Performance Analysis of Grid-Enabled GAMS

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Welcome/Agenda

- GAMS Grid Computing Facility
- Performance World / PAVER
- Computational Experiments
- Results & Summary
## Agenda

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<tr>
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<td><strong>GAMS Grid Computing Facility</strong></td>
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<td><strong>Performance World / PAVER</strong></td>
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<td><strong>Results &amp; Summary</strong></td>
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What’s New???

- Improvements on all frontiers
  - Connectivity Tools
    - Databases
    - Spreadsheets
    - Specialized Visualization Tools (e.g. VEDA)
  - Productivity Tools
    - IDE Improvements
    - Charting Engine
  - Interfaces
    - Using GAMS from Application Environments
  - Solver Interfacing
    - Branch-and-Cut-and-Heuristic (BCH) Facility
    - Grid Computing
What is Grid Computing?

A pool of connected computers managed and available as a common computing resource

• Effective sharing of CPU power
• Massively parallel task execution
• Scheduler handles management tasks
• E.g. Condor, Sun N6 Grid Engine, Globus
• Can be rented or owned in common
• Licensing & security issues
mymodel.solvelink=3;
loop(scenario,
    demand=demand(scenario); cost=cost(scenario);
solve mymodel min obj using minlp;
    report(scenario) = var.l);
)

Repeat
    loop(scenario$h(scenario),
        if(handlestatus(h(scenario))=2,
            mymodel.handle=h(scenario); h(scenario)=0;
            execute_loadhandle mymodel;
            report(scenario) = var.l
        )
    if(card(h), execute 'sleep 1');
    until card(h)=0 or timeelapsed > 100;
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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
Performance Libraries

• Performance tests require public test libraries
  – Creating models for this is not feasible
  – Shared test libraries allow reproducible results

• PerformLIB contains multiple MIP libraries
  – FCNETLIB
  – MIPLIB
  – MittelmannMIP
  – NEOS
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

Solve with “other” systems

Web

GAMS Models

Solve with GAMS

Web

PAVER Server

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: Efficiency

Resource Time Utility:

• Cross comparison of solver resource times of two solvers
• Ratios of resource times

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

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

<table>
<thead>
<tr>
<th>Solver</th>
<th>Solver A infinitely faster</th>
<th>Solver A much faster</th>
<th>Solver A faster</th>
<th>Solvers perform the same</th>
<th>Solver B faster</th>
<th>Solver B much faster</th>
<th>Solver B infinitely faster</th>
<th>Both solvers failed to solve optimally</th>
<th>Total models</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>12</td>
<td>10</td>
<td>31</td>
<td>12</td>
<td>20</td>
<td>20</td>
<td>8</td>
<td>99</td>
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<tr>
<td></td>
<td>4</td>
<td>1</td>
<td>7</td>
<td>23</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>8</td>
<td></td>
</tr>
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<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

**Total models:** 99
### 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>synthet</td>
<td>0.2878</td>
<td>2.0600</td>
<td>0.140</td>
<td>1.5497335E+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>2.85506508E+05</td>
<td>2.85506508E+05</td>
</tr>
<tr>
<td>ex1222</td>
<td>0.0629</td>
<td>99999.0000</td>
<td>0.000</td>
<td>1.07654308E+00</td>
<td>1.07654308E+00</td>
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<tr>
<td>ex4</td>
<td>1.1326</td>
<td>3.8400</td>
<td>0.295</td>
<td>-8.06413616E+00</td>
<td>-8.06413616E+00</td>
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<tr>
<td>util</td>
<td>0.6693</td>
<td>14.2400</td>
<td>0.047</td>
<td>9.99578750E+02</td>
<td>9.99578800E+02</td>
</tr>
</tbody>
</table>
Tools: Visualization

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)
Profiles (best resource time)
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Parallel MIP

- MIP/B&C Algorithm ideal to parallelize
  - Multi-threaded (SMP, shared memory) B&B
    - E.g. CPLEX, XPRESS
  - Master/Worker Paradigm (process nodes in parallel)
    - Software: FATCOP/Condor, BCP/PVM, PICO/MPI
  - A-priori subdivision into $n$ independent problems
    - Seymour problem solved that way
    - Open Pit Mining (openpit in GAMS Model library)
      - Partitioning integer variables to subdivide model into 4096 sub-problems
      - Experiments (Ferris) at UW using Condor Pool
Problems with a-priori Partitioning

- 99% of sub-problems very easy to solve
- 1% (almost) as difficult as the original problem

- How can we find $n$ sub-problems with similar (but reduced) level of difficulty?
  - B&C Code keeps a list of open/unexplored nodes
  - Problem-bounds of these open nodes represent partitioning of the original problem

<table>
<thead>
<tr>
<th>Node</th>
<th>Left</th>
<th>Objective</th>
<th>IInf</th>
<th>Integer</th>
<th>Best Node</th>
<th>ItCnt</th>
<th>Gap</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>29.6862</td>
<td>64</td>
<td>29.6862</td>
<td>165</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>37</td>
<td>17.0000</td>
<td>14</td>
<td>25.0000</td>
<td>2230</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>70</td>
<td>21.8429</td>
<td>22</td>
<td>24.0000</td>
<td>4022</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- GAMS/CPLEX Option `dumptree n` creates $n$ bound files
Putting it all together

Generate n=64 sub-problems using GAMS/CPLEX with dump tree 64;

loop(n,
    load nth bound file;
    generate and submit nth sub-problem
);

Repeat
    loop(n$(not collected),
        if (n finished,
            load nth-solution and mark n as collected);
        sleep some time;
    Until all collected;
Communication & Strategy

- An incumbent solution allows one to prune nodes with larger LP solution value in all sub-problems.
- Ergo, communicate a newly found incumbent to all sub-problems
  - Sub-problems not started: Start with a cutoff
  - Running sub-problems: Update the cutoff with a GAMS/CPLEX option file that is read while running

- Strategy:
  - Have one machine working on good solutions (e.g. CPLEX mipemphasis 1 or 4) using original problem
  - Sub-problems emphasize on best-bound (e.g. CPLEX mipemphasis 3)
Test environment

• Start with MIP models from PerformLib
  – MIPLIB, MittelmannMIP, NEOS
  – Single-thread CPLEX solve with 3hr limit to pick models
• Accessing a large grid was non-trivial - benchmarking runs require priority on a grid or time measurements are inaccurate.
• We substituted a “mini-grid”, a 4-CPU machine
• Each problem was submitted as a batch of 64 sub-problems
• For each problem, measure:
  – Wall time: start-to-finish time, including model generation
  – Max time: maximum solution time of any sub-problem
Performance profile, 24 models (proven optimal)
## Some results

<table>
<thead>
<tr>
<th>Problem</th>
<th>Max</th>
<th>Wall</th>
<th>CPLEX-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>bienst2</td>
<td>245</td>
<td>721</td>
<td>570</td>
</tr>
<tr>
<td>harp2</td>
<td>1000</td>
<td>1046</td>
<td>469</td>
</tr>
<tr>
<td>mas74</td>
<td>87</td>
<td>294</td>
<td>290</td>
</tr>
<tr>
<td>seymour1</td>
<td>48</td>
<td>349</td>
<td>340</td>
</tr>
<tr>
<td>tr12-30</td>
<td>480</td>
<td>2169</td>
<td>1662</td>
</tr>
</tbody>
</table>
Solution times, CPLEX-1, 3hr limit
Performance profile, 5 models (proven optimal)
Summary

• PAVER tools are still available and very useful
• GAMS Grid Facility useful for parallelizing MIP solves
  – Needs good division into subproblems – divide the work equally
  – Not so useful for easy problems
• Most MIP models in the test libraries seem to be easy or very difficult