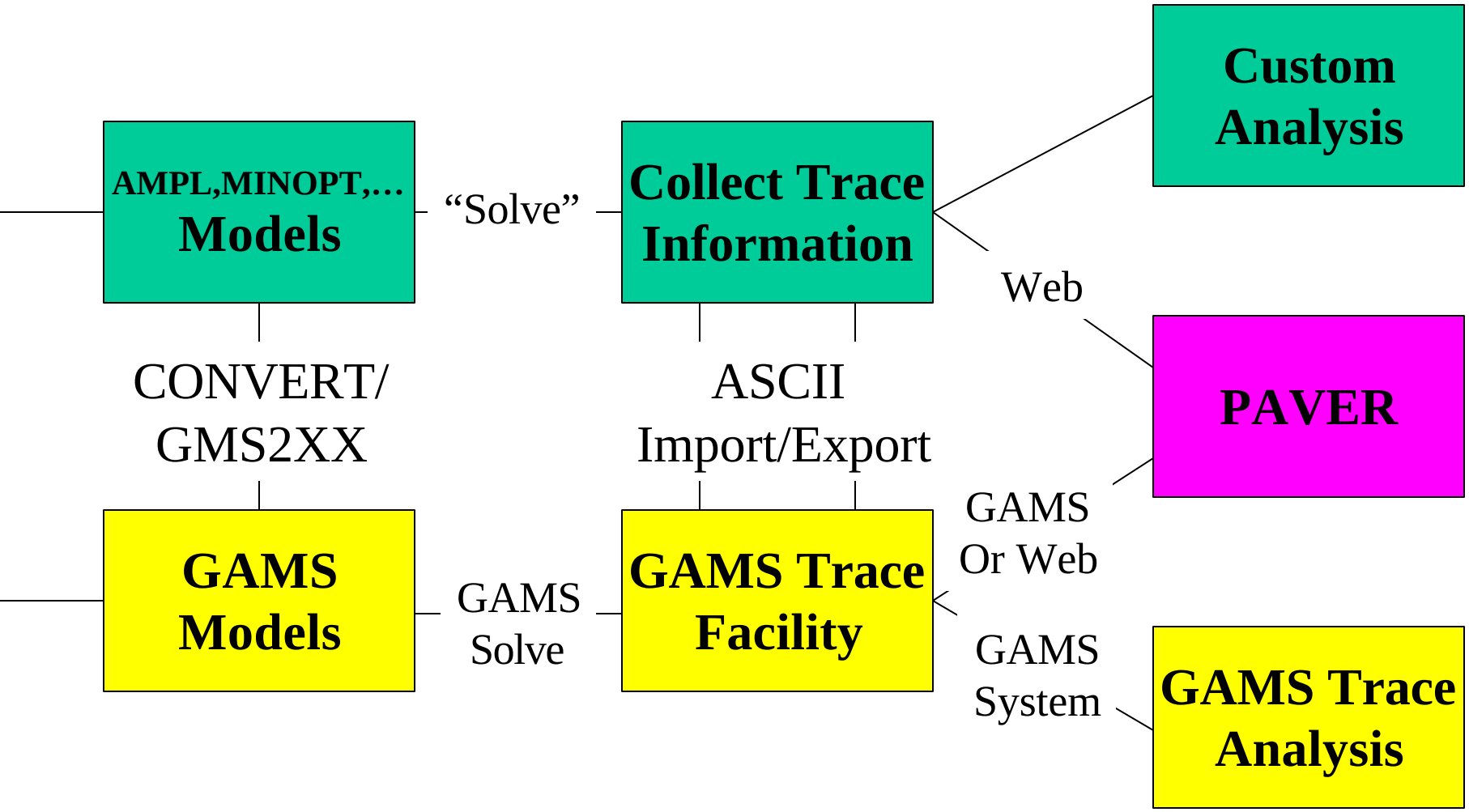
For example, model structures and results get published in commercial and academic papers but it is virtually impossible to reproduce any of those results or lift model components and data from one study to be used in some other study. Algorithm implementers face a similar dilemma when trying to get their hands on real world data models and data to test and refine their systems. This web site offers a few, well focused and maintained services to help with the dissemination of problems and solutions.

GAMS World is featured by GAMS Development Corp. and GAMS Software GmbH

Open Testing Architecture

- Test models
  - Open source GAMS models
  - Automatic translation into different formats, e.g. AMPL
  - Web/Email interface for this translation service
- Trace facility API
  - ASCII import/export of trace files
- Analysis tools
  - open source GAMS programs
  - Web interface for PAVER (**P**erformance **A**nalysis and **V**isualization for **E**ffortless **R**eproducibility)

Open Testing Architecture



Conclusions

- Addition of three well known global optimization codes to the GAMS solver portfolio.
- Commitment to quality assurance in the optimization world (critical for success in the commercial environment).
- Presentation will be available at **`http://www.gams.com/presentations`**