1. Performance World
   - Brief overview

2. Main Focus: Performance Tools
   - Performance Tools and Metrics
   - PAYER Web Server (Automation)
   - Examples
   - Conclusions
Welcome to the Performance World!

Performance World is a forum for discussion and dissemination of information and tools about all aspects of performance testing of solvers for mathematical programming problems. This world has been established in response to user demands for independent and reproducible performance results.

Overall performance highly depends on problem formulation, solver, and tuning parameters. Our performance tools are designed to serve the different needs of our user community. One user may be interested in finding the most reliable way to solve a proprietary or classified model. On the other hand, an academic researcher may be interested in testing a new algorithm against a set of existing test problems and competing approaches. The main features are:

- Uniform access to a comprehensive set of established and new test problems
- Automation tools for collecting performance measurements
- Tools for analyzing and visualizing test results

What's New:

- Try our online PAVER Server for automated performance analysis and visualization, batch file creation and model translation
- New tools for analyzing non-convex or discrete models
- MINLP type models from the MINLP World have been added to the PerformanceLib
Motivation for Tools

Performance Tools **driven by user needs:**

- Finding the **most reliable way to solve a proprietary model**
- **Testing a new algorithm** against a set of existing test problems and competing approaches
- **Reproducibility** of performance results
Performance World

Applications-Oriented User -> Performance World -> Algorithm-Oriented User

- Default Solver Options
- Performance Analysis & Visualization
- Custom Solver Options
Tools: Performance Analysis

Different objectives:

- Solver robustness and correctness
- Solver efficiency
- Quality of solution (nonconvex and discrete models)

Tools are **GAMS independent**
Results in HTML format: **platform independent**
Open Testing Architecture

Can use Performance World tools

Translate: GAMS/Convert

GAMS Models

Solve with GAMS

PAVER Server

Solve with “other” systems

Web

I. Models

II. Data Collection

III. Analysis & Visualization
PAVER Server

- PAVER server (Performance Analysis and Visualization for Effortless Reproducibility)

  www.gamsworld.org/performance/paver

- Online server to facilitate performance testing and analysis/visualization

- Results sent via e-mail in HTML format
  - System independent
Tools: Robustness

Solver Square Utility:

- Cross comparison of solver outcomes of two solvers:
  - Optimal, integer, infeasible, unbounded, fail
- Compact tabular form for results
- Shows resource time and objective value information

→ Can use online using PAVER
PAVER: Solver Square

Solvers used:

<table>
<thead>
<tr>
<th>Solver</th>
<th>% models optimal</th>
<th>% models feasible</th>
<th>% models infeasible</th>
<th>% models unbounded</th>
<th>% models fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solver A</td>
<td>-</td>
<td>71.72</td>
<td>1.01</td>
<td>-</td>
<td>27.27</td>
</tr>
<tr>
<td>Solver B</td>
<td>-</td>
<td>87.88</td>
<td>8.08</td>
<td>-</td>
<td>4.04</td>
</tr>
</tbody>
</table>

Result Totals in Percent:

Result Totals in Number of Models:

<table>
<thead>
<tr>
<th>Solver A</th>
<th>optimal</th>
<th>feasible</th>
<th>infeasible</th>
<th>unbounded</th>
<th>fail</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>optimal</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>feasible</td>
<td>-</td>
<td>57</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>71</td>
</tr>
<tr>
<td>infeasible</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>unbounded</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>fail</td>
<td>-</td>
<td>19</td>
<td>6</td>
<td>-</td>
<td>2</td>
<td>27</td>
</tr>
<tr>
<td>total Solver A</td>
<td>-</td>
<td>87</td>
<td>14</td>
<td>-</td>
<td>4</td>
<td>99</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solver B</th>
<th>optimal</th>
<th>feasible</th>
<th>infeasible</th>
<th>unbounded</th>
<th>fail</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>optimal</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>feasible</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>infeasible</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>unbounded</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>fail</td>
<td>-</td>
<td>19</td>
<td>6</td>
<td>-</td>
<td>2</td>
<td>27</td>
</tr>
</tbody>
</table>
Solver Resource Times

- Models for each solver pair outcome. Listed are the solver resource times in seconds, as well as the ratio of resource times for the two solvers if both solved optimally.
- Also listed are the objective values using both solvers. The better solution found is listed in boldface. A solution is considered better, if the relative objective function difference is greater than 1.00E-05.
- Solver resource time ratios for a particular model are listed only if one solver has resource greater than 5.00E-02.

<table>
<thead>
<tr>
<th>Modelname</th>
<th>Solver A</th>
<th>Solver B</th>
<th>Ratio (Solver A/Solver B)</th>
<th>Obj (Solver A)</th>
<th>Obj (Solver B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>alen</td>
<td>0.0973</td>
<td>0.0100</td>
<td>9.730</td>
<td>3.600000000</td>
<td>2.925000000</td>
</tr>
<tr>
<td>batch</td>
<td>0.2470</td>
<td>0.5100</td>
<td>0.485</td>
<td>205506.50824405</td>
<td>205506.5000000</td>
</tr>
<tr>
<td>batchdes</td>
<td>0.1094</td>
<td>0.0400</td>
<td>2.735</td>
<td>167427.65711470</td>
<td>167427.7000000</td>
</tr>
<tr>
<td>du-opt</td>
<td>1.9718</td>
<td>0.5200</td>
<td>3.792</td>
<td>31.02527833</td>
<td>31.02527833</td>
</tr>
<tr>
<td>du-opt5</td>
<td>2.0975</td>
<td>1.7000</td>
<td>1.234</td>
<td>40.77273140</td>
<td>6.07365800</td>
</tr>
<tr>
<td>eg_all_s</td>
<td>28.3584</td>
<td>19.7400</td>
<td>1.437</td>
<td>11.23946680</td>
<td>7.92010200</td>
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<tr>
<td>eg_disc2_s</td>
<td>63.1667</td>
<td>5.3400</td>
<td>11.829</td>
<td>6.92006923</td>
<td>5.64210100</td>
</tr>
<tr>
<td>eg_disc_s</td>
<td>88.8061</td>
<td>9.3800</td>
<td>9.458</td>
<td>10.42127936</td>
<td>5.76054000</td>
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<tr>
<td>eg_int_s</td>
<td>106.3869</td>
<td>7.7900</td>
<td>13.657</td>
<td>7.88724302</td>
<td>7.46308000</td>
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<tr>
<td>e1f</td>
<td>0.0573</td>
<td>15.3200</td>
<td>0.004</td>
<td>1.67500000</td>
<td>0.19166670</td>
</tr>
<tr>
<td>ex1221</td>
<td>0.0270</td>
<td>0.0000</td>
<td>---</td>
<td>7.66718007</td>
<td>7.66718000</td>
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<tr>
<td>ex1222</td>
<td>0.0629</td>
<td>99999.00</td>
<td>0.000</td>
<td>1.07654300</td>
<td>1.07654300</td>
</tr>
</tbody>
</table>
Tools: Efficiency

Resource Time Utility:

- Cross comparison of solver resource times of two solvers
- Further disaggregation by objective function
- Ratios of resource times

→ Can use online using PAVER
### PAVER: Solver Resource Time

<table>
<thead>
<tr>
<th>Solvers used</th>
<th>Solvers used</th>
<th>Modeltype(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solver A</td>
<td>Solver B</td>
<td>MINLP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Obj Solver A better</th>
<th>Obj same</th>
<th>Obj Solver B better</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solver Solver A</td>
<td>13</td>
<td>1</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Solver Solver B</td>
<td>10</td>
<td>-</td>
<td>23</td>
<td>-</td>
</tr>
<tr>
<td>Solvers perform the same</td>
<td>51</td>
<td>-</td>
<td>17</td>
<td>-</td>
</tr>
<tr>
<td>Both solvers failed to solve optimally</td>
<td>9</td>
<td>-</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>Total models</td>
<td>99</td>
<td>5</td>
<td>47</td>
<td>47</td>
</tr>
</tbody>
</table>
### Solver Solver A much faster - Obj of Solver A better:

<table>
<thead>
<tr>
<th>Modelname</th>
<th>Solver A</th>
<th>Solver B</th>
<th>Ratio (Solver A / Solver B)</th>
<th>Obj Solver A</th>
<th>Obj Solver B</th>
</tr>
</thead>
<tbody>
<tr>
<td>synheat</td>
<td>0.2670</td>
<td>2.0600</td>
<td>0.140</td>
<td>1.54997335E+05</td>
<td>1.60435500E+05</td>
</tr>
</tbody>
</table>

### Solver Solver A much faster - Obj same for both solvers:

<table>
<thead>
<tr>
<th>Modelname</th>
<th>Solver A</th>
<th>Solver B</th>
<th>Ratio (Solver A / Solver B)</th>
<th>Obj Solver A</th>
<th>Obj Solver B</th>
</tr>
</thead>
<tbody>
<tr>
<td>batch</td>
<td>0.2478</td>
<td>0.5100</td>
<td>0.486</td>
<td>2.85506850E+05</td>
<td>2.85506500E+05</td>
</tr>
<tr>
<td>ex1222</td>
<td>0.0629</td>
<td>99999.0000</td>
<td>0.000</td>
<td>1.07654300E+00</td>
<td>1.07654300E+00</td>
</tr>
<tr>
<td>ex4</td>
<td>1.1326</td>
<td>3.8400</td>
<td>0.295</td>
<td>-8.06413616E+00</td>
<td>-8.06413600E+00</td>
</tr>
<tr>
<td>util</td>
<td>0.6693</td>
<td>14.2400</td>
<td>0.047</td>
<td>9.99578750E+02</td>
<td>9.99578000E+02</td>
</tr>
</tbody>
</table>
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 $\tau$ times fastest time ($\tau=$ratio)
Interpretation (for $\tau = \text{ratio}, \ P = \text{profile}$):

- Efficiency: $P(\tau)$ for $\tau = 1$

- Probability of success:
  $$\lim_{\tau \to \infty} P(\tau)$$

- Compact graphs summarize all information
Profiles (best resource time)
Performance Profiles: considers both

- Further disaggregation by objective function:
  - Success only if best solution (over all solvers) found
Profiles (best objective)
Benchmarking process

Two components:

- **Subjective component:**
  - Choice of models
  - Choice of solvers
  - Choice of solver options

- **Non-subjective component:**
  - Obtaining performance data
  - Performance analysis and visualization
    → reproducible
Subjectivity in Benchmarking

Performance Tools:
- Takes care of non-subjective component

Choices:
- Models?
- Solver and solver options?

Example:
- Can choose a set of models where each solver is best:
Profile: MI NLP/Filter (best obj.)
Profile: SBB (best obj.)
Profile: DICOPT (best time)
Choice of models, solvers, options is subjective!

- **Models used** can skew data
  - several models of same structure may exist with different data
- **Default or custom solver options**
- **Platform dependence:**
  - Different resource times on different platforms
Other Issues

Timings:

- How is resource time measured (dependence on solver)?
- How are resource time limits enforced?
- Intermediate results if resource time limit reached
Conclusions

- Automation tools for collecting performance measurements

- Tools for analyzing and visualizing test results
  - Solver efficiency, robustness
  - Profiles and profile plots

- Enable users to reproduce performance results

- Automated performance analysis using the PAVER Server:
  www.gamsworld.org/performance/paver