

# What's New in Gurobi 8.0



#### New Gurobi team members in 2018...





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#### Gurobi 2018





## What's New in 8.0?



- New features
  - Significant enhancements to Compute Server and Instant Cloud
  - Enhanced MATLAB and R interfaces
  - Support for MATLAB problem-based modeling
  - Partition heuristic
  - Multiple MIP starts
  - Support for .NET Core 2.0
- Performance improvements



# **Enhanced MATLAB and R interfaces**

## **Completing the MATLAB and R Interfaces**



- Previously missing features:
  - Multi-objective optimization
  - Solution pools
  - General constraints
  - Several other (smaller) features
- Now available in MATLAB and R
- Also now available:
  - Full set of Gurobi examples for MATLAB and R

#### **MATLAB Problem-Based Modeling**



- Problem-based modeling: new feature in MATLAB 2017b Optimization Toolbox
  - A more structured approach to building an optimization model

```
x = optimvar('x', 'Type','integer','LowerBound',0,'UpperBound',1);
y = optimvar('y', 'Type','integer','LowerBound',0,'UpperBound',1);
z = optimvar('z', 'Type','integer','LowerBound',0,'UpperBound',1);
prob = optimproblem('ObjectiveSense','maximize');
prob.Objective = x + y + 2 * z;
prob.Constraints.cons1 = x + 2 * y + 3 * z <= 4;
prob.Constraints.cons2 = x + y >= 1;
sol = solve(prob, options)
```

• You can now call Gurobi through the MATLAB solve() function



## **Partition Heuristic**

## **User-Specified Local Improvement Heuristic**



- RINS is our most effective heuristic
- It is a *sub-MIP* heuristic:
  - Fix a subset of the variables to incumbent values
  - Solve the resulting MIP (recursively)
    - Reoptimizes over just that portion of the problem
- Sub-MIP heuristics extremely effective in general
- How to choose the sub-problem to reoptimize?
  - RINS chooses automatically
  - New feature allows user to make the choice
    - Example sub-problems:
      - All decisions related to a single time period
      - · All decisions related to a single machine
      - All decisions related to physical sub-regions (e.g., Western US, Eastern US, etc.)



# **Multiple MIP Starts**

## **Multiple MIP Starts**



- User can now provide multiple MIP starts
- Useful when you have multiple partial solutions
  - MIP solver will try to complete them, and will store the ones it finds
- For distributed MIP, MIP starts will be evaluated on different machines



# .NET Core 2.0

#### .NET Core 2.0



- Gurobi users can now write .NET programs that run on Windows, Linux, and Mac
  - Using new Microsoft .NET Core 2.0



# **Compute Server and Instant Cloud**

## **Compute Server Improved Architecture**





- Standard Communication Protocol Support for HTTP and HTTPS has been added for improved security, ease of deployment, and robustness.
- **Clustering** New clustering that allows nodes to be added to and removed from clusters dynamically.

#### **Compute Server Monitoring and Management**



<pre>\$ grbclusterserver=server1 nodes</pre>											
ADDRESS	STATUS	TYPE	LICENSE	#Q	#R	$\mathbf{JL}$	IDLE	%MEM	%CPU		
server1	ALIVE	COMPUTE	VALID	0		2	0m	66.02	99.04		
server2	ALIVE	COMPUTE	VALID	0	0	2	1m	50.19	2.42		

\$ grbclus	sterse	erver=server1	recent				
JOBID	ADDRESS	STATUS	STIME		USER	OPT	API
8a8cd65e	server1	COMPLETED	2018-04-09	10:44:54	user1	OPTIMAL	Python
ecfabdeb	server2	COMPLETED	2018-03-29	12:05:25	user1	INFEASIBLE	Java
fe60d00b	server1	IDLETIMEOUT	2018-03-29	12:01:35	user1	OPTIMAL	Python
977eb86d	server2	DISCONNECTED	2018-03-28	11:51:49	user1		

- Commands A new command line tool can now monitor and manage your cluster.
  - Users can display the status of the cluster, list running and recently processed jobs, and access job logs and parameters.
  - An administrator can list the licenses, abort jobs, and manage the nodes of the cluster.
- REST API A new cluster REST API allows you to programmatically monitor and manage your cluster.

## **Instant Cloud Improved Architecture**





• **HTTPS** – Support for HTTPS has been added for better security, robustness, and easier integration.

## **Improved Machine and Pool Management**



	Pools														⊘	0 G
Instant Cloud	Show	10\$	pools										Search:	Curre	ent Licer	ises Only
			ID 🔺	#Min Servers	#Launching	#Ready (	#Stopping	Machine	Region	License 🛊	Rate Plan	Distributed Workers				
JOBS			999999-							000000	6-14				-	-
		•	default	1:	U	1	0	c4.4xlarge	us-east-1	999999	Gold	0	0	્ય	۷	5
		0	999999- distributed	1	1	0	0	c4.2xlarge	us-east-1	999999	Gold	4	1	1	<b>±</b>	5
MANUAL LAUNCH		•	999999-	1	0	0	0	r3.8xlarge	us-east-1	999999	Gold	0	1	†1	+	5
🕙 HISTORY 🛛 🗸 🗸	_		large										0	0	0	9
🔹 SETTINGS 🛛 🗸		•	999999- production	5	0	0	0	c4.8xlarge	us-east-1	999999	Gold	0	1	<b>*</b>	•	5
	Showing	g 1 to	4 of 4 pools									First Pre	vious	1	Next	Last
	SELECT	г	DELETE	TERMINATE	LAUNCH											÷

- Pool Scaling New pool scaling allows the user to dynamically add or remove machines to and from pools.
- Machine Metrics New machine metrics display CPU and memory usage on each machine.

## **New Job Monitoring**





- Job List A new job list now displays the jobs queued, running, and recently processed.
- Job Dashboard A new dashboard displays detailed job information, such as status, log, parameters, and metrics, in one place.
- Job History A new archive functionality allows users to store job logs and statuses from the past three months.



# **Gurobi 8.0 Performance Improvements**

#### **Two Kinds of Benchmarks**



- Internal benchmarks
  - Most important: compare Gurobi version-over-version
  - Based on internal library of 4538 models
- External, competitive benchmarks
  - Conducted by Hans Mittelmann, Arizona State University
    - <u>http://plato.asu.edu/bench.html</u>
  - For MIP largely based upon MIPLIB 2010



## **Internal Benchmarks**

#### **Gurobi MIP Library**





#### **Performance Improvements: 7.5 to 8.0**



Problem Class			>1s		>100s						
	#	Wins	Losses	Speedup	#	Wins	Losses	Speedup			
LP: concur.	482	66	56	1.01x	151	45	35	1.01x			
primal	487	79	62 1.07x		209	54	40	1.16x			
dual	466	110	61	1.12x	171	77	31	1.31x			
barrier	490	58	43	1.05x	165	37	32	1.10x			
MIP	2263	1068	634	1.16x	920	484	296	1.26x			
MIQP	177	71	46	1.15x	77	40	22	1.30x			
MIQCP	261	136	73	1.22x	68	38	25	1.67x			

• Gurobi 7.5 vs. 8.0: > 1.00x means that Gurobi 8.0 is faster than Gurobi 7.5

#### **Performance Improvements: 7.0 to 8.0**



Problem Class			>1s		>100s						
	#	Wins	Losses	Speedup	#	Wins	Losses	Speedup			
LP: concur.	449	135	134	1.15x	146	72	44	1.46x			
primal	459	138	133	1.24x	208	87	48	1.49x			
dual	441	165	119	1.32x	171	96	43	1.82x			
barrier	457	126	136	1.13x	157	68	50	1.44x			
MIP	2276	1351	561	1.52x	980	669	225	2.10x			
MIQP	121	84	24	3.76x	67	52	12	9.24x			
MIQCP	244	105	89	1.20x	68	38	26	1.83x			

• Gurobi 7.0 vs. 8.0: > 1.00x means that Gurobi 8.0 is faster than Gurobi 7.0

#### **Continual Performance Improvements**



