Gurobi 8 Performance Benchmarks

February 11, 2019
Thank You for Your Interest in Gurobi

The Gurobi Optimizer was designed from the ground up to be the fastest, most powerful solver available for your MIP (MILP, MIQP, and MIQCP), LP and QP problems.

• In industry standard public benchmark tests Gurobi has the…

  • Fastest overall solve times for MIP models
  • Fastest overall solve times for LP models
  • Fastest overall solve times for QP models

  And, as problems get harder, our relative performance gets even better.
Two Types of Benchmark Testing

**Internal**
- Primary Objectives
  - Robustness testing
  - Compare version-to-version improvements
- Test Bank
  - Internal library of over 10,000 models from industry and academia

**Public**
- Primary Objective
  - Competitive benchmarks against other solvers
- Test Bank
  - Based on MIPLIB 2010 and 2017
  - Tests performed by Prof. Hans Mittelmann, Arizona State University

On the next slides we’ll share some specific results as well as results from our own internal testing. Of course, every model is different so we invite you to try Gurobi for yourself or contact us with any questions.
Gurobi Keeps Getting Better

Comparison of Gurobi Versions (PAR10)

Time limit: 10000 sec.
Intel Xeon CPU E3-1240 v3 @ 3.40GHz
4 cores, 8 hyper-threads
32 GB RAM

Test set has 5656 models:
- 410 discarded due to inconsistent answers
- 1741 solved in < 100s by all the versions
- 1493 discarded that none of the versions can solve
- speed-up measured on >100s bracket: 2012 models

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Broad Performance Improvements in v8.0

- Consistent with prior releases, the Gurobi Optimizer v8.0 delivers performance improvements over v7.0 across a broad range of model types:

  - **MIP**—57% faster overall, 109% faster on models that take >100 seconds to solve
  - **LP**
    - Concurrent—15% faster overall, 46% faster on models that take >100 seconds to solve
    - Primal Simplex—24% faster overall, 49% faster on models that take >100 seconds to solve
    - Dual Simplex—32% faster overall, 82% faster on models that take >100s to solve
    - Barrier—13% faster overall, 44% faster on models that take >100s to solve
  - **MIQP**—2.76x faster overall
  - **MIQCP**—20% faster overall
  - **SOCP**—19% faster overall
Performance Improvements in v8.1

- Gurobi Optimizer v8.1 improves performance significantly over v8.0 on integer quadratic programs:
  - MIQP – 2.8x faster overall
  - MIQCP – 38% faster overall
  - LP – both dual simplex and barrier are 10% faster on models that take > 100 seconds to solve
MILP Competitive Benchmarks
Gurobi 8.1.0 vs. CPLEX 12.8.0 vs. XPRESS 8.5.1
Tests performed by Prof. Hans Mittelmann

Gurobi is...
• Fastest to optimality (MIPLIB 2010 benchmark)
• Fastest on the new MIPLIB 2017 benchmark
• Fastest to feasibility (MIPLIB 2010 feasibility benchmark)
• Fastest to infeasibility (MIPLIB 2010 infeasibility benchmark)
Gurobi is Fastest on MIPLIB 2010 Benchmark

For example, on time to optimality benchmark (87 models) using 4 threads (P=4), CPLEX was 50% slower (1.50) and XPRESS was 66% slower (1.66) than Gurobi.
Gurobi is Fastest on the New MIPLIB 2017 Benchmark

MIPLIB 2017 Benchmark Comparison

Lower is better

P=12

P=48
Gurobi Solves More Models in MIPLIB 2017 Benchmark

Number of Models not Solved

Lower is better

<table>
<thead>
<tr>
<th></th>
<th>P=12</th>
<th>P=48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gurobi</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>CPLEX</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>XPRESS</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

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Gurobi is Fastest to Feasibility

Feasibility Benchmark Comparison (P=4)

Lower is better

Gurobi

CPLEX

XPRESS
Gurobi is Fastest to Detect Infeasibility

Infeasibility Benchmark Comparison (P=4)
LP Competitive Benchmarks
Gurobi 8.1.0 vs. CPLEX 12.8.0 vs. XPRESS 8.5.1 vs. Mosek 8.1.0.x
Tests performed by Prof. Hans Mittelmann

Gurobi has the fastest solve times
Gurobi is Fastest Across All LP Benchmarks

LP Solver Benchmark Comparison

Lower is better

Gurobi
CPLEX
XPRESS
Mosek
QP Competitive Benchmarks
Gurobi 8.1.0 vs. CPLEX 12.8.0 vs. XPRESS 8.5.1 vs. Mosek 8.1.0.x
Tests performed by Prof. Hans Mittelmann

Gurobi has the fastest solve times
Gurobi is Fastest Across All QP Benchmarks

Quadratic Model Solve Times

<table>
<thead>
<tr>
<th>Model Type</th>
<th>Gurobi</th>
<th>CPLEX</th>
<th>XPRESS</th>
<th>Mosek</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOCP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MISOCP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Binary QP</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Convex Discrete</td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

Lower is better

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LPSolve and GLPK are not included here as they solved too few models (seven and two respectively) to calculate useful performance comparisons.

Open-source and MATLAB solver performance is worse than shown as unsolved models are treated as solved at max time limit.
Pushing Performance Even Higher

Taking advantage of Gurobi’s Parameter Tuning and Distributed Optimization capabilities
Tuning can have a significant positive impact on performance results

- Test Set: MIPLIB 2010 benchmark, 87 models
  - Default tuning run with TuneTrial=1, each model separately
    - It uses 10X of default solving time
    - Two tuning runs, one with a single machine, one with 5 machines

- Results: (> 1 means faster)
  - Mean improvement from the best settings:
    - A single machine: 1.68X
    - 5 machines: 2.52X

Gurobi gives you industry-leading out-of-the-box performance. However, you can take that performance up even higher by tuning Gurobi’s parameters for your model(s).

To help you do that we provide an automatic tuning tool you can run on just one machine (the 1.68X performance improvement you see above across the test set), or on a number of machines (the 2.52X improvement in the five machine example above).

Note, the performance gain on your particular model could be higher or lower than the test results above. We are always happy to assist our commercial users in tuning and evaluating Gurobi’s performance.
Using distributed optimization can further improve Gurobi’s performance

- **MIPLIB 2010 (87 models)**
  - Note: This test set was not designed for testing distributed optimization. Because of this, the results below understate the potential gains.

- Models that take >1 second to solve

<table>
<thead>
<tr>
<th>Machines</th>
<th>Distributed</th>
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<tbody>
<tr>
<td>4</td>
<td>1.43X</td>
</tr>
<tr>
<td>8</td>
<td>1.53X</td>
</tr>
</tbody>
</table>

- Models that take >100 seconds to solve

<table>
<thead>
<tr>
<th>Machines</th>
<th>Distributed</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>2.09X</td>
</tr>
<tr>
<td>8</td>
<td>2.87X</td>
</tr>
</tbody>
</table>
Models suited for distributed optimization can see significantly greater speed-ups

- Model: seymour
  - Hard set covering model from MIPLIB 2010
  - 4944 constraints, 1372 (binary) variables, 33K non-zeroes

<table>
<thead>
<tr>
<th>Machines</th>
<th>Nodes</th>
<th>Time (s)</th>
<th>Speedup</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>476,642</td>
<td>9,267s</td>
<td>-</td>
</tr>
<tr>
<td>16</td>
<td>1,314,062</td>
<td>1,015s</td>
<td>9.1X</td>
</tr>
<tr>
<td>32</td>
<td>1,321,048</td>
<td>633s</td>
<td>14.6X</td>
</tr>
</tbody>
</table>
Isn’t it time you considered upgrading to Gurobi?

1. You can get a free academic license at www.gurobi.com.
2. You can request a free commercial evaluation license by contacting us at: info@gurobi.com.
3. We are happy to assist with benchmarking your own models.