

# GUROBI OPTIMIZER REFERENCE MANUAL



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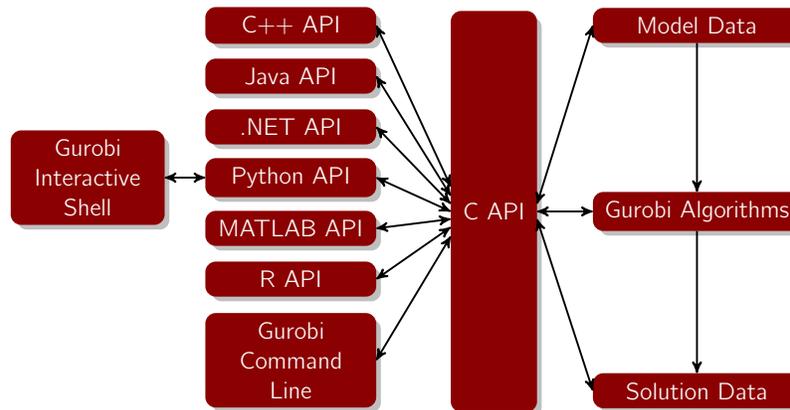
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This is the reference manual for the Gurobi™ Optimizer. It contains documentation for the following Gurobi language interfaces:

- [C](#)
- [C++](#)
- [Java®](#)
- [Microsoft®.NET](#)
- [Python®](#)
- [MATLAB®](#)
- [R](#)

The *Gurobi interactive shell* is also documented in the [Python](#) section.

The different Gurobi language interfaces share many common features. These are described at the end of this manual. Two particularly important common features are the [Attribute](#) interface and the Gurobi [Parameter](#) set. You may wish to bookmark these pages, since you are likely to refer to them frequently as you develop applications that use the Gurobi Optimizer.

This document also includes information on our [Distributed Parallel Algorithms](#), which allow you to use multiple machines to achieve higher performance, [Gurobi Compute Server](#), which allows you to offload Gurobi computations from a set of client machines onto one or more servers, and [Gurobi Instant Cloud](#), which allows you to launch machines on the cloud and offload Gurobi computations to them.

## Additional Resources

You can consult the [Gurobi Quick Start](#) for a high-level overview of the Gurobi Optimizer, or the [Gurobi Example Tour](#) for a quick tour of the examples provided with the Gurobi distribution.

## Getting Help

If you have a question that is not answered in this document, you can post it to the [Gurobi Google Group](#). If you have a current maintenance contract with us, you can send your question to [support@gurobi.com](mailto:support@gurobi.com).

This section documents the Gurobi C interface. This manual begins with a quick overview of the functions in the interface, and continues with [detailed descriptions of all of the available interface routines](#).

If you are new to the Gurobi Optimizer, we suggest that you start with the [Quick Start Guide](#) or the [Example Tour](#). These documents provide concrete examples of how to use the routines described here.

## Environments

The first step in using the Gurobi C optimizer is to create an environment, using the [GRBloadenv](#) call. The environment acts as a container for all data associated with a set of optimization runs. You will generally only need one environment in your program, even if you wish to work with multiple optimization models. Once you are done with an environment, you should call [GRBfreeenv](#) to release the associated resources.

## Models

You can create one or more optimization models within an environment. A model consists of a set of variables, a linear, quadratic, or piecewise-linear objective function on those variables, and a set of constraints. Each variable has an associated lower bound, upper bound, type (continuous, binary, integer, semi-continuous, or semi-integer), and linear objective coefficient. Each linear constraint has an associated sense (less-than-or-equal, greater-than-or-equal, or equal), and right-hand side value. Refer to [this section](#) for more information on variables and constraints.

An optimization model may be specified all at once, through the [GRBloadmodel](#) routine, or built incrementally, by first calling [GRBnewmodel](#) and then calling [GRBaddvars](#) to add variables and [GRBaddconstr](#), [GRBaddqconstr](#), [GRBaddsos](#), or any of the [GRBaddgenconstrXxx](#) methods to add constraints. Models are dynamic entities; you can always add or delete variables or constraints.

Specific variables and constraints are referred to throughout the Gurobi C interface using their indices. Variable indices are assigned as variables are added to the model, in a contiguous fashion. The same is true for constraints. In adherence to C language conventions, indices all start at 0.

We often refer to the *class* of an optimization model. A model with a linear objective function, linear constraints, and continuous variables is a *Linear Program (LP)*. If the objective is quadratic, the model is a *Quadratic Program (QP)*. If any of the constraints are quadratic, the model is a *Quadratically-Constrained Program (QCP)*. We'll sometimes also discuss a special case of QCP, the *Second-Order Cone Program (SOCP)*. If the model contains any integer variables, semi-continuous variables, semi-integer variables, Special Ordered Set (SOS) constraints, or general constraints, the model is a *Mixed Integer Program (MIP)*. We'll also sometimes discuss special cases of MIP, including *Mixed Integer Linear Programs (MILP)*, *Mixed Integer Quadratic Programs (MIQP)*, *Mixed Integer Quadratically-Constrained Programs (MIQCP)*, and *Mixed Integer Second-Order Cone Programs (MISOCP)*. The Gurobi Optimizer handles all of these model classes.

## Solving a Model

Once you have built a model, you can call [GRBoptimize](#) to compute a solution. By default, `GRBoptimize()` will use the [concurrent optimizer](#) to solve LP models, the barrier algorithm to solve QP and QCP models, and the branch-and-cut algorithm to solve mixed integer models. The solution is stored as a set of *attributes* of the model. The C interface contains an extensive set of routines for querying these attributes.

The Gurobi algorithms keep careful track of the state of the model, so calls to `GRBoptimize()` will only perform further optimization if relevant data has changed since the model was last optimized. If you would like to discard previously computed solution information and restart the optimization from scratch without changing the model, you can call [GRBresetmodel](#).

After a MIP model has been solved, you can call [GRBfixedmodel](#) to compute the associated *fixed* model. This model is identical to the input model, except that all integer variables are fixed to their values in the MIP solution. In some applications, it is useful to compute information on this continuous version of the MIP model (e.g., dual variables, sensitivity information, etc.).

## Multiple Solutions and Multiple Objectives

By default, the Gurobi Optimizer assumes that your goal is to find one proven optimal solution to a model with a single objective function. Gurobi provides features that allow you to relax either of these assumptions. You should refer to the section on [Solution Pools](#) for information on how to request more than one solution, or the section on [Multiple Objectives](#) for information on how to specify multiple objective functions and control the tradeoff between them.

## Infeasible Models

You have a few options if a model is found to be infeasible. You can try to diagnose the cause of the infeasibility, attempt to repair the infeasibility, or both. To obtain information that can be useful for diagnosing the cause of an infeasibility, call [GRBcomputeIIS](#) to compute an Irreducible Inconsistent Subsystem (IIS). This routine can be used for both continuous and MIP models, but you should be aware that the MIP version can be quite expensive. This routine populates a set of IIS attributes.

To attempt to repair an infeasibility, call [GRBfeasrelax](#) to compute a feasibility relaxation for the model. This relaxation allows you to find a solution that minimizes the magnitude of the constraint violation.

## Querying and Modifying Attributes

Most of the information associated with a Gurobi model is stored in a set of attributes. Some attributes are associated with the variables of the model, some with the constraints of the model, and some with the model itself. To give a simple example, solving an optimization model causes the `X` variable attribute to be populated. Attributes such as `X` that are computed by the Gurobi optimizer cannot be modified directly by the user, while others, such as the variable lower bound array (the `LB` attribute) can.

The Gurobi C interface contains an extensive set of routines for querying or modifying attribute values. The exact routine to use for a particular attribute depends on the type of the attribute. As mentioned earlier, attributes can be either variable attributes, constraint attributes, or model attributes. Variable and constraint attributes are arrays, and use a set of array attribute routines. Model attributes are scalars, and use a set of scalar routines. Attribute values can additionally be of type *char*, *int*, *double*, or *string* (really *char \**).

Scalar model attributes are accessed through a set of `GRBget*attr()` routines (e.g., `GRBgetintattr`). In addition, those model attributes that can be set directly by the user (e.g., the objective sense) may be modified through the `GRBset*attr()` routines (e.g., `GRBsetdblattr`).

Array attributes are accessed through three sets of routines. The first set, the `GRBget*attrarray()` routines (e.g., `GRBgetcharattrarray`) return a contiguous sub-array of the attribute array, specified using the index of the first member and the length of the desired sub-array. The second set, the `GRBget*attrelement()` routines (e.g., `GRBgetcharattrelement`) return a single entry from the attribute array. Finally, the `GRBget*attrlist()` routines (e.g., `GRBgetdblattrlist`) retrieve attribute values for a list of indices.

Array attributes that can be set by the user are modified through the `GRBset*attrarray()`, `GRBset*attrelement()`, and `GRBset*attrlist()` routines.

The full list of Gurobi attributes can be found in the [Attributes](#) section.

### Additional Model Modification Information

Most modifications to an existing model are done through the attribute interface (e.g., changes to variable bounds, constraint right-hand sides, etc.). The main exceptions are modifications to the constraints themselves, and to the quadratic and piecewise-linear portions of the objective function.

The constraint matrix can be modified in a few ways. The first is to call `GRBchgcoeffs` to change individual matrix coefficients. This routine can be used to modify the value of an existing non-zero, to set an existing non-zero to zero, or to create a new non-zero. The constraint matrix is also modified when you remove constraints (through `GRBdelconstrs`) or variables (through `GRBdelvars`). The non-zero values associated with the deleted constraints or variables are removed along with the constraints or variables themselves.

Quadratic objective terms are added to the objective function using the `GRBaddqpterms` routine. You can add a list of quadratic terms in one call, or you can add terms incrementally through multiple calls. The `GRBdelq` routine allows you to delete all quadratic terms from the model. Note that quadratic models will typically have both quadratic and linear terms. Linear terms are entered and modified through the `Obj` attribute, in the same way that they are handled for models with purely linear objective functions.

If your variables have piecewise-linear objectives, you can specify them using the `GRBsetpwlobj` routine. Call this routine once for each relevant variable. The Gurobi simplex solver includes algorithmic support for convex piecewise-linear objective functions, so for continuous models you should see a substantial performance benefit from using this feature. To clear a previously specified piecewise-linear objective function, simply set the `Obj` attribute on the corresponding variable to 0.

### Lazy Updates

One important item to note about model modification in the Gurobi optimizer is that it is performed in a *lazy* fashion, meaning that modifications don't affect the model immediately. Rather, they are queued and applied later. If your program simply creates a model and solves it, you will probably never notice this behavior. However, if you ask for information about the model before your modifications have been applied, the details of the lazy update approach may be relevant to you.

As we just noted, model modifications (bound changes, right-hand side changes, objective changes, etc.) are placed in a queue. These queued modifications can be applied to the model in three different ways. The first is by an explicit call to `GRBupdatemodel`. The second is by a

call to [GRBoptimize](#). The third is by a call to [GRBwrite](#) to write out the model. The first case gives you fine-grained control over when modifications are applied. The second and third make the assumption that you want all pending modifications to be applied before you optimize your model or write it to disk.

Why does the Gurobi interface behave in this manner? There are a few reasons. The first is that this approach makes it much easier to perform multiple modifications to a model, since the model remains unchanged between modifications. The second is that processing model modifications can be expensive, particularly in a Compute Server environment, where modifications require communication between machines. Thus, it is useful to have visibility into exactly when these modifications are applied. In general, if your program needs to make multiple modifications to the model, you should aim to make them in phases, where you make a set of modifications, then update, then make more modifications, then update again, etc. Updating after each individual modification can be extremely expensive.

If you forget to call update, your program won't crash. Your query will simply return the value of the requested data from the point of the last update. If the object you tried to query didn't exist then, you'll get an `INDEX_OUT_OF_RANGE` error instead.

The semantics of lazy updates have changed in this release. While the vast majority of programs will continue to work unmodified, you can use the [UpdateMode](#) parameter to revert to the previous behavior if you run into an issue.

## Managing Parameters

The Gurobi optimizer provides a set of parameters that allow you to control many of the details of the optimization process. Factors like feasibility and optimality tolerances, choices of algorithms, strategies for exploring the MIP search tree, etc., can be controlled by modifying Gurobi parameters before beginning the optimization. Parameters are set using the `GRBset*param()` routines (e.g., [GRBsetintparam](#)). Current values can be retrieved with the `GRBget*param()` routines (e.g., [GRBgetdblparam](#)). Parameters can be of type *int*, *double*, or *char \** (string). You can also read a set of parameter settings from a file using [GRBreadparams](#), or write the set of changed parameters using [GRBwriteparams](#).

We also include an automated parameter tuning tool that explores many different sets of parameter changes in order to find a set that improves performance. You can call [GRBtunemodel](#) to invoke the tuning tool on a model. Refer to the [parameter tuning tool](#) section for more information.

One thing we should note is that each model gets its own copy of the environment when it is created. Parameter changes to the original environment therefore have no effect on existing models. Use [GRBgetenv](#) to retrieve the environment associated with a particular model if you want to change a parameter for that model.

## Monitoring Progress - Logging and Callbacks

Progress of the optimization can be monitored through Gurobi logging. By default, Gurobi will send output to the screen. A few simple controls are available for modifying the default logging behavior. If you would like to direct output to a file as well as to the screen, specify the log file name in [GRBloadenv](#) when you create your environment. You can modify the [LogFile](#) parameter if you wish to redirect the log to a different file after creating the environment. The frequency of logging output can be controlled with the [DisplayInterval](#) parameter, and logging can be turned off entirely with the [OutputFlag](#) parameter. A detailed description of the Gurobi log file can be found in the [Logging](#) section.

More detailed progress monitoring can be done through the Gurobi callback function. The [GRBsetcallbackfunc](#) routine allows you to install a function that the Gurobi optimizer will call regularly during the optimization process. You can call [GRBcbget](#) from within the callback to obtain additional information about the state of the optimization.

### **Modifying Solver Behavior - Callbacks**

Callbacks can also be used to modify the behavior of the Gurobi optimizer. If you call routine [GRBterminate](#) from within a callback, for example, the optimizer will terminate at the earliest convenient point. Routine [GRBcbsolution](#) allows you to inject a feasible solution (or partial solution) during the solution of a MIP model. Routines [GRBcbcut](#) and [GRBcblazy](#) allow you to add *cutting planes* and *lazy constraints* during a MIP optimization, respectively.

### **Error Handling**

Most of the Gurobi C library routines return an integer error code. A zero return value indicates that the routine completed successfully, while a non-zero value indicates that an error occurred. The list of possible error return codes can be found in the [Error Codes](#) section.

When an error occurs, additional information on the error can be obtained by calling [GRBgeterrormsg](#).

## 2.1 Environment Creation and Destruction

### GRBloadenv

```
int GRBloadenv ( GRBenv      **envP,  
                 const char *logfilename )
```

Create an environment. Optimization models live within an environment, so this is typically the first Gurobi routine called in an application.

In addition to creating a new environment, this routine will also check the current working directory for a file named `gurobi.env`, and it will attempt to read parameter settings from this file if it exists. The file should be in [PRM](#) format (briefly, each line should contain a parameter name, followed by the desired value for that parameter).

In general, you should aim to create a single Gurobi environment in your program, even if you plan to work with multiple models. Reusing one environment is much more efficient than creating and destroying multiple environments.

#### Return value:

A non-zero return value indicates that there was a problem creating the environment. Refer to the [Error Code](#) table for a list of possible return values.

#### Arguments:

**envP:** The location in which the pointer to the newly created environment should be placed.

**logfilename:** The name of the log file for this environment. May be NULL (or an empty string), in which case no log file is created.

### GRBloadclientenv

```
int GRBloadclientenv ( GRBenv      **envP,  
                       const char *logfilename,  
                       const char *computeserver,  
                       int         port,  
                       const char *password,  
                       int         priority,  
                       double      timeout )
```

Create a client environment on a compute server. Optimization models live within an environment, so this is typically the first Gurobi routine called in an application. This call specifies the compute server on which those optimization models will be solved, as well as the priority of the associated jobs.

In addition to creating a new environment, this routine will also check the current working directory for a file named `gurobi.env`, and it will attempt to read parameter settings from this file if it exists. The file should be in [PRM](#) format (briefly, each line should contain a parameter name, followed by the desired value for that parameter).

In general, you should aim to create a single Gurobi environment in your program, even if you plan to work with multiple models. Reusing one environment is much more efficient than creating and destroying multiple environments.

#### Return value:

A non-zero return value indicates that there was a problem creating the environment. Refer to the [Error Code](#) table for a list of possible return values.

## Arguments:

- envP:** The location in which the pointer to the newly created environment should be placed.
- logfile:** The name of the log file for this environment. May be NULL (or an empty string), in which case no log file is created.
- computeserver:** A comma-separated list of Gurobi compute servers. You can refer to compute server machines using their names or their IP addresses.
- port:** The port number used to connect to the compute server. You should pass a -1 value, which indicates that the default port should be used, unless your server administrator has changed our recommended port settings.
- password:** The password for gaining access to the specified compute servers. Pass an empty string if no password is required.
- priority:** The priority of the job. Priorities must be between -100 and 100, with a default value of 0 (by convention). Higher priority jobs are chosen from the server job queue before lower priority jobs. A job with priority 100 runs immediately, bypassing the job queue and ignoring the job limit on the server. You should exercise caution with priority 100 jobs, since they can severely overload a server, which can cause jobs to fail, and in extreme cases can cause the server to crash.
- timeout:** Job timeout (in seconds). If the job doesn't reach the front of the queue before the specified timeout, the call will exit with a `JOB_REJECTED` error. Use a negative value to indicate that the call should never timeout.

## Example usage:

```
GRBenv *env;
error = GRBloadclientenv(&env, "gurobi.log",
                        "server1.mydomain.com,server2.mydomain.com",
                        "", 5, -1.0);
```

## GRBloadcloudenv

```
int GRBloadcloudenv ( GRBenv      **envP,
                      const char  *logfile,
                      const char  *accessID,
                      const char  *secretKey,
                      const char  *pool )
```

Create a Gurobi Instant Cloud environment. Optimization models live within an environment, so this is typically the first Gurobi routine called in an application. This call will use an existing Instant Cloud machine if one is currently running within the specified machine pool, and it will launch a new one otherwise. Note that launching a new machine can take a few minutes.

You should visit the Gurobi Instant Cloud site to obtain your `accessID` and `secretKey`, configure your machine pools, and perform other cloud setup and maintenance tasks.

You should keep your `secretKey` private. Sharing it with others will allow them to launch Instant Cloud instances in your account.

In addition to creating a new environment, this routine will also check the current working directory for a file named `gurobi.env`, and it will attempt to read parameter settings from this file if it exists. The file should be in [PRM](#) format (briefly, each line should contain a parameter name, followed by the desired value for that parameter).

In general, you should aim to create a single Gurobi environment in your program, even if you plan to work with multiple models. Reusing one environment is much more efficient than creating and destroying multiple environments.

**Return value:**

A non-zero return value indicates that there was a problem creating the environment. Refer to the [Error Code](#) table for a list of possible return values.

**Arguments:**

**envP:** The location in which the pointer to the newly created environment should be placed.

**logfile:** The name of the log file for this environment. May be NULL (or an empty string), in which case no log file is created.

**accessID:** The access ID for your Gurobi Instant Cloud license. This can be retrieved from the Gurobi Instant Cloud website. When used in combination with your **secretKey**, this allows you to launch Instant Cloud instances and submit jobs to them.

**secretKey:** The secret key for your Gurobi Instant Cloud license. This can be retrieved from the Gurobi Instant Cloud website. When used in combination with your **accessID**, this allows you to launch Instant Cloud instances and submit jobs to them. Note that you should keep your secret key private.

**pool:** The machine pool. Machine pools allow you to create fixed configurations on the Instant Cloud website (capturing things like type of machine, geographic region, etc.), and then launch and share machines from client programs without having to restart the configuration information each time you launch a machine. May be NULL (or an empty string), in which case your job will be launched in the default pool associated with your cloud license.

**Example usage:**

```
GRBEnv *env;
error = GRBloadcloudenv(&env, "gurobi.log",
                      "3d1ecef9-dfad-eff4-b3fa", "ae6L23a1Je3+fas", "");
```

## GRBfreeenv

```
void GRBfreeenv ( GRBEnv *env )
```

Free an environment that was previously allocated by [GRBloadenv](#), and release the associated memory. This routine should be called when an environment is no longer needed. In particular, it should only be called once all models built using the environment have been freed.

**Arguments:**

**env:** The environment to be freed.

## GRBgetconcurrentenv

```
GRBEnv * GRBgetconcurrentenv ( GRBmodel *model,
                               int num )
```

Create/retrieve a concurrent environment for a model.

This routine provides fine-grained control over the concurrent optimizer. By creating your own concurrent environments and setting appropriate parameters on these environments (e.g., the [Method](#) parameter), you can control exactly which strategies the concurrent optimizer employs.

For example, if you create two concurrent environments, and set **Method** to primal simplex for one and dual simplex for the other, subsequent concurrent optimizer runs will use the two simplex algorithms rather than the default choices.

Note that you must create contiguously numbered concurrent environments, starting with **num**=0. For example, if you want three concurrent environments, they must be numbered 0, 1, and 2.

Once you create concurrent environments, they will be used for every subsequent concurrent optimization on that model. Use [GRBdiscardconcurrentenvs](#) to revert back to default concurrent optimizer behavior.

**Return value:**

The concurrent environment. A NULL return value indicates that there was a problem creating the environment.

**Arguments:**

**model:** The model for the concurrent environment.

**num:** The concurrent environment number.

**Example usage:**

```
GRBEnv *env0 = GRBgetconcurrentenv(model, 0);
```

```
GRBEnv *env1 = GRBgetconcurrentenv(model, 1);
```

## GRBdiscardconcurrentenvs

```
void GRBdiscardconcurrentenvs ( GRBmodel * model )
```

Discard concurrent environments for a model.

The concurrent environments created by [GRBgetconcurrentenv](#) will be used by every subsequent call to the concurrent optimizer until the concurrent environments are discarded.

**Arguments:**

**model:** The model for the concurrent environment.

**Example usage:**

```
GRBdiscardconcurrentenvs(model);
```

## 2.2 Model Creation and Modification

### GRBloadmodel

```
int GRBloadmodel ( GRBenv      *env,
                  GRBmodel    **modelP,
                  const char  *Pname,
                  int         numvars,
                  int         numconstrs,
                  int         objsense,
                  double      objcon,
                  double      *obj,
                  char        *sense,
                  double      *rhs,
                  int         *vbeg,
                  int         *vlen,
                  int         *vind,
                  double      *vval,
                  double      *lb,
                  double      *ub,
                  char        *vtype,
                  const char  **varnames,
                  const char  **constrnames )
```

Create a new optimization model, using the provided arguments to initialize the model data (objective function, variable bounds, constraint matrix, etc.). The model is then ready for optimization, or for modification (e.g., addition of variables or constraints, changes to variable types or bounds, etc.).

If your constraint matrix may contain more than 2 billion non-zero values, you should consider using the [GRBxloadmodel](#) variant of this routine.

#### Return value:

A non-zero return value indicates that a problem occurred while creating the model. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

#### Arguments:

**env:** The environment in which the new model should be created. Note that the new model gets a copy of this environment, so subsequent modifications to the original environment (e.g., parameter changes) won't affect the new model. Use [GRBgetenv](#) to modify the environment associated with a model.

**modelP:** The location in which the pointer to the newly created model should be placed.

**Pname:** The name of the model.

**numvars:** The number of variables in the model.

**numconstrs:** The number of constraints in the model.

**objsense:** The sense of the objective function. Allowed values are 1 (minimization) or -1 (maximization).

**objcon:** Constant objective offset.

**obj:** Objective coefficients for the new variables. This argument can be `NULL`, in which case the objective coefficients are set to `0.0`.

**sense:** The senses of the new constraints. Options are `'='` (equal), `'<'` (less-than-or-equal), or `'>'` (greater-than-or-equal). You can also use constants `GRB_EQUAL`, `GRB_LESS_EQUAL`, or `GRB_GREATER_EQUAL`.

**rhs:** Right-hand-side values for the new constraints. This argument can be `NULL` if you are not adding any constraint.

**vbeg:** Constraint matrix non-zero values are passed into this routine in Compressed Sparse Column (CSC) format. Each column in the constraint matrix is represented as a list of index-value pairs, where each index entry provides the constraint index for a non-zero coefficient, and each value entry provides the corresponding non-zero value. Each variable in the model has a `vbeg` and `vlen` value, indicating the start position of the non-zeros for that variable in the `vind` and `vval` arrays, and the number of non-zero values for that variable, respectively. Thus, for example, if `vbeg[2] = 10` and `vlen[2] = 2`, that would indicate that variable 2 has two non-zero values associated with it. Their constraint indices can be found in `vind[10]` and `vind[11]`, and the numerical values for those non-zeros can be found in `vval[10]` and `vval[11]`.

**vlen:** Number of constraint matrix non-zero values associated with each variable. See the description of the `vbeg` argument for more information.

**vind:** Constraint indices associated with non-zero values. See the description of the `vbeg` argument for more information.

**vval:** Numerical values associated with constraint matrix non-zeros. See the description of the `vbeg` argument for more information.

**lb:** Lower bounds for the new variables. This argument can be `NULL`, in which case all variables get lower bounds of `0.0`.

**ub:** Upper bounds for the new variables. This argument can be `NULL`, in which case all variables get infinite upper bounds.

**vtype:** Types for the variables. Options are `GRB_CONTINUOUS`, `GRB_BINARY`, `GRB_INTEGER`, `GRB_SEMICONT`, or `GRB_SEMIINT`. This argument can be `NULL`, in which case all variables are assumed to be continuous.

**varnames:** Names for the new variables. This argument can be `NULL`, in which case all variables are given default names.

**constrnames:** Names for the new constraints. This argument can be `NULL`, in which case all constraints are given default names.

### Important notes:

We recommend that you build a model one constraint or one variable at a time, using [GRBadconstr](#) or [GRBaddvar](#), rather than using this routine to load the entire constraint matrix at once. It is much simpler, less error prone, and it introduces no significant overhead.

### Example usage:

```

/* maximize    x +   y + 2 z
   subject to  x + 2 y + 3 z <= 4
              x +   y           >= 1
   x, y, z binary */

int   vars    = 3;
int   constrs = 2;

```

```

int    vbegin[] = {0, 2, 4};
int    vlen[]   = {2, 2, 1};
int    vind[]   = {0, 1, 0, 1, 0};
double vval[]   = {1.0, 1.0, 2.0, 1.0, 3.0};
double obj[]    = {1.0, 1.0, 2.0};
char   sense[]  = {GRB_LESS_EQUAL, GRB_GREATER_EQUAL};
double rhs[]    = {4.0, 1.0};
char   vtype[]  = {GRB_BINARY, GRB_BINARY, GRB_BINARY};

error = GRBloadmodel(env, &model, "example", vars, constra, -1, 0.0,
                    obj, sense, rhs, vbegin, vlen, vind, vval,
                    NULL, NULL, vtype, NULL, NULL);

```

## GRBnewmodel

```

int GRBnewmodel ( GRBenv      *env,
                  GRBmodel    **modelP,
                  const char  *Pname,
                  int         numvars,
                  double      *obj,
                  double      *lb,
                  double      *ub,
                  char        *vtype,
                  const char  **varnames )

```

Create a new optimization model. This routine allows you to specify an initial set of variables (with objective coefficients, bounds, types, and names), but the initial model will have no constraints. Constraints can be added later with [GRBaddconstr](#) or [GRBaddconstrs](#).

### Return value:

A non-zero return value indicates that a problem occurred while creating the new model. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**env:** The environment in which the new model should be created. Note that the new model will get a copy of this environment, so subsequent modifications to the original environment (e.g., parameter changes) won't affect the new model. Use [GRBgetenv](#) to modify the environment associated with a model.

**modelP:** The location in which the pointer to the new model should be placed.

**Pname:** The name of the model.

**numvars:** The number of variables in the model.

**obj:** Objective coefficients for the new variables. This argument can be NULL, in which case the objective coefficients are set to 0.0.

**lb:** Lower bounds for the new variables. This argument can be NULL, in which case all variables get lower bounds of 0.0.

**ub:** Upper bounds for the new variables. This argument can be NULL, in which case all variables get infinite upper bounds.

**vtype:** Types for the variables. Options are `GRB_CONTINUOUS`, `GRB_BINARY`, `GRB_INTEGER`, `GRB_SEMICONT`, or `GRB_SEMIINT`. This argument can be `NULL`, in which case all variables are assumed to be continuous.

**varnames:** Names for the new variables. This argument can be `NULL`, in which case all variables are given default names.

**Example usage:**

```
double obj[] = {1.0, 1.0};
char *names[] = {"var1", "var2"};
error = GRBnewmodel(env, &model, "New", 2, obj, NULL, NULL, NULL, names);
```

## GRBcopymodel

```
GRBmodel * GRBcopymodel ( GRBmodel *model )
```

Create a copy of an existing model.

**Return value:**

A copy of the input model. A `NULL` return value indicates that a problem was encountered.

**Arguments:**

**model:** The model to copy.

**Example usage:**

```
GRBmodel *copy = GRBcopymodel(orig);
```

## GRBaddconstr

```
int GRBaddconstr ( GRBmodel *model,
                  int numnz,
                  int *cind,
                  double *cval,
                  char sense,
                  double rhs,
                  const char *constrname )
```

Add a new linear constraint to a model. Note that, due to our lazy update approach, the new constraint won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

**Return value:**

A non-zero return value indicates that a problem occurred while adding the constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**model:** The model to which the new constraint should be added.

**numnz:** The number of non-zero coefficients in the new constraint.

**cind:** Variable indices for non-zero values in the new constraint.

**cval:** Numerical values for non-zero values in the new constraint.

**sense:** Sense for the new constraint. Options are `GRB_LESS_EQUAL`, `GRB_EQUAL`, or `GRB_GREATER_EQUAL`.

**rhs:** Right-hand-side value for the new constraint.

**constrname:** Name for the new constraint. This argument can be NULL, in which case the constraint is given a default name.

**Example usage:**

```
int    ind[] = {1, 3, 4};
double val[] = {1.0, 2.0, 1.0};
/* x1 + 2 x3 + x4 = 1 */
error = GRBaddconstr(model, 3, ind, val, GRB_EQUAL, 1.0, "New");
```

## GRBaddconstrs

```
int GRBaddconstrs ( GRBmodel *model,
                   int      numconstrs,
                   int      numnz,
                   int      *cbeg,
                   int      *cind,
                   double   *cval,
                   char     *sense,
                   double   *rhs,
                   const char **constrnames )
```

Add new linear constraints to a model. Note that, due to our lazy update approach, the new constraints won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

We recommend that you build your model one constraint at a time (using [GRBaddconstr](#)), since it introduces no significant overhead and we find that it produces simpler code. Feel free to use this routine if you disagree, though.

If your constraint matrix may contain more than 2 billion non-zero values, you should consider using the [GRBXaddconstrs](#) variant of this routine.

**Return value:**

A non-zero return value indicates that a problem occurred while adding the constraints. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**model:** The model to which the new constraints should be added.

**numconstrs:** The number of new constraints to add.

**numnz:** The total number of non-zero coefficients in the new constraints.

**cbeg:** Constraint matrix non-zero values are passed into this routine in Compressed Sparse Row (CSR) format by this routine. Each constraint in the constraint matrix is represented as a list of index-value pairs, where each index entry provides the variable index for a non-zero coefficient, and each value entry provides the corresponding non-zero value. Each new constraint has an associated **cbeg** value, indicating the start position of the non-zeros for that constraint in the **cind** and **cval** arrays. This routine requires that the non-zeros for constraint *i* immediately follow those for constraint *i-1* in **cind** and **cval**. Thus, **cbeg[i]** indicates both the index of the first non-zero in constraint *i* and the end of the non-zeros for constraint *i-1*. To give an example of how this representation is used, consider a case where **cbeg[2] = 10** and **cbeg[3] = 12**. This would indicate that constraint 2 has two non-zero values associated with it. Their variable indices can be found in **cind[10]** and

`cind[11]`, and the numerical values for those non-zeros can be found in `cval[10]` and `cval[11]`.

**cind**: Variable indices associated with non-zero values. See the description of the `cbeg` argument for more information.

**cval**: Numerical values associated with constraint matrix non-zeros. See the description of the `cbeg` argument for more information.

**sense**: Sense for the new constraints. Options are `GRB_LESS_EQUAL`, `GRB_EQUAL`, or `GRB_GREATER_EQUAL`.

**rhs**: Right-hand-side values for the new constraints. This argument can be `NULL`, in which case the right-hand-side values are set to `0.0`.

**constrnames**: Names for the new constraints. This argument can be `NULL`, in which case all constraints are given default names.

## GRBaddgenconstrXxx

Each of the functions described below adds a new *general constraint* to a model.

Mathematical programming has traditionally defined a set of fundamental constraint types: variable bound constraints, linear constraints, quadratic constraints, integrality constraints, and SOS constraints. These are typically treated directly by the underlying solver (although not always), and are fundamental to the overall algorithm.

Gurobi accepts a number of additional constraint types, which we collectively refer to as *general constraints*. These are typically *not* treated directly by the solver. Rather, they are transformed by presolve into mathematically equivalent sets of constraints (and variables), chosen from among the fundamental types listed above. These general constraints are provided as a convenience to users. If such constraints appear in your model, but if you prefer to reformulate them yourself using fundamental constraint types instead, you can certainly do so. However, note that Gurobi can sometimes exploit information contained in the other constraints in the model to build a more efficient formulation than what you might create.

The additional constraint types that fall under this *general constraint* umbrella are:

- MAX ([GRBaddgenconstrMax](#)): set a decision variable equal to the maximum value from among a set of decision variables
- MIN ([GRBaddgenconstrMin](#)): set a decision variable equal to the minimum value from among a set of decision variables
- ABS ([GRBaddgenconstrAbs](#)): set a decision variable equal to the absolute value of some other decision variable
- AND ([GRBaddgenconstrAnd](#)): set a binary variable equal to one if and only if all of a set of binary decision variables are equal to one
- OR ([GRBaddgenconstrOr](#)): set a binary variable equal to one if and only if at least one variable out of a set of binary decision variables is equal to one
- INDICATOR ([GRBaddgenconstrIndicator](#)): a given binary variable may only take a certain value if a given linear constraint is satisfied

Please refer to [this section](#) for additional details on general constraints.

## GRBaddgenconstrMax

```
int GRBaddgenconstrMax ( GRBmodel    *model,
                        const char  *name,
                        int         resvar,
                        int         nvars,
                        int*        vars,
                        double      constant )
```

Add a new general constraint of type `GRB_GENCONSTR_MAX` to a model. Note that, due to our lazy update approach, the new constraint won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

A MAX constraint  $r = \max\{x_1, \dots, x_n, c\}$  states that the resultant variable  $r$  should be equal to the maximum of the operand variables  $x_1, \dots, x_n$  and the constant  $c$ .

### Return value:

A non-zero return value indicates that a problem occurred while adding the general constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model to which the new general constraint should be added.

**name:** Name for the new general constraint. This argument can be `NULL`, in which case the constraint is given a default name.

**int resvar:** The index of the resultant variable  $r$  whose value will be equal to the max of the other variables.

**int nvars:** The number  $n$  of operand variables over which the max will be taken.

**const int \*vars:** An array containing the indices of the operand variables  $x_j$  over which the max will be taken.

**double constant:** An additional operand that allows you to include a constant  $c$  among the arguments of the max operation.

### Example usage:

```
/* x5 = max(x1, x3, x4, 2.0) */
int ind[] = {1, 3, 4};
error = GRBaddgenconstrMax(model, "maxconstr", 5,
                          3, ind, 2.0);
```

## GRBaddgenconstrMin

```
int GRBaddgenconstrMin ( GRBmodel    *model,
                        const char  *name,
                        int         resvar,
                        int         nvars,
                        int*        vars,
                        double      constant )
```

Add a new general constraint of type `GRB_GENCONSTR_MIN` to a model. Note that, due to our lazy update approach, the new constraint won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

A MIN constraint  $r = \min\{x_1, \dots, x_n, c\}$  states that the resultant variable  $r$  should be equal to the minimum of the operand variables  $x_1, \dots, x_n$  and the constant  $c$ .

**Return value:**

A non-zero return value indicates that a problem occurred while adding the general constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** The model to which the new general constraint should be added.

**name:** Name for the new general constraint. This argument can be NULL, in which case the constraint is given a default name.

**int resvar:** The index of the resultant variable  $r$  whose value will be equal to the min of the other variables.

**int nvars:** The number  $n$  of operand variables over which the min will be taken.

**const int \*vars:** An array containing the indices of the operand variables  $x_j$  over which the min will be taken.

**double constant:** An additional operand that allows you to include a constant  $c$  among the arguments of the min operation.

**Example usage:**

```
/* x5 = min(x1, x3, x4, 2.0) */
int ind[] = {1, 3, 4};
error = GRBaddgenconstrMin(model, "minconstr", 5,
                           3, ind, 2.0);
```

## GRBaddgenconstrAbs

```
int GRBaddgenconstrAbs ( GRBmodel    *model,
                        const char  *name,
                        int         resvar,
                        int         argvar )
```

Add a new general constraint of type `GRB_GENCONSTR_ABS` to a model. Note that, due to our lazy update approach, the new constraint won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

An ABS constraint  $r = \text{abs}\{x\}$  states that the resultant variable  $r$  should be equal to the absolute value of the argument variable  $x$ .

**Return value:**

A non-zero return value indicates that a problem occurred while adding the general constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** The model to which the new general constraint should be added.

**name:** Name for the new general constraint. This argument can be NULL, in which case the constraint is given a default name.

**int resvar:** The index of the resultant variable  $r$  whose value will be to equal the absolute value of the argument variable.

**int argvar:** The index of the argument variable  $x$  for which the absolute value will be taken.

**Example usage:**

```
/* x5 = abs(x1) */  
error = GRBaddgenconstrAbs(model, "absconstr", 5, 1);
```

## GRBaddgenconstrAnd

```
int GRBaddgenconstrAnd ( GRBmodel *model,  
                        const char *name,  
                        int resvar,  
                        int nvars,  
                        int* vars )
```

Add a new general constraint of type `GRB_GENCONSTR_AND` to a model. Note that, due to our lazy update approach, the new constraint won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

An AND constraint  $r = \text{and}\{x_1, \dots, x_n\}$  states that the binary resultant variable  $r$  should be 1 if and only if all of the operand variables  $x_1, \dots, x_n$  are equal to 1. If any of the operand variables is 0, then the resultant should be 0 as well.

Note that all variables participating in such a constraint will be forced to be binary; independently of how they were created.

**Arguments:**

**model:** The model to which the new general constraint should be added.

**name:** Name for the new general constraint. This argument can be NULL, in which case the constraint is given a default name.

**int resvar:** The index of the binary resultant variable  $r$  whose value will be equal to the AND concatenation of the other variables.

**int nvars:** The number  $n$  of binary operand variables over which the AND will be taken.

**const int \*vars:** An array containing the indices of the binary operand variables  $x_j$  over which the AND concatenation will be taken.

**Return value:**

A non-zero return value indicates that a problem occurred while adding the general constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Example usage:**

```
/* x5 = and(x1, x3, x4) */  
int ind[] = {1, 3, 4};  
error = GRBaddgenconstrAnd(model, "andconstr", 5, 3, ind);
```

## GRBaddgenconstrOr

```
int GRBaddgenconstrOr ( GRBmodel *model,  
                       const char *name,  
                       int resvar,  
                       int nvars,  
                       int* vars )
```

Add a new general constraint of type `GRB_GENCONSTR_OR` to a model. Note that, due to our lazy update approach, the new constraint won't actually be added until you update the model (using `GRBupdatemodel`), optimize the model (using `GRBoptimize`), or write the model to disk (using `GRBwrite`).

An OR constraint  $r = \text{or}\{x_1, \dots, x_n\}$  states that the binary resultant variable  $r$  should be 1 if and only if any of the operand variables  $x_1, \dots, x_n$  is equal to 1. If all operand variables are 0, then the resultant should be 0 as well.

Note that all variables participating in such a constraint will be forced to be binary; independently of how they were created.

**Arguments:**

**model:** The model to which the new general constraint should be added.

**name:** Name for the new general constraint. This argument can be `NULL`, in which case the constraint is given a default name.

**int resvar:** The index of the binary resultant variable  $r$  whose value will be equal to the OR concatenation of the other variables.

**int nvars:** The number  $n$  of binary operand variables over which the OR will be taken.

**const int \*vars:** An array containing the indices of the binary operand variables  $x_j$  over which the OR concatenation will be taken.

**Return value:**

A non-zero return value indicates that a problem occurred while adding the general constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling `GRBgeterrormsg`.

**Example usage:**

```
/* x5 = or(x1, x3, x4) */
int ind[] = {1, 3, 4};
error = GRBaddgenconstrOr(model, "orconstr", 5, 3, ind);
```

## GRBaddgenconstrIndicator

```
int GRBaddgenconstrIndicator ( GRBmodel    *model,
                              const char  *name,
                              int         binvar,
                              int         binval,
                              int         nvars,
                              int*        ind,
                              double*    val,
                              char        sense,
                              double      rhs )
```

Add a new general constraint of type `GRB_GENCONSTR_INDICATOR` to a model. Note that, due to our lazy update approach, the new constraint won't actually be added until you update the model (using `GRBupdatemodel`), optimize the model (using `GRBoptimize`), or write the model to disk (using `GRBwrite`).

An INDICATOR constraint  $z = f \rightarrow a^T x \leq b$  states that if the binary indicator variable  $z$  is equal to  $f \in \{0, 1\}$ , then the linear constraint  $a^T x \leq b$  should hold. On the other hand, if  $z = 1 - f$ , the linear constraint may be violated. The sense of the linear constraint can also be specified to be “=” or “≥”.

Note that the indicator variable  $z$  of a constraint will be forced to be binary; independently of how it was created.

**Arguments:**

- model:** The model to which the new general constraint should be added.
- name:** Name for the new general constraint. This argument can be NULL, in which case the constraint is given a default name.
- int binvar:** The index of the binary indicator variable  $z$ .
- int binval:** The value  $f$  for the binary indicator variable that would force the linear constraint to be satisfied (0 or 1).
- int nvars:** The number  $n$  of non-zero coefficients in the linear constraint triggered by the indicator.
- const int \*ind:** Indices for the variables  $x_j$  with non-zero values in the linear constraint.
- const double \*val:** Numerical values for non-zero values  $a_j$  in the linear constraint.
- char sense:** Sense for the linear constraint. Options are GRB\_LESS\_EQUAL, GRB\_EQUAL, or GRB\_GREATER\_EQUAL.
- double rhs:** Right-hand-side value for the linear constraint.

**Return value:**

A non-zero return value indicates that a problem occurred while adding the general constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Example usage:**

```
/* x7 = 1 -> x1 + 2 x3 + x4 = 1 */
int    ind[] = {1, 3, 4};
double val[] = {1.0, 2.0, 1.0};
error = GRBaddgenconstrIndicator(model, NULL, 7, 1,
                                3, ind, val, GRB_EQUAL, 1.0);
```

## GRBaddqconstr

```
int GRBaddqconstr ( GRBmodel    *model,
                   int          numlnz,
                   int          *lind,
                   double       *lval,
                   int          numqnz,
                   int          *qrow,
                   int          *qcol,
                   double       *qval,
                   char         sense,
                   double       rhs,
                   const char   *constrname )
```

Add a new quadratic constraint to a model. Note that, due to our lazy update approach, the new constraint won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

A quadratic constraint consists of a set of quadratic terms, a set of linear terms, a sense, and a right-hand side value:  $x^T Qx + q^T x \leq b$ . The quadratic terms are input through the `numqnz`, `qrow`,

`qcol`, and `qval` arguments, and the linear terms are input through the `numlnz`, `lind`, and `lval` arguments.

Important note: the algorithms Gurobi uses to solve quadratically constrained problems can only handle certain types of quadratic constraints. Constraints of the following forms are always accepted:

- $x^T Q x + q^T x \leq b$ , where  $Q$  is Positive Semi-Definite (PSD)
- $x^T x \leq y^2$ , where  $x$  is a vector of variables, and  $y$  is a non-negative variable (a Second-Order Cone)
- $x^T x \leq yz$ , where  $x$  is a vector of variables, and  $y$  and  $z$  are non-negative variables (a rotated Second-Order Cone)

If you add a constraint that isn't in one of these forms (and Gurobi presolve is unable to transform the constraint into one of these forms), you'll get an error when you try to solve the model. Constraints where the quadratic terms only involve binary variables will always be transformed into one of these forms.

**Return value:**

A non-zero return value indicates that a problem occurred while adding the quadratic constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling `GRBgeterrormsg`.

**Arguments:**

**model:** The model to which the new constraint should be added.

**numlnz:** The number of linear terms in the new quadratic constraint.

**lind:** Variable indices associated with linear terms.

**lval:** Numerical values associated with linear terms.

**numqlnz:** The number of quadratic terms in the new quadratic constraint.

**qrow:** Row indices associated with quadratic terms. A quadratic term is represented using three values: a pair of indices (stored in `qrow` and `qcol`), and a coefficient (stored in `qval`).

The associated arguments arrays provide the corresponding values for each quadratic term.

To give an example, if you wish to input quadratic terms  $2x_0^2 + x_0x_1 + x_1^2$ , you would call this routine with `numqnz=3`, `qrow[] = {0, 0, 1}`, `qcol[] = {0, 1, 1}`, and `qval[] = {2.0, 1.0, 1.0}`.

**qcol:** Column indices associated with quadratic terms. See the description of the `qrow` argument for more information.

**qval:** Numerical values associated with quadratic terms. See the description of the `qrow` argument for more information.

**sense:** Sense for the new quadratic constraint. Options are `GRB_LESS_EQUAL` or `GRB_GREATER_EQUAL`.

**rhs:** Right-hand-side value for the new quadratic constraint.

**constrname:** Name for the new quadratic constraint. This argument can be `NULL`, in which case the constraint is given a default name.

**Example usage:**

```
int    lind[] = {1, 2};
double lval[] = {2.0, 1.0};
int    qrow[] = {0, 0, 1};
```

```

int    qcol[] = {0, 1, 1};
double qval[] = {2.0, 1.0, 1.0};
/* 2 x0^2 + x0 x1 + x1^2 + 2 x1 + x2 <= 1 */
error = GRBaddqconstr(model, 2, lind, lval, 3, qrow, qcol, qval,
                    GRB_LESS_EQUAL, 1.0, "New");

```

## GRBaddqpterm

```

int GRBaddqpterm ( GRBmodel *model,
                  int      numqnz,
                  int      *qrow,
                  int      *qcol,
                  double   *qval )

```

Add new quadratic objective terms into an existing model. Note that new terms are (numerically) added into existing terms, and that adding a term in row *i* and column *j* is equivalent to adding a term in row *j* and column *i*. You can add all quadratic objective terms in a single call, or you can add them incrementally in multiple calls.

Note that, due to our lazy update approach, the new quadratic terms won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

To build an objective that contains both linear and quadratic terms, use this routine to add the quadratic terms and use the [Obj](#) attribute to add the linear terms.

If you wish to change a quadratic term, you can either add the difference between the current term and the desired term using this routine, or you can call [GRBdelq](#) to delete all quadratic terms, and then rebuild your new quadratic objective from scratch.

### Return value:

A non-zero return value indicates that a problem occurred while adding the quadratic terms. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**model:** The model to which the new quadratic objective terms should be added.

**numqnz:** The number of new quadratic objective terms to add.

**qrow:** Row indices associated with quadratic terms. A quadratic term is represented using three values: a pair of indices (stored in **qrow** and **qcol**), and a coefficient (stored in **qval**).

The three argument arrays provide the corresponding values for each quadratic term. To give an example, if you wish to input quadratic objective  $2x_0^2 + x_0x_1 + x_1^2$ , you would call this routine with **numqnz**=3, **qrow**[] = {0, 0, 1}, **qcol**[] = {0, 1, 1}, and **qval**[] = {2.0, 1.0, 1.0}.

**qcol:** Column indices associated with quadratic terms. See the description of the **qrow** argument for more information.

**qval:** Numerical values associated with quadratic terms. See the description of the **qrow** argument for more information.

### Important notes:

Note that building quadratic objectives requires some care, particularly if you are migrating an application from another solver. Some solvers require you to specify the entire *Q* matrix, while others only accept the lower triangle. In addition, some solvers include an implicit 0.5 multiplier

on  $Q$ , while others do not. The Gurobi interface is built around quadratic terms, rather than a  $Q$  matrix. If your quadratic objective contains a term  $2 x y$ , you can enter it as a single term,  $2 x y$ , or as a pair of terms,  $x y$  and  $y x$ .

**Example usage:**

```
int    qrow[] = {0, 0, 1};
int    qcol[] = {0, 1, 1};
double qval[] = {2.0, 1.0, 3.0};
/* minimize 2 x^2 + x*y + 3 y^2 */
error = GRBaddqpterm(model, 3, qrow, qcol, qval);
```

## GRBaddrangeconstr

```
int GRBaddrangeconstr ( GRBmodel    *model,
                        int          numnz,
                        int          *cind,
                        double       *cval,
                        double       lower,
                        double       upper,
                        const char   *constrname )
```

Add a new range constraint to a model. A range constraint states that the value of the input expression must be between the specified **lower** and **upper** bounds in any solution. Note that, due to our lazy update approach, the new constraint won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

**Return value:**

A non-zero return value indicates that a problem occurred while adding the constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

- model**: The model to which the new constraint should be added.
- numnz**: The number of non-zero coefficients in the linear expression.
- cind**: Variable indices for non-zero values in the linear expression.
- cval**: Numerical values for non-zero values in the linear expression.
- lower**: Lower bound on linear expression.
- upper**: Upper bound on linear expression.
- constrname**: Name for the new constraint. This argument can be NULL, in which case the constraint is given a default name.

**Important notes:**

Note that adding a range constraint to the model adds both a new constraint and a new variable. If you are keeping a count of the variables in the model, remember to add one whenever you add a range.

Note also that range constraints are stored internally as equality constraints. We use the extra variable that is added with a range constraint to capture the range information. Thus, the [Sense](#) attribute on a range constraint will always be `GRB_EQUAL`.

**Example usage:**

```

int    ind[] = {1, 3, 4};
double val[] = {1.0, 2.0, 3.0};
/* 1 <= x1 + 2 x3 + 3 x4 <= 2 */
error = GRBaddrangeconstr(model, 3, ind, val, 1.0, 2.0, "NewRange");

```

## GRBaddrangeconstrs

```

int  GRBaddrangeconstrs (  GRBmodel    *model,
                           int         numconstrs,
                           int         numnz,
                           int         *cbeg,
                           int         *cind,
                           double      *cval,
                           double      *lower,
                           double      *upper,
                           const char  **constrnames )

```

Add new range constraints to a model. A range constraint states that the value of the input expression must be between the specified `lower` and `upper` bounds in any solution. Note that, due to our lazy update approach, the new constraints won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

If your constraint matrix may contain more than 2 billion non-zero values, you should consider using the [GRBXaddrangeconstrs](#) variant of this routine.

### Return value:

A non-zero return value indicates that a problem occurred while adding the constraints. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model to which the new constraints should be added.

**numconstrs:** The number of new constraints to add.

**numnz:** The total number of non-zero coefficients in the new constraints.

**cbeg:** Constraint matrix non-zero values are passed into this routine in Compressed Sparse Row (CSR) format by this routine. Each constraint in the constraint matrix is represented as a list of index-value pairs, where each index entry provides the variable index for a non-zero coefficient, and each value entry provides the corresponding non-zero value. Each new constraint has an associated `cbeg` value, indicating the start position of the non-zeros for that constraint in the `cind` and `cval` arrays. This routine requires that the non-zeros for constraint `i` immediately follow those for constraint `i-1` in `cind` and `cval`. Thus, `cbeg[i]` indicates both the index of the first non-zero in constraint `i` and the end of the non-zeros for constraint `i-1`. To give an example of how this representation is used, consider a case where `cbeg[2] = 10` and `cbeg[3] = 12`. This would indicate that constraint 2 has two non-zero values associated with it. Their variable indices can be found in `cind[10]` and `cind[11]`, and the numerical values for those non-zeros can be found in `cval[10]` and `cval[11]`.

**cind:** Variable indices associated with non-zero values. See the description of the `cbeg` argument for more information.

**cval:** Numerical values associated with constraint matrix non-zeros. See the description of the `cbeg` argument for more information.

**lower:** Lower bounds for the linear expressions.

**upper:** Upper bounds for the linear expressions.

**constrnames:** Names for the new constraints. This argument can be NULL, in which case all constraints are given default names.

**Important notes:**

Note that adding a range constraint to the model adds both a new constraint and a new variable. If you are keeping a count of the variables in the model, remember to add one for each range constraint.

Note also that range constraints are stored internally as equality constraints. We use the extra variable that is added with a range constraint to capture the range information. Thus, the `Sense` attribute on a range constraint will always be `GRB_EQUAL`.

**GRBaddsos**

```
int GRBaddsos ( GRBmodel *model,
               int      numsos,
               int      nummembers,
               int      *types,
               int      *beg,
               int      *ind,
               double   *weight )
```

Add new Special Ordered Set (SOS) constraints to a model. Note that, due to our lazy update approach, the new SOS constraints won't actually be added until you update the model (using `GRBupdatemodel`), optimize the model (using `GRBoptimize`), or write the model to disk (using `GRBwrite`).

Please refer to [this section](#) for details on SOS constraints.

**Return value:**

A non-zero return value indicates that a problem occurred while adding the SOS constraints. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling `GRBgeterrmsg`.

**Arguments:**

- model:** The model to which the new SOSs should be added.
- numsos:** The number of new SOSs to add.
- nummembers:** The total number of SOS members in the new SOSs.
- types:** The types of the SOS sets. SOS sets can be of type `GRB_SOS_TYPE1` or `GRB_SOS_TYPE2`.
- beg:** The members of the added SOS sets are passed into this routine in Compressed Sparse Row (CSR) format. Each SOS is represented as a list of index-value pairs, where each index entry provides the variable index for an SOS member, and each value entry provides the weight of that variable in the corresponding SOS set. Each new SOS has an associated **beg** value, indicating the start position of the SOS member list in the **ind** and **weight** arrays. This routine requires that the members for SOS *i* immediately follow those for

SOS  $i-1$  in `ind` and `weight`. Thus, `beg[i]` indicates both the index of the first non-zero in constraint  $i$  and the end of the non-zeros for constraint  $i-1$ . To give an example of how this representation is used, consider a case where `beg[2] = 10` and `beg[3] = 12`. This would indicate that SOS number 2 has two members. Their variable indices can be found in `ind[10]` and `ind[11]`, and the associated weights can be found in `weight[10]` and `weight[11]`.

**ind:** Variable indices associated with SOS members. See the description of the `beg` argument for more information.

**weight:** Weights associated with SOS members. See the description of the `beg` argument for more information.

**Example usage:**

```
int    types[] = {GRB_SOS_TYPE1, GRB_SOS_TYPE1};
int    beg[]   = {0, 2};
int    ind[]   = {1, 2, 1, 3};
double weight[] = {1, 2, 1, 2};
error = GRBaddsos(model, 2, 4, types, beg, ind, weight);
```

## GRBaddvar

```
int GRBaddvar ( GRBmodel *model,
               int      numnz,
               int      *vind,
               double   *vval,
               double   obj,
               double   lb,
               double   ub,
               char      vtype,
               const char *varname )
```

Add a new variable to a model. Note that, due to our lazy update approach, the new variable won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

**Return value:**

A non-zero return value indicates that a problem occurred while adding the variable. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

- model:** The model to which the new variable should be added.
- numnz:** The number of non-zero coefficients in the new column.
- vind:** Constraint indices associated with non-zero values for the new variable.
- vval:** Numerical values associated with non-zero values for the new variable.
- obj:** Objective coefficient for the new variable.
- lb:** Lower bound for the new variable.
- ub:** Upper bound for the new variable.
- vtype:** Type for the new variable. Options are `GRB_CONTINUOUS`, `GRB_BINARY`, `GRB_INTEGER`, `GRB_SEMICONT`, or `GRB_SEMIINT`.

**varname:** Name for the new variable. This argument can be NULL, in which case the variable is given a default name.

**Example usage:**

```
int    ind[] = {1, 3, 4};
double val[] = {1.0, 1.0, 1.0};
error = GRBaddvar(model, 3, ind, val, 1.0, 0.0, GRB_INFINITY,
                 GRB_CONTINUOUS, "New");
```

## GRBaddvars

```
int  GRBaddvars ( GRBmodel    *model,
                  int         numvars,
                  int         numnz,
                  int         *vbeg,
                  int         *vind,
                  double      *vval,
                  double      *obj,
                  double      *lb,
                  double      *ub,
                  char        *vtype,
                  const char  **varnames )
```

Add new variables to a model. Note that, due to our lazy update approach, the new variables won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

If your constraint matrix may contain more than 2 billion non-zero values, you should consider using the [GRBXaddvars](#) variant of this routine.

**Return value:**

A non-zero return value indicates that a problem occurred while adding the variables. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**model:** The model to which the new variables should be added.

**numvars:** The number of new variables to add.

**numnz:** The total number of non-zero coefficients in the new columns.

**vbeg:** Constraint matrix non-zero values are passed into this routine in Compressed Sparse Column (CSC) format. Each column in the constraint matrix is represented as a list of index-value pairs, where each index entry provides the constraint index for a non-zero coefficient, and each value entry provides the corresponding non-zero value. Each variable in the model has a **vbeg**, indicating the start position of the non-zeros for that variable in the **vind** and **vval** arrays. This routine requires columns to be stored contiguously, so the start position for a variable is the end position for the previous variable. To give an example, if **vbeg**[2] = 10 and **vbeg**[3] = 12, that would indicate that variable 2 has two non-zero values associated with it. Their constraint indices can be found in **vind**[10] and **vind**[11], and the numerical values for those non-zeros can be found in **vval**[10] and **vval**[11].

- vind:** Constraint indices associated with non-zero values. See the description of the `vbeg` argument for more information.
- vval:** Numerical values associated with constraint matrix non-zeros. See the description of the `vbeg` argument for more information.
- obj:** Objective coefficients for the new variables. This argument can be `NULL`, in which case the objective coefficients are set to `0.0`.
- lb:** Lower bounds for the new variables. This argument can be `NULL`, in which case all variables get lower bounds of `0.0`.
- ub:** Upper bounds for the new variables. This argument can be `NULL`, in which case all variables get infinite upper bounds.
- vtype:** Types for the variables. Options are `GRB_CONTINUOUS`, `GRB_BINARY`, `GRB_INTEGER`, `GRB_SEMICONT`, or `GRB_SEMIINT`. This argument can be `NULL`, in which case all variables are assumed to be continuous.
- varnames:** Names for the new variables. This argument can be `NULL`, in which case all variables are given default names.

## GRBchgcoeffs

```
int GRBchgcoeffs ( GRBmodel *model,
                  int      numchgs,
                  int      *cind,
                  int      *vind,
                  double   *val )
```

Change a set of constraint matrix coefficients. This routine can be used to set a non-zero coefficient to zero, to create a non-zero coefficient where the coefficient is currently zero, or to change an existing non-zero coefficient to a new non-zero value. If you make multiple changes to the same coefficient, the last one will be applied.

Note that, due to our lazy update approach, the changes won't actually be integrated into the model until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

If your constraint matrix may contain more than 2 billion non-zero values, you should consider using the [GRBXchgcoeffs](#) variant of this routine.

### Return value:

A non-zero return value indicates that a problem occurred while performing the modification. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

- model:** The model to modify.
- numchgs:** The number of coefficients to modify.
- cind:** Constraint indices for the coefficients to modify.
- vind:** Variable indices for the coefficients to modify.
- val:** The new values for the coefficients. For example, if `cind[0] = 1`, `vind[0] = 3`, and `val[0] = 2.0`, then the coefficient in constraint 1 associated with variable 3 would be changed to 2.0.

### Example usage:

```
int cind[] = {0, 1};
int vind[] = {0, 0};
double val[] = {1.0, 1.0};
error = GRBchgcoeffs(model, 2, cind, vind, val);
```

## GRBdelconstrs

```
int GRBdelconstrs ( GRBmodel *model,
                   int      numdel,
                   int      *ind )
```

Delete a list of constraints from an existing model. Note that, due to our lazy update approach, the constraints won't actually be removed until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

### Return value:

A non-zero return value indicates that a problem occurred while deleting the constraints. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model to modify.  
**numdel:** The number of constraints to remove.  
**ind:** The indices of the constraints to remove.

### Example usage:

```
int first_four[] = {0, 1, 2, 3};
error = GRBdelconstrs(model, 4, first_four);
```

## GRBdelgenconstrs

```
int GRBdelgenconstrs ( GRBmodel *model,
                      int      numdel,
                      int      *ind )
```

Delete a list of general constraints from an existing model. Note that, due to our lazy update approach, the general constraints won't actually be removed until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

### Return value:

A non-zero return value indicates that a problem occurred while deleting the constraints. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model to modify.  
**numdel:** The number of general constraints to remove.  
**ind:** The indices of the general constraints to remove.

### Example usage:

```
int first_four[] = {0, 1, 2, 3};
error = GRBdelgenconstrs(model, 4, first_four);
```

## GRBdelq

```
int GRBdelq ( GRBmodel *model )
```

Delete all quadratic objective terms from an existing model. Note that, due to our lazy update approach, the quadratic terms won't actually be removed until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

### Return value:

A non-zero return value indicates that a problem occurred while deleting the quadratic objective terms. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model to modify.

### Example usage:

```
error = GRBdelq(model);
```

## GRBdelqconstrs

```
int GRBdelqconstrs ( GRBmodel *model,
                    int      numdel,
                    int      *ind )
```

Delete a list of quadratic constraints from an existing model. Note that, due to our lazy update approach, the quadratic constraints won't actually be removed until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

### Return value:

A non-zero return value indicates that a problem occurred while deleting the quadratic constraints. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model to modify.

**numdel:** The number of quadratic constraints to remove.

**ind:** The indices of the quadratic constraints remove.

### Example usage:

```
int first_four[] = {0, 1, 2, 3};
error = GRBdelqconstrs(model, 4, first_four);
```

## GRBdelsos

```
int GRBdelsos ( GRBmodel *model,
               int      numdel,
               int      *ind )
```

Delete a list of Special Ordered Set (SOS) constraints from an existing model. Note that, due to our lazy update approach, the SOS constraints won't actually be removed until you update the

model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

**Return value:**

A non-zero return value indicates that a problem occurred while deleting the constraints. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** The model to modify.  
**numdel:** The number of SOSs to remove.  
**ind:** The indices of the SOSs to remove.

**Example usage:**

```
int first_four[] = {0, 1, 2, 3};  
error = GRBdelsos(model, 4, first_four);
```

## GRBdelvars

```
int GRBdelvars ( GRBmodel *model,  
                int      numdel,  
                int      *ind )
```

Delete a list of variables from an existing model. Note that, due to our lazy update approach, the variables won't actually be removed until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

**Return value:**

A non-zero return value indicates that a problem occurred while deleting the variables. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** The model to modify.  
**numdel:** The number of variables to remove.  
**ind:** The indices of the variables to remove.

**Example usage:**

```
int first_two[] = {0, 1};  
error = GRBdelvars(model, 2, first_two);
```

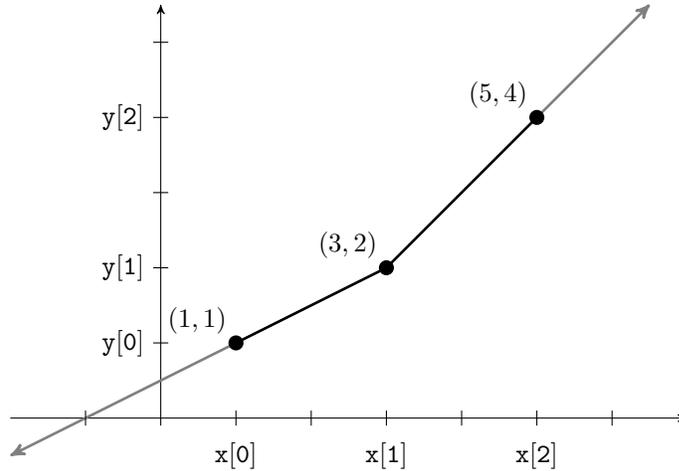
## GRBsetpwlobj

```
int GRBsetpwlobj ( GRBmodel *model,  
                  int      var,  
                  int      npoints,  
                  double   *x,  
                  double   *y )
```

Set a piecewise-linear objective function for a variable.

The arguments to this method specify a list of points that define a piecewise-linear objective function for a single variable. Specifically, the  $x$  and  $y$  arguments give coordinates for the vertices of the function.

For example, suppose we want to define the function  $f(x)$  shown below:



The vertices of the function occur at the points (1, 1), (3, 2) and (5, 4), so `npoints` is 3, `x` is {1, 3, 5}, and `y` is {1, 2, 4}. With these arguments we define  $f(1) = 1$ ,  $f(3) = 2$  and  $f(5) = 4$ . Other objective values are linearly interpolated between neighboring points. The first pair and last pair of points each define a ray, so values outside the specified  $x$  values are extrapolated from these points. Thus, in our example,  $f(-1) = 0$  and  $f(6) = 5$ .

More formally, a set of  $n$  points

$$\mathbf{x} = \{x_1, \dots, x_n\}, \quad \mathbf{y} = \{y_1, \dots, y_n\}$$

define the following piecewise-linear function:

$$f(v) = \begin{cases} y_1 + \frac{y_2 - y_1}{x_2 - x_1}(v - x_1), & \text{if } v \leq x_1, \\ y_i + \frac{y_{i+1} - y_i}{x_{i+1} - x_i}(v - x_i), & \text{if } v \geq x_i \text{ and } v \leq x_{i+1}, \\ y_n + \frac{y_n - y_{n-1}}{x_n - x_{n-1}}(v - x_n), & \text{if } v \geq x_n. \end{cases}$$

The  $x$  entries must appear in non-decreasing order. Two points can have the same  $x$  coordinate — this can be useful for specifying a discrete jump in the objective function.

Note that a piecewise-linear objective can change the type of a model. Specifically, including a non-convex piecewise linear objective function in a continuous model will transform that model into a MIP. This can significantly increase the cost of solving the model.

Setting a piecewise-linear objective for a variable will set the `Obj attribute` on that variable to 0. Similarly, setting the `Obj` attribute will delete the piecewise-linear objective on that variable.

Each variable can have its own piecewise-linear objective function. They must be specified individually, even if multiple variables share the same function.

Note that, due to our lazy update approach, the new piecewise-linear objective won't actually be added until you update the model (using `GRBupdatemodel`), optimize the model (using `GRBoptimize`), or write the model to disk (using `GRBwrite`).

**Return value:**

A non-zero return value indicates that a problem occurred while setting the piecewise-linear objective. Refer to the `Error Code` table for a list of possible return values. Details on the error can be obtained by calling `GRBgeterrmsg`.

**Arguments:**

**model:** The model to modify.

**var:** The variable whose objective function is being changed.

**npoints:** The number of points that define the piecewise-linear function.

**x:** The  $x$  values for the points that define the piecewise-linear function. Must be in non-decreasing order.

**y:** The  $y$  values for the points that define the piecewise-linear function.

**Example usage:**

```
double x[] = {1, 3, 5};  
double y[] = {1, 2, 4};  
error = GRBsetpwlobj(model, var, 3, x, y);
```

**GRBupdatemodel**

```
int GRBupdatemodel ( GRBmodel *model )
```

Process any pending model modifications.

**Return value:**

A non-zero return value indicates that a problem occurred while updating the model. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** The model to update.

**Example usage:**

```
error = GRBupdatemodel(model);
```

**GRBfreemodel**

```
int GRBfreemodel ( GRBmodel *model )
```

Free a model and release the associated memory.

**Return value:**

A non-zero return value indicates that a problem occurred while freeing the model. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** The model to be freed.

**Example usage:**

```
error = GRBfreemodel(model);
```

## GRBXaddconstrs

```
int GRBXaddconstrs ( GRBmodel *model,
                    int numconstrs,
                    size_t numnz,
                    size_t *cbeg,
                    int *cind,
                    double *cval,
                    char *sense,
                    double *rhs,
                    const char **constrnames )
```

The `size_t` version of [GRBaddconstrs](#). The two arguments that count non-zero values are of type `size_t` in this version to support models with more than 2 billion non-zero values.

Add new linear constraints to a model. Note that, due to our lazy update approach, the new constraints won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

We recommend that you build your model one constraint at a time (using [GRBaddconstr](#)), since it introduces no significant overhead and we find that it produces simpler code. Feel free to use this routine if you disagree, though.

### Return value:

A non-zero return value indicates that a problem occurred while adding the constraints. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model to which the new constraints should be added.

**numconstrs:** The number of new constraints to add.

**numnz:** The total number of non-zero coefficients in the new constraints.

**cbeg:** Constraint matrix non-zero values are passed into this routine in Compressed Sparse Row (CSR) format by this routine. Each constraint in the constraint matrix is represented as a list of index-value pairs, where each index entry provides the variable index for a non-zero coefficient, and each value entry provides the corresponding non-zero value. Each new constraint has an associated `cbeg` value, indicating the start position of the non-zeros for that constraint in the `cind` and `cval` arrays. This routine requires that the non-zeros for constraint `i` immediately follow those for constraint `i-1` in `cind` and `cval`. Thus, `cbeg[i]` indicates both the index of the first non-zero in constraint `i` and the end of the non-zeros for constraint `i-1`. To give an example of how this representation is used, consider a case where `cbeg[2] = 10` and `cbeg[3] = 12`. This would indicate that constraint 2 has two non-zero values associated with it. Their variable indices can be found in `cind[10]` and `cind[11]`, and the numerical values for those non-zeros can be found in `cval[10]` and `cval[11]`.

**cind:** Variable indices associated with non-zero values. See the description of the `cbeg` argument for more information.

**cval:** Numerical values associated with constraint matrix non-zeros. See the description of the `cbeg` argument for more information.

**sense:** Sense for the new constraints. Options are `GRB_LESS_EQUAL`, `GRB_EQUAL`, or `GRB_GREATER_EQUAL`.

**rhs:** Right-hand-side values for the new constraints. This argument can be NULL, in which case the right-hand-side values are set to 0.0.

**constrnames:** Names for the new constraints. This argument can be NULL, in which case all constraints are given default names.

## GRBXaddrangeconstrs

```
int GRBXaddrangeconstrs ( GRBmodel    *model,
                          int          numconstrs,
                          size_t       numnz,
                          size_t       *cbeg,
                          int          *cind,
                          double       *cval,
                          double       *lower,
                          double       *upper,
                          const char   **constrnames )
```

The `size_t` version of [GRBaddrangeconstrs](#). The argument that counts non-zero values is of type `size_t` in this version to support models with more than 2 billion non-zero values.

Add new range constraints to a model. A range constraint states that the value of the input expression must be between the specified `lower` and `upper` bounds in any solution. Note that, due to our lazy update approach, the new constraints won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

### Return value:

A non-zero return value indicates that a problem occurred while adding the constraints. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model to which the new constraints should be added.

**numconstrs:** The number of new constraints to add.

**numnz:** The total number of non-zero coefficients in the new constraints.

**cbeg:** Constraint matrix non-zero values are passed into this routine in Compressed Sparse Row (CSR) format by this routine. Each constraint in the constraint matrix is represented as a list of index-value pairs, where each index entry provides the variable index for a non-zero coefficient, and each value entry provides the corresponding non-zero value. Each new constraint has an associated `cbeg` value, indicating the start position of the non-zeros for that constraint in the `cind` and `cval` arrays. This routine requires that the non-zeros for constraint `i` immediately follow those for constraint `i-1` in `cind` and `cval`. Thus, `cbeg[i]` indicates both the index of the first non-zero in constraint `i` and the end of the non-zeros for constraint `i-1`. To give an example of how this representation is used, consider a case where `cbeg[2] = 10` and `cbeg[3] = 12`. This would indicate that constraint 2 has two non-zero values associated with it. Their variable indices can be found in `cind[10]` and `cind[11]`, and the numerical values for those non-zeros can be found in `cval[10]` and `cval[11]`.

**cind:** Variable indices associated with non-zero values. See the description of the `cbeg` argument for more information.

**cval:** Numerical values associated with constraint matrix non-zeros. See the description of the **cbeg** argument for more information.  
**lower:** Lower bounds for the linear expressions.  
**upper:** Upper bounds for the linear expressions.  
**constrnames:** Names for the new constraints. This argument can be NULL, in which case all constraints are given default names.

### Important notes:

Note that adding a range constraint to the model adds both a new constraint and a new variable. If you are keeping a count of the variables in the model, remember to add one for each range constraint.

Note also that range constraints are stored internally as equality constraints. We use the extra variable that is added with a range constraint to capture the range information. Thus, the [Sense](#) attribute on a range constraint will always be GRB\_EQUAL.

## GRBXaddvars

```
int GRBXaddvars ( GRBmodel    *model,
                 int         numvars,
                 size_t      numnz,
                 size_t      vbeg,
                 int         vind,
                 double       vval,
                 double       obj,
                 double       lb,
                 double       ub,
                 char         vtype,
                 const char  **varnames )
```

The `size_t` version of [GRBaddvars](#). The two arguments that count non-zero values are of type `size_t` in this version to support models with more than 2 billion non-zero values.

Add new variables to a model. Note that, due to our lazy update approach, the new variables won't actually be added until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

### Return value:

A non-zero return value indicates that a problem occurred while adding the variables. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model to which the new variables should be added.

**numvars:** The number of new variables to add.

**numnz:** The total number of non-zero coefficients in the new columns.

**vbeg:** Constraint matrix non-zero values are passed into this routine in Compressed Sparse Column (CSC) format. Each column in the constraint matrix is represented as a list of index-value pairs, where each index entry provides the constraint index for a non-zero coefficient, and each value entry provides the corresponding non-zero value. Each variable in the model has a `vbeg`, indicating the start position of the non-zeros for that variable in the `vind` and `vval` arrays. This routine requires columns to be stored contiguously,

so the start position for a variable is the end position for the previous variable. To give an example, if `vbeg[2] = 10` and `vbeg[3] = 12`, that would indicate that variable 2 has two non-zero values associated with it. Their constraint indices can be found in `vind[10]` and `vind[11]`, and the numerical values for those non-zeros can be found in `vval[10]` and `vval[11]`.

**vind**: Constraint indices associated with non-zero values. See the description of the `vbeg` argument for more information.

**vval**: Numerical values associated with constraint matrix non-zeros. See the description of the `vbeg` argument for more information.

**obj**: Objective coefficients for the new variables. This argument can be `NULL`, in which case the objective coefficients are set to `0.0`.

**lb**: Lower bounds for the new variables. This argument can be `NULL`, in which case all variables get lower bounds of `0.0`.

**ub**: Upper bounds for the new variables. This argument can be `NULL`, in which case all variables get infinite upper bounds.

**vtype**: Types for the variables. Options are `GRB_CONTINUOUS`, `GRB_BINARY`, `GRB_INTEGER`, `GRB_SEMICONT`, or `GRB_SEMIINT`. This argument can be `NULL`, in which case all variables are assumed to be continuous.

**varnames**: Names for the new variables. This argument can be `NULL`, in which case all variables are given default names.

## GRBXchgcoeffs

```
int GRBXchgcoeffs ( GRBmodel *model,
                   size_t   numchgs,
                   int       *cind,
                   int       *vind,
                   double    *val )
```

The `size_t` version of [GRBchgcoeffs](#). The argument that counts non-zero values is of type `size_t` in this version to support models with more than 2 billion non-zero values.

Change a set of constraint matrix coefficients. This routine can be used to set a non-zero coefficient to zero, to create a non-zero coefficient where the coefficient is currently zero, or to change an existing non-zero coefficient to a new non-zero value. If you make multiple changes to the same coefficient, the last one will be applied.

Note that, due to our lazy update approach, the changes won't actually be integrated into the model until you update the model (using [GRBupdatemodel](#)), optimize the model (using [GRBoptimize](#)), or write the model to disk (using [GRBwrite](#)).

### Return value:

A non-zero return value indicates that a problem occurred while performing the modification. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model**: The model to modify.

**numchgs**: The number of coefficients to modify.

**cind**: Constraint indices for the coefficients to modify.

**vind**: Variable indices for the coefficients to modify.

**val:** The new values for the coefficients. For example, if `cind[0] = 1`, `vind[0] = 3`, and `val[0] = 2.0`, then the coefficient in constraint 1 associated with variable 3 would be changed to 2.0.

**Example usage:**

```
int cind[] = {0, 1};
int vind[] = {0, 0};
double val[] = {1.0, 1.0};
error = GRBXchgcoeffs(model, 2, cind, vind, val);
```

## GRBXloadmodel

```
int GRBXloadmodel ( GRBenv      *env,
                    GRBmodel   **modelP,
                    const char *Pname,
                    int         numvars,
                    int         numconstrs,
                    int         objsense,
                    double      objcon,
                    double      *obj,
                    char        *sense,
                    double      *rhs,
                    size_t      *vbeg,
                    int         *vlen,
                    int         *vind,
                    double      *vval,
                    double      *lb,
                    double      *ub,
                    char        *vtype,
                    const char **varnames,
                    const char **constrnames )
```

The `size_t` version of [GRBloadmodel](#). The argument that counts non-zero values is of type `size_t` in this version to support models with more than 2 billion non-zero values.

Create a new optimization model, using the provided arguments to initialize the model data (objective function, variable bounds, constraint matrix, etc.). The model is then ready for optimization, or for modification (e.g., addition of variables or constraints, changes to variable types or bounds, etc.).

**Return value:**

A non-zero return value indicates that a problem occurred while creating the model. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**env:** The environment in which the new model should be created. Note that the new model gets a copy of this environment, so subsequent modifications to the original environment (e.g., parameter changes) won't affect the new model. Use [GRBgetenv](#) to modify the environment associated with a model.

**modelP:** The location in which the pointer to the newly created model should be placed.

**Pname:** The name of the model.

**numvars:** The number of variables in the model.

**numconstrs:** The number of constraints in the model.

**objsense:** The sense of the objective function. Allowed values are 1 (minimization) or -1 (maximization).

**objcon:** Constant objective offset.

**obj:** Objective coefficients for the new variables. This argument can be NULL, in which case the objective coefficients are set to 0.0.

**sense:** The senses of the new constraints. Options are '=' (equal), '<' (less-than-or-equal), or '>' (greater-than-or-equal). You can also use constants GRB\_EQUAL, GRB\_LESS\_EQUAL, or GRB\_GREATER\_EQUAL.

**rhs:** Right-hand-side values for the new constraints. This argument can be NULL, in which case the right-hand-side values are set to 0.0.

**vbeg:** Constraint matrix non-zero values are passed into this routine in Compressed Sparse Column (CSC) format. Each column in the constraint matrix is represented as a list of index-value pairs, where each index entry provides the constraint index for a non-zero coefficient, and each value entry provides the corresponding non-zero value. Each variable in the model has a vbeg and vlen value, indicating the start position of the non-zeros for that variable in the vind and vval arrays, and the number of non-zero values for that variable, respectively. Thus, for example, if vbeg[2] = 10 and vlen[2] = 2, that would indicate that variable 2 has two non-zero values associated with it. Their constraint indices can be found in vind[10] and vind[11], and the numerical values for those non-zeros can be found in vval[10] and vval[11].

**vlen:** Number of constraint matrix non-zero values associated with each variable. See the description of the vbeg argument for more information.

**vind:** Constraint indices associated with non-zero values. See the description of the vbeg argument for more information.

**vval:** Numerical values associated with constraint matrix non-zeros. See the description of the vbeg argument for more information.

**lb:** Lower bounds for the new variables. This argument can be NULL, in which case all variables get lower bounds of 0.0.

**ub:** Upper bounds for the new variables. This argument can be NULL, in which case all variables get infinite upper bounds.

**vtype:** Types for the variables. Options are GRB\_CONTINUOUS, GRB\_BINARY, GRB\_INTEGER, GRB\_SEMICONT, or GRB\_SEMIINT. This argument can be NULL, in which case all variables are assumed to be continuous.

**varnames:** Names for the new variables. This argument can be NULL, in which case all variables are given default names.

**constrnames:** Names for the new constraints. This argument can be NULL, in which case all constraints are given default names.

### Important notes:

We recommend that you build a model one constraint or one variable at a time, using [GRBaddconstr](#) or [GRBaddvar](#), rather than using this routine to load the entire constraint matrix at once. It is much simpler, less error prone, and it introduces no significant overhead.

### Example usage:

```

/* maximize    x +  y + 2 z
   subject to  x + 2 y + 3 z <= 4
              x +  y      >= 1
   x, y, z binary */

int   vars     = 3;
int   constra = 2;
size_t vbegin[] = {0, 2, 4};
int   vlen[]   = {2, 2, 1};
int   vind[]   = {0, 1, 0, 1, 0};
double vval[]  = {1.0, 1.0, 2.0, 1.0, 3.0};
double obj[]   = {1.0, 1.0, 2.0};
char   sense[] = {GRB_LESS_EQUAL, GRB_GREATER_EQUAL};
double rhs[]   = {4.0, 1.0};
char   vtype[] = {GRB_BINARY, GRB_BINARY, GRB_BINARY};

error = GRBloadmodel(env, &model, "example", vars, constra, -1, 0.0,
                    obj, sense, rhs, vbegin, vlen, vind, vval,
                    NULL, NULL, vtype, NULL, NULL);

```

## 2.3 Model Solution

### GRBoptimize

```
| int GRBoptimize ( GRBmodel *model )
```

Optimize a model. The algorithm used for the optimization depends on the model type (simplex or barrier for a continuous model; branch-and-cut for a MIP model). Upon successful completion, this method will populate the solution related attributes of the model. See the [Attributes](#) section for more information on attributes.

Please consult [this section](#) for a discussion of some of the practical issues associated with solving a precisely defined mathematical model using finite-precision floating-point arithmetic.

Note that this routine will process all pending model modifications.

#### Return value:

A non-zero return value indicates that a problem occurred while optimizing the model. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

#### Arguments:

**model:** The model to optimize. Note that this routine only reports whether the optimization ran into an error. Query the **Status** attribute to determine the result of the optimization (see the [Attributes](#) section for more information on querying attributes).

#### Example usage:

```
error = GRBoptimize(model);
```

### GRBoptimizeasync

```
| int GRBoptimizeasync ( GRBmodel *model )
```

Optimize a model asynchronously. This routine returns immediately. Your program can perform other computations while optimization proceeds in the background. To check the state of the asynchronous optimization, query the [Status](#) attribute for the model. A value of `IN_PROGRESS` indicates that the optimization has not yet completed. When you are done with your foreground tasks, you must call [GRBSync](#) to sync your foreground program with the asynchronous optimization task.

Note that the set of Gurobi calls that you are allowed to make while optimization is running in the background is severely limited. Specifically, you can only perform attribute queries, and only for a few attributes (listed below). Any other calls on the running model, *or on any other models that were built within the same Gurobi environment*, will fail with error code `OPTIMIZATION_IN_PROGRESS`.

Note that there are no such restrictions on models built in other environments. Thus, for example, you could create multiple environments, and then have a single foreground program launch multiple simultaneous asynchronous optimizations, each in its own environment.

As already noted, you are allowed to query the value of the **Status** attribute while an asynchronous optimization is in progress. The other attributes that can be queried are: [ObjVal](#), [ObjBound](#), [IterCount](#), [NodeCount](#), and [BarIterCount](#). In each case, the returned value reflects progress in the optimization to that point. Any attempt to query the value of an attribute not on this list will return an `OPTIMIZATION_IN_PROGRESS` error.

**Return value:**

A non-zero return value indicates that a problem occurred while optimizing the model. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** The model to optimize. Note that this routine only reports whether launching the asynchronous job ran into an error. Query the **Status** attribute to determine the result of the optimization (see the [Attributes](#) section for more information on querying attributes). The return value of [GRBSync](#) indicates whether the background optimization ran into an error.

**Example usage:**

```
error = GRBoptimizeasync(model);

/* ... perform other compute-intensive tasks... */

error = GRBSync(model);
```

**GRBcomputeIIS**

```
| int GRBcomputeIIS ( GRBmodel *model )
```

Compute an Irreducible Inconsistent Subsystem (IIS). An IIS is a subset of the constraints and variable bounds of the original model. If all constraints in the model except those in the IIS are removed, the model is still infeasible. However, further removing any one member of the IIS produces a feasible result.

This routine populates the [IISConstr](#), [IISGenConstr](#), [IISQConstr](#), [IISOS](#), [IISLB](#), and [IISUB](#) attributes. You can also obtain information about the results of the IIS computation by writing a `.ilp` format file (see [GRBwrite](#)). This file contains only the IIS from the original model.

Note that this routine can be used to compute IISs for both continuous and MIP models.

**Return value:**

A non-zero return value indicates that a problem occurred while computing the IIS. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** The infeasible model. This routine will return an error if the input model is feasible.

**Important note:**

This routine only reports whether the computation ran into an error. Query the [IISConstr](#), [IISGenConstr](#), [IISQConstr](#), [IISOS](#), [IISLB](#), or [IISUB](#) attributes to determine the result of the computation (see the [Attributes](#) section for more information on querying attributes).

**Example usage:**

```
error = GRBcomputeIIS(model);
```

## GRBfeasrelax

```
int GRBfeasrelax ( GRBmodel *model,
                  int      relaxobjtype,
                  int      minrelax,
                  double   *lbpen,
                  double   *ubpen,
                  double   *rhspen,
                  double   *feasobjP )
```

Modifies the input model to create a feasibility relaxation. Note that you need to call [GRBoptimize](#) on the result to compute the actual relaxed solution.

The feasibility relaxation is a model that, when solved, minimizes the amount by which the solution violates the bounds and linear constraints of the original model. This routine provides a number of options for specifying the relaxation.

If you specify `relaxobjtype=0`, the objective of the feasibility relaxation is to minimize the sum of the weighted magnitudes of the bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the cost per unit violation in the lower bounds, upper bounds, and linear constraints, respectively.

If you specify `relaxobjtype=1`, the objective of the feasibility relaxation is to minimize the weighted sum of the squares of the bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the coefficients on the squares of the lower bound, upper bound, and linear constraint violations, respectively.

If you specify `relaxobjtype=2`, the objective of the feasibility relaxation is to minimize the weighted count of bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the cost of violating a lower bound, upper bound, and linear constraint, respectively.

To give an example, a violation of 2.0 on constraint `i` would contribute `2*rhspen[i]` to the feasibility relaxation objective for `relaxobjtype=0`, it would contribute `2*2*rhspen[i]` for `relaxobjtype=1`, and it would contribute `rhspen[i]` for `relaxobjtype=2`.

The `minrelax` argument is a boolean that controls the type of feasibility relaxation that is created. If `minrelax=0`, optimizing the returned model gives a solution that minimizes the cost of the violation. If `minrelax=1`, optimizing the returned model finds a solution that minimizes the original objective, but only from among those solutions that minimize the cost of the violation. Note that `GRBfeasrelax` must solve an optimization problem to find the minimum possible relaxation for `minrelax=1`, which can be quite expensive.

In all cases, you can specify a penalty of `GRB_INFINITY` to indicate that a specific bound or linear constraint may not be violated.

Note that this is a destructive routine: it modifies the model passed to it. If you don't want to modify your original model, use [GRBcopymodel](#) to create a copy before calling this routine.

### Return value:

A non-zero return value indicates that a problem occurred while computing the feasibility relaxation. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The original (infeasible) model. The model is modified by this routine.

**relaxobjtype:** The cost function used when finding the minimum cost relaxation.

**minrelax:** The type of feasibility relaxation to perform.

- lbpen:** The penalty associated with violating a lower bound. Can be NULL, in which case no lower bound violations are allowed.
- ubpen:** The penalty associated with violating an upper bound. Can be NULL, in which case no upper bound violations are allowed.
- rhspen:** The penalty associated with violating a linear constraint. Can be NULL, in which case no constraint violations are allowed.
- feasobjP:** When `minrelax=1`, this returns the objective value for the minimum cost relaxation.

**Example usage:**

```
double penalties[];
error = GRBfeasrelax(model, 0, 0, NULL, NULL, penalties, NULL);
error = GRBoptimize(model);
```

## GRBfixedmodel

```
| GRBmodel * GRBfixedmodel ( GRBmodel *model )
```

Create the fixed model associated with a MIP model. The MIP model must have a solution loaded (e.g., after a call to [GRBoptimize](#)). In the fixed model, each integer variable is fixed to the value that variable takes in the MIP solution.

**Return value:**

This routine returns the computed model. If there is a problem, the routine returns NULL.

**Arguments:**

`model`: The MIP model (with a solution loaded).

**Example usage:**

```
GRBmodel *fixed = GRBfixedmodel(model);
```

## GRBresetmodel

```
| int GRBresetmodel ( GRBmodel *model )
```

Reset the model to an unsolved state, discarding any previously computed solution information.

**Return value:**

A non-zero return value indicates that a problem occurred while resetting the model. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

`model`: The model to reset.

**Example usage:**

```
error = GRBresetmodel(model);
```

## GRBsync

```
| int GRBsync ( GRBmodel *model )
```

Wait for a previous asynchronous optimization call to complete.

Calling `GRBoptimizeasync` returns control to the calling routine immediately. The caller can perform other computations while optimization proceeds, and can check on the progress of the optimization by querying various model attributes. The `GRBsync` call forces the calling program to wait until the asynchronous optimization completes. You *must* call `GRBsync` before the corresponding model is freed.

The `GRBsync` call returns a non-zero error code if the optimization itself ran into any problems. In other words, error codes returned by this method are those that `GRBoptimize` itself would have returned, had the original method not been asynchronous.

Note that you need to call `GRBsync` even if you know that the asynchronous optimization has already completed.

**Return value:**

A non-zero return value indicates that a problem occurred while solving the model. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling `GRBgeterrmsg`.

**Arguments:**

`model`: The model that is currently being solved.

**Example usage:**

```
error = GRBoptimizeasync(model);

/* ... perform other compute-intensive tasks... */

error = GRBsync(model);
```

## 2.4 Model Queries

While most model related queries are handled through the [attribute](#) interface, a few fall outside of that interface. These are described here.

### GRBgetcoeff

```
int GRBgetcoeff ( GRBmodel *model,
                  int      constrind,
                  int      varind,
                  double   *valP )
```

Retrieve a single constraint matrix coefficient.

#### Return value:

A non-zero return value indicates that a problem occurred while retrieving the coefficient. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

#### Arguments:

**model:** The model from which the coefficient should be retrieved.

**constrind:** The constraint index for the desired coefficient.

**varind:** The variable index for the desired coefficient.

**valP:** The location in which the requested matrix coefficient should be placed.

#### Example usage:

```
double A12;
error = GRBgetcoeff(model, 1, 2, &A12);
```

### GRBgetconstrbyname

```
int GRBgetconstrbyname ( GRBmodel *model,
                         const char *name,
                         int      *constrnumP )
```

Retrieves a linear constraint from its name. If multiple linear constraints have the same name, this routine chooses one arbitrarily.

#### Return value:

A non-zero return value indicates that a problem occurred while retrieving the constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

#### Arguments:

**model:** The model from which the linear constraint should be retrieved.

**name:** The name of the desired linear constraint.

**constrnumP:** Constraint number for a linear constraint with the indicated name. Returns -1 if no matching name is found.

## GRBgetconstrs

```
int GRBgetconstrs ( GRBmodel *model,
                   int      *numnzP,
                   int      *cbeg,
                   int      *cind,
                   double   *cval,
                   int      start,
                   int      len )
```

Retrieve the non-zeros for a set of linear constraints from the constraint matrix. Typical usage is to call this routine twice. In the first call, you specify the requested set of constraints, with NULL values for `cbeg`, `cind`, and `cval`. The routine returns the number of non-zero values for the specified constraint range in `numnzP`. That allows you to make certain that `cind` and `cval` are of sufficient size to hold the result of the second call.

If your constraint matrix may contain more than 2 billion non-zero values, you should consider using the [GRBXgetconstrs](#) variant of this routine.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the constraint coefficients. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model from which the linear constraints should be retrieved.

**numnzP:** The number of non-zero values retrieved.

**cbeg:** Constraint matrix non-zero values are returned in Compressed Sparse Row (CSR) format. Each constraint in the constraint matrix is represented as a list of index-value pairs, where each index entry provides the variable index for a non-zero coefficient, and each value entry provides the corresponding non-zero value. Each constraint has an associated `cbeg` value, indicating the start position of the non-zeros for that constraint in the `cind` and `cval` arrays. The non-zeros for constraint `i` immediately follow those for constraint `i-1` in `cind` and `cval`. Thus, `cbeg[i]` indicates both the index of the first non-zero in constraint `i` and the end of the non-zeros for constraint `i-1`. For example, consider the case where `cbeg[2] = 10` and `cbeg[3] = 12`. This would indicate that constraint 2 has two non-zero values associated with it. Their variable indices can be found in `cind[10]` and `cind[11]`, and the numerical values for those non-zeros can be found in `cval[10]` and `cval[11]`.

**cind:** Variable indices associated with non-zero values. See the description of the `cbeg` argument for more information.

**cval:** Numerical values associated with constraint matrix non-zeros. See the description of the `cbeg` argument for more information.

**start:** The index of the first linear constraint to retrieve.

**len:** The number of linear constraints to retrieve.

## GRBgetenv

```
GRBenv * GRBgetenv ( GRBmodel *model )
```

Retrieve the environment associated with a model.

**Return value:**

The environment associated with the model. A NULL return value indicates that there was a problem retrieving the environment.

**Arguments:**

**model:** The model from which the environment should be retrieved.

**Example usage:**

```
GRBEnv *env = GRBgetenv(model);
```

## GRBgetgenconstrMax

```
int GRBgetgenconstrMax ( GRBmodel *model,
                        int id,
                        int* resvarP,
                        int* nvarsP,
                        int* vars,
                        double* constantP )
```

Retrieve the data of a general constraint of type MAX. Calling this function for a general constraint of different type leads to an error return code. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with a NULL value for the **vars** argument. The routine returns the total number of operand variables in the specified general constraint in **nvarsP**. That allows you to make certain that the **vars** array is of sufficient size to hold the result of the second call.

See also [GRBaddgenconstrMax](#) for a description of the semantics of this general constraint type.

**Return value:**

A non-zero return value indicates that a problem occurred while retrieving the data of the general constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**model:** The model to which the new general constraint should be added.

**id:** The index of the general constraint to retrieve.

Note that any combination of the following arguments can be NULL.

**int \*resvarP:** The variable index associated with the resultant variable of the constraint.

**int \*nvarsP:** The number of operand variables of the constraint.

**int \*vars:** An array to store the variable indices associated with the variable operands of the constraint.

**double \*constantP:** The additional constant operand of the constraint.

**Example usage:**

```
int type;
int resvar;
int nvars;
int *vars;
double constant;
```

```
error = GRBgetintattrelement(model, GRB_INT_ATTR_GENCONSTRTYPE, 3, &type);
```

```

if (type == GRB_GENCONSTR_MAX) {
    error = GRBgetgenconstrMax(model, 3, &resvar, &nvars, NULL, &constant);
    /* ...allocate vars to hold 'nvars' values... */
    error = GRBgetgenconstrMax(model, 3, NULL, NULL, vars, NULL);
}

```

## GRBgetgenconstrMin

```

int GRBgetgenconstrMin ( GRBmodel *model,
                        int id,
                        int* resvarP,
                        int* nvarsP,
                        int* vars,
                        double* constantP )

```

Retrieve the data of a general constraint of type MIN. Calling this function for a general constraint of different type leads to an error return code. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with a NULL value for the `vars` argument. The routine returns the total number of operand variables in the specified general constraint in `nvarsP`. That allows you to make certain that the `vars` array is of sufficient size to hold the result of the second call.

See also [GRBaddgenconstrMin](#) for a description of the semantics of this general constraint type.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the data of the general constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model to which the new general constraint should be added.

**id:** The index of the general constraint to retrieve.

Note that any combination of the following arguments can be NULL.

**int \*resvarP:** The variable index associated with the resultant variable of the constraint.

**int \*nvarsP:** The number of operand variables of the constraint.

**int \*vars:** An array to store the variable indices associated with the variable operands of the constraint.

**double \*constantP:** The additional constant operand of the constraint.

### Example usage:

```

int type;
int resvar;
int nvars;
int *vars;
double constant;

error = GRBgetintattrelement(model, GRB_INT_ATTR_GENCONSTRTYPE, 3, &type);
if (type == GRB_GENCONSTR_MIN) {
    error = GRBgetgenconstrMin(model, 3, &resvar, &nvars, NULL, &constant);
    /* ...allocate vars to hold 'nvars' values... */
}

```

```

    error = GRBgetgenconstrMin(model, 3, NULL, NULL, vars, NULL);
}

```

## GRBgetgenconstrAbs

```

int GRBgetgenconstrAbs ( GRBmodel *model,
                        int id,
                        int* resvarP,
                        int* argvarP )

```

Retrieve the data of a general constraint of type ABS. Calling this function for a general constraint of different type leads to an error return code. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [GRBaddgenconstrAbs](#) for a description of the semantics of this general constraint type.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the data of the general constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model to which the new general constraint should be added.

**id:** The index of the general constraint to retrieve.

Note that any combination of the following arguments can be NULL.

**int \*resvarP:** The variable index associated with the resultant variable of the constraint.

**int \*argvarP:** The variable index associated with the argument variable of the constraint.

### Example usage:

```

int type;
int resvar;
int argvar;

error = GRBgetintattrelement(model, GRB_INT_ATTR_GENCONSTRTYPE, 3, &type);
if (type == GRB_GENCONSTR_ABS) {
    error = GRBgetgenconstrAbs(model, 3, &resvar, &argvar);
}

```

## GRBgetgenconstrAnd

```

int GRBgetgenconstrAnd ( GRBmodel *model,
                        int id,
                        int* resvarP,
                        int* nvarsP,
                        int* vars )

```

Retrieve the data of a general constraint of type AND. Calling this function for a general constraint of different type leads to an error return code. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with a NULL value for the `vars` argument. The routine returns the total number of

operand variables in the specified general constraint in `nvarsP`. That allows you to make certain that the `vars` array is of sufficient size to hold the result of the second call.

See also [GRBaddgenconstrAnd](#) for a description of the semantics of this general constraint type.

**Return value:**

A non-zero return value indicates that a problem occurred while retrieving the data of the general constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**model:** The model to which the new general constraint should be added.

**id:** The index of the general constraint to retrieve.

Note that any combination of the following arguments can be NULL.

**int \*resvarP:** The variable index associated with the binary resultant variable of the constraint.

**int \*nvarsP:** The number of binary operand variables of the constraint.

**int \*vars:** An array to store the variable indices associated with the binary variable operands of the constraint.

**Example usage:**

```
int type;
int resvar;
int nvars;
int *vars;

error = GRBgetintattrelement(model, GRB_INT_ATTR_GENCONSTRTYPE, 3, &type);
if (type == GRB_GENCONSTR_AND) {
    error = GRBgetgenconstrAnd(model, 3, &resvar, &nvars, NULL);
    /* ...allocate vars to hold 'nvars' values... */
    error = GRBgetgenconstrAnd(model, 3, NULL, NULL, vars);
}
```

## GRBgetgenconstrOr

```
int GRBgetgenconstrOr ( GRBmodel *model,
                       int id,
                       int* resvarP,
                       int* nvarsP,
                       int* vars )
```

Retrieve the data of a general constraint of type OR. Calling this function for a general constraint of different type leads to an error return code. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with a NULL value for the `vars` argument. The routine returns the total number of operand variables in the specified general constraint in `nvarsP`. That allows you to make certain that the `vars` array is of sufficient size to hold the result of the second call.

See also [GRBaddgenconstrOr](#) for a description of the semantics of this general constraint type.

**Return value:**

A non-zero return value indicates that a problem occurred while retrieving the data of the general constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**model:** The model to which the new general constraint should be added.

**id:** The index of the general constraint to retrieve.

Note that any combination of the following arguments can be NULL.

**int \*resvarP:** The variable index associated with the binary resultant variable of the constraint.

**int \*nvarsP:** The number of binary operand variables of the constraint.

**int \*vars:** An array to store the variable indices associated with the binary variable operands of the constraint.

**Example usage:**

```
int type;
int resvar;
int nvars;
int *vars;

error = GRBgetintattrelement(model, GRB_INT_ATTR_GENCONSTRTYPE, 3, &type);
if (type == GRB_GENCONSTR_OR) {
    error = GRBgetgenconstrOr(model, 3, &resvar, &nvars, NULL);
    /* ...allocate vars to hold 'nvars' values... */
    error = GRBgetgenconstrOr(model, 3, NULL, NULL, vars);
}
```

### GRBgetgenconstrIndicator

```
int GRBgetgenconstrIndicator ( GRBmodel *model,
                              int id,
                              int* binvarP,
                              int* binvalP,
                              int* nvarsP,
                              int* ind,
                              double* val,
                              char* senseP,
                              double* rhsP )
```

Retrieve the data of a general constraint of type INDICATOR. Calling this function for a general constraint of different type leads to an error return code. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with NULL values for the `ind` and `val` arguments. The routine returns the total number of non-zero coefficients in the linear constraint associated with the specified indicator constraint in `nvarsP`. That allows you to make certain that the `ind` and `val` arrays are of sufficient size to hold the result of the second call.

See also [GRBaddgenconstrIndicator](#) for a description of the semantics of this general constraint type.

**Return value:**

A non-zero return value indicates that a problem occurred while retrieving the data of the general constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling `GRBgeterrmsg`.

**Arguments:**

**model:** The model to which the new general constraint should be added.

**id:** The index of the general constraint to retrieve.

Note that any combination of the following arguments can be NULL.

**int \*binvarP:** The variable index associated with the binary indicator variable.

**int \*binvalP:** The value that the indicator variable has to take in order to trigger the linear constraint.

**int \*nvarsP:** The number of non-zero coefficients in the linear constraint triggered by the indicator.

**int \*ind:** An array to store the variable indices for non-zero values in the linear constraint.

**double \*val:** An array to store the numerical values for non-zero values in the linear constraint.

**char \*senseP:** Sense for the linear constraint. Options are `GRB_LESS_EQUAL`, `GRB_EQUAL`, or `GRB_GREATER_EQUAL`.

**double \*rhsP:** Right-hand-side value for the linear constraint.

**Example usage:**

```
int type;
int binvar;
int binval;
int nvars;
int *ind;
double *val;
char sense;
double rhs;

error = GRBgetintattrelement(model, GRB_INT_ATTR_GENCONSTRTYPE, 3, &type);
if (type == GRB_GENCONSTR_INDICATOR) {
    error = GRBgetgenconstrIndicator(model, 3, &binvar, &binval, &nvars,
                                    NULL, NULL, &sense, &rhs);
    /* ...allocate ind and val to hold 'nvars' values... */
    error = GRBgetgenconstrIndicator(model, 3, NULL, NULL, NULL,
                                    ind, val, NULL, NULL);
}
```

**GRBgetpwlobj**

```
int GRBgetpwlobj ( GRBmodel *model,
                  int var,
                  int *npointsP,
                  double *x,
                  double *y )
```

Retrieve the piecewise-linear objective function for a variable. The  $x$  and  $y$  arguments must be large enough to hold the result. If either are NULL, then `npointsP` will contain the number of points in the function on return.

Refer to the description of [GRBsetpwlobj](#) for additional information on what the values in  $x$  and  $y$  mean.

**Return value:**

A non-zero return value indicates that a problem occurred while retrieving the piecewise-linear objective function. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** The model from which the piecewise-linear objective function is being retrieved.

**var:** The variable whose objective function is being retrieved.

**npointsP:** The number of points that define the piecewise-linear function.

**x:** The  $x$  values for the points that define the piecewise-linear function. These will always be in non-decreasing order.

**y:** The  $y$  values for the points that define the piecewise-linear function.

**Example usage:**

```
double *x;
double *y;

error = GRBgetpwlobj(model, var, &npoints, NULL, NULL);
/* ...allocate x and y to hold 'npoints' values... */
error = GRBgetpwlobj(model, var, &npoints, x, y);
```

## GRBgetq

```
int GRBgetq ( GRBmodel *model,
              int      *numqnzP,
              int      *qrow,
              int      *qcol,
              double   *qval )
```

Retrieve all quadratic objective terms. The `qrow`, `qcol`, and `qval` arguments must be large enough to hold the result. You can query the [NumQNZs](#) attribute to determine how many terms will be returned.

**Return value:**

A non-zero return value indicates that a problem occurred while retrieving the quadratic objective terms. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** The model from which the quadratic objective terms should be retrieved.

**numqnzP:** The number of quadratic objective terms retrieved.

**qrow:** Row indices associated with quadratic terms. A quadratic term is represented using three values: a pair of indices (stored in `qrow` and `qcol`), and a coefficient (stored in `qval`). The array arguments give the corresponding values for each quadratic term. To give an example, if the quadratic terms in the model are  $2x_0^2 + x_0x_1 + x_1^2$ , this routine would return `qrow[] = {0, 0, 1}`, `qcol[] = {0, 1, 1}`, and `qval[] = {2.0, 1.0, 1.0}`.

**qcol**: Column indices associated with quadratic terms. See the description of the **qrow** argument for more information.

**qval**: Numerical values associated with quadratic terms. See the description of the **qrow** argument for more information.

**Example usage:**

```
int    qnz;
int    *qrow, *qcol;
double *qval;

error = GRBgetdblattr(model, GRB_DBL_ATTR_NUMQNZS, &qnz);
/* ...allocate qrow, qcol, qval to hold 'qnz' values... */
error = GRBgetq(model, &qnz, qrow, qcol, qval);
```

## GRBgetqconstr

```
int GRBgetqconstr ( GRBmodel *model,
                   int       qconstr,
                   int       *numlnzP,
                   int       *lind,
                   double    *lval,
                   int       *numqnzP,
                   int       *qrow,
                   int       *qcol,
                   double    *qval )
```

Retrieve the linear and quadratic terms associated with a single quadratic constraint. Typical usage is to call this routine twice. In the first call, you specify the requested quadratic constraint, with NULL values for the array arguments. The routine returns the total number of linear and quadratic terms in the specified quadratic constraint in **numlnzP** and **numqnzP**, respectively. That allows you to make certain that **lind**, **lval**, **qrow**, **qcol**, and **qval** are of sufficient size to hold the result of the second call.

**Return value:**

A non-zero return value indicates that a problem occurred while retrieving the quadratic constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**model**: The model from which the quadratic constraint should be retrieved.

**qconstr**: The index of the requested quadratic constraint.

**numlnzP**: The number of linear terms retrieved for the requested quadratic constraint.

**lind**: Variable indices associated with linear terms.

**lval**: Numerical coefficients associated with linear terms.

**numqnzP**: The number of quadratic terms retrieved for the requested quadratic constraint.

**qrow**: Row indices associated with quadratic terms. A quadratic term is represented using three values: a pair of indices (stored in **qrow** and **qcol**), and a coefficient (stored in **qval**). The associated arguments arrays provide the corresponding values for each quadratic term.

To give an example, if the requested quadratic constraint has quadratic terms  $2x_0^2 + x_0x_1 +$

$x_1^2$ , this routine would return `*numqnzP=3`, `qrow[] = {0, 0, 1}`, `qcol[] = {0, 1, 1}`, and `qval[] = {2.0, 1.0, 1.0}`.

**qcol**: Column indices associated with quadratic terms. See the description of the **qrow** argument for more information.

**qval**: Numerical values associated with quadratic terms. See the description of the **qrow** argument for more information.

## GRBgetsos

```
int GRBgetsos ( GRBmodel *model,
                int      *nummembersP,
                int      *sostype,
                int      *beg,
                int      *ind,
                double   *weight,
                int      start,
                int      len )
```

Retrieve the members and weights of a set of SOS constraints. Typical usage is to call this routine twice. In the first call, you specify the requested SOS constraints, with `NULL` values for **ind** and **weight**. The routine returns the total number of members for the specified SOS constraints in **nummembersP**. That allows you to make certain that **ind** and **weight** are of sufficient size to hold the result of the second call.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the SOS members. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model**: The model from which the SOS constraints should be retrieved.

**nummembersP**: The total number of SOS members retrieved.

**sostype**: The types of the SOS constraints. Possible values are `GRB_SOS_TYPE1` or `GRB_SOS_TYPE2`

**beg**: SOS constraints are returned in Compressed Sparse Row (CSR) format. Each SOS constraint in the model is represented as a list of index-value pairs, where each index entry provides the variable index for an SOS member, and each value entry provides the corresponding SOS constraint weight. Each SOS constraint has an associated **beg** value, indicating the start position of the members of that constraint in the **ind** and **weight** arrays. The members for SOS constraint *i* immediately follow those for constraint *i-1* in **ind** and **weight**. Thus, **beg[i]** indicates both the index of the first member of SOS constraint *i* and the end of the member list for SOS constraint *i-1*. For example, consider the case where **beg[2] = 10** and **beg[3] = 12**. This would indicate that SOS constraint 2 has two members. Their variable indices can be found in **ind[10]** and **ind[11]**, and their SOS weights can be found in **weight[10]** and **weight[11]**.

**ind**: Variable indices associated with SOS members. See the description of the **beg** argument for more information.

**weight**: Weights associated with SOS members. See the description of the **beg** argument for more information.

**start:** The index of the first SOS constraint to retrieve.

**len:** The number of SOS constraints to retrieve.

## GRBgetvarbyname

```
int GRBgetvarbyname ( GRBmodel *model,
                      const char *name,
                      int *varnumP )
```

Retrieves a variable from its name. If multiple variables have the same name, this routine chooses one arbitrarily.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the variable. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**model:** The model from which the variable should be retrieved.

**name:** The name of the desired variable.

**varnumP:** Variable number for a variable with the indicated name. Returns -1 if no matching name is found.

## GRBgetvars

```
int GRBgetvars ( GRBmodel *model,
                 int *numnzP,
                 int *vbeg,
                 int *vind,
                 double *vval,
                 int start,
                 int len )
```

Retrieve the non-zeros for a set of variables from the constraint matrix. Typical usage is to call this routine twice. In the first call, you specify the requested set of variables, with NULL values for `vbeg`, `vind`, and `vval`. The routine returns the number of non-zero values for the specified variables in `numnzP`. That allows you to make certain that `vind` and `vval` are of sufficient size to hold the result of the second call.

If your constraint matrix may contain more than 2 billion non-zero values, you should consider using the [GRBXgetvars](#) variant of this routine.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the variable coefficients. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**model:** The model from which the variables should be retrieved.

**numnzP:** The number of non-zero values retrieved.

**vbeg:** Constraint matrix non-zero values are returned in Compressed Sparse Column (CSC) format by this routine. Each column in the constraint matrix is represented as a list

of index-value pairs, where each index entry provides the constraint index for a non-zero coefficient, and each value entry provides the corresponding non-zero value. Each variable has an associated `vbeg` value, indicating the start position of the non-zeros for that constraint in the `vind` and `vval` arrays. The non-zeros for variable `i` immediately follow those for variable `i-1` in `vind` and `vval`. Thus, `vbeg[i]` indicates both the index of the first non-zero in variable `i` and the end of the non-zeros for variable `i-1`. For example, consider the case where `vbeg[2] = 10` and `vbeg[3] = 12`. This would indicate that variable 2 has two non-zero values associated with it. Their constraint indices can be found in `vind[10]` and `vind[11]`, and the numerical values for those non-zeros can be found in `vval[10]` and `vval[11]`.

**vind:** Constraint indices associated with non-zero values. See the description of the `vbeg` argument for more information.

**vval:** Numerical values associated with constraint matrix non-zeros. See the description of the `vbeg` argument for more information.

**start:** The index of the first variable to retrieve.

**len:** The number of variables to retrieve.

## GRBXgetconstrs

```
int GRBXgetconstrs ( GRBmodel *model,
                    size_t *numnzP,
                    size_t *cbeg,
                    int *cind,
                    double *cval,
                    int start,
                    int len )
```

The `size_t` version of [GRBgetconstrs](#). The two arguments that count non-zero values are of type `size_t` in this version to support models with more than 2 billion non-zero values.

Retrieve the non-zeros for a set of linear constraints from the constraint matrix. Typical usage is to call this routine twice. In the first call, you specify the requested set of constraints, with NULL values for `cbeg`, `cind`, and `cval`. The routine returns the number of non-zero values for the specified constraint range in `numnzP`. That allows you to make certain that `cind` and `cval` are of sufficient size to hold the result of the second call.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the constraint coefficients. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model from which the constraints should be retrieved.

**numnzP:** The number of non-zero values retrieved.

**cbeg:** Constraint matrix non-zero values are returned in Compressed Sparse Row (CSR) format. Each constraint in the constraint matrix is represented as a list of index-value pairs, where each index entry provides the variable index for a non-zero coefficient, and each value entry provides the corresponding non-zero value. Each constraint has an associated `cbeg` value, indicating the start position of the non-zeros for that constraint in the `cind` and `cval` arrays. The non-zeros for constraint `i` immediately follow those for constraint

$i-1$  in `cind` and `cval`. Thus, `cbeg[i]` indicates both the index of the first non-zero in constraint  $i$  and the end of the non-zeros for constraint  $i-1$ . For example, consider the case where `cbeg[2] = 10` and `cbeg[3] = 12`. This would indicate that constraint 2 has two non-zero values associated with it. Their variable indices can be found in `cind[10]` and `cind[11]`, and the numerical values for those non-zeros can be found in `cval[10]` and `cval[11]`.

**cind:** Variable indices associated with non-zero values. See the description of the `cbeg` argument for more information.

**cval:** Numerical values associated with constraint matrix non-zeros. See the description of the `cbeg` argument for more information.

**start:** The index of the first constraint to retrieve.

**len:** The number of constraints to retrieve.

## GRBXgetvars

```
int GRBXgetvars ( GRBmodel *model,
                  size_t   *numnzP,
                  size_t   *vbeg,
                  int       *vind,
                  double    *vval,
                  int       start,
                  int       len )
```

The `size_t` version of [GRBgetvars](#). The two arguments that count non-zero values are of type `size_t` in this version to support models with more than 2 billion non-zero values.

Retrieve the non-zeros for a set of variables from the constraint matrix. Typical usage is to call this routine twice. In the first call, you specify the requested set of variables, with `NULL` values for `vbeg`, `vind`, and `vval`. The routine returns the number of non-zero values for the specified variables in `numnzP`. That allows you to make certain that `vind` and `vval` are of sufficient size to hold the result of the second call.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the variable coefficients. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model from which the variables should be retrieved.

**numnzP:** The number of non-zero values retrieved.

**vbeg:** Constraint matrix non-zero values are returned in Compressed Sparse Column (CSC) format by this routine. Each column in the constraint matrix is represented as a list of index-value pairs, where each index entry provides the constraint index for a non-zero coefficient, and each value entry provides the corresponding non-zero value. Each variable has an associated `vbeg` value, indicating the start position of the non-zeros for that constraint in the `vind` and `vval` arrays. The non-zeros for variable  $i$  immediately follow those for variable  $i-1$  in `vind` and `vval`. Thus, `vbeg[i]` indicates both the index of the first non-zero in variable  $i$  and the end of the non-zeros for variable  $i-1$ . For example, consider the case where `vbeg[2] = 10` and `vbeg[3] = 12`. This would indicate that variable 2 has two non-zero values associated with it. Their constraint indices can

be found in `vind[10]` and `vind[11]`, and the numerical values for those non-zeros can be found in `vval[10]` and `vval[11]`.

**vind**: Constraint indices associated with non-zero values. See the description of the `vbeg` argument for more information.

**vval**: Numerical values associated with constraint matrix non-zeros. See the description of the `vbeg` argument for more information.

**start**: The index of the first variable to retrieve.

**len**: The number of variables to retrieve.

## 2.5 Input/Output

### GRBreadmodel

```
int GRBreadmodel ( GRBenv      *env,  
                  const char  *filename,  
                  GRBmodel    **modelP )
```

Read a model from a file.

#### Return value:

A non-zero return value indicates that a problem occurred while reading the model. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

#### Arguments:

**env:** The environment in which to load the new model. This should come from a previous call to [GRBloadenv](#).

**filename:** The path to the file to be read. Note that the type of the file is encoded in the file name suffix. Valid suffixes are `.mps`, `.rew`, `.lp`, `.rlp`, `.ilp`, or `.opb`. The files can be compressed, so additional suffixes of `.zip`, `.gz`, `.bz2`, or `.7z` are accepted.

**modelP:** The location in which the pointer to the model should be placed.

#### Example usage:

```
GRBmodel *model;  
error = GRBreadmodel(env, "/tmp/model.mps.bz2", &model);
```

### GRBread

```
int GRBread ( GRBmodel    *model,  
             const char  *filename )
```

Import optimization data from a file. This routine is the general entry point for importing data from a file into a model. It can be used to read start vectors for MIP models, basis files for LP models, or parameter settings. The type of data read is determined by the file suffix. File formats are described in the [File Format](#) section.

#### Return value:

A non-zero return value indicates that a problem occurred while reading the file. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

#### Arguments:

**model:** The model that will receive the start vector.

**filename:** The path to the file to be read. The suffix on the file must be either `.mst` or `.sol` for a MIP start file, `.hnt` for a MIP hint file, `.ord` for a priority order file, `.bas` for a basis file, or `.prm` for a parameter file. The suffix may optionally be followed by `.zip`, `.gz`, `.bz2`, or `.7z`.

#### Example usage:

```
error = GRBread(model, "/tmp/model.mst.bz2");
```

## GRBwrite

```
int GRBwrite ( GRBmodel *model,  
              const char *filename )
```

This routine is the general entry point for writing optimization data to a file. It can be used to write optimization models, solutions vectors, basis vectors, start vectors, or parameter settings. The type of data written is determined by the file suffix. File formats are described in the [File Format](#) section.

Note that writing a model to a file will process all pending model modifications. However, writing other model information (solutions, bases, etc.) will not.

### Return value:

A non-zero return value indicates that a problem occurred while writing the file. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** The model containing the data to be written.

**filename:** The name of the file to be written. The file type is encoded in the file name suffix. Valid suffixes are `.mps`, `.rew`, `.lp`, or `.rlp` for writing the model itself, `.ilp` for writing just the IIS associated with an infeasible model (see [GRBcomputeIIS](#) for further information), `.sol` for writing the current solution, `.mst` for writing a start vector, `.hnt` for writing a hint file, `.bas` for writing an LP basis, or `.prm` for writing modified parameter settings. The files can be compressed, so additional suffixes of `.gz`, `.bz2`, or `.7z` are accepted.

### Example usage:

```
error = GRBwrite(model, "/tmp/model.rlp.gz");
```

## 2.6 Attribute Management

### GRBgetattrinfo

```
int GRBgetattrinfo ( GRBmodel   *model,
                    const char *attrname,
                    int         *datatypeP,
                    int         *attrtypeP,
                    int         *settableP )
```

Obtain information about an attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while obtaining information about the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of an attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**datatypeP:** On completion, the integer pointed to by this argument will indicate the data type of the attribute. Possible types are char (0), int (1), double (2), or string(3). This argument can be NULL.

**attrtypeP:** On completion, the integer pointed to by this argument will indicate the type of the attribute. Possible types are model attribute (0), variable attribute (1), linear constraint attribute (2), (3) SOS constraint attribute, (4) quadratic constraint attribute, or (5) general constraint attribute. This argument can be NULL.

**settableP:** On completion, the integer pointed to by this argument will indicate whether the attribute can be set (1) or not (0). This argument can be NULL.

**Example usage:**

```
int datatype, attrtype, settable;
error = GRBgetattrinfo(model, "ModelName", &datatype, &attrtype, &settable);
```

### GRBgetintattr

```
int GRBgetintattr ( GRBmodel   *model,
                   const char *attrname,
                   int         *valueP )
```

Query the value of an integer-valued model attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of an integer-valued model attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**valueP:** The location in which the current value of the requested attribute should be placed.

**Important note:**

Note that this method should be used for scalar attributes only (i.e., model attributes). To query a single element of an array attribute, use [GRBgetintattrelement](#) instead.

**Example usage:**

```
error = GRBgetintattr(model, "NumBinVars", &numbin);
```

## GRBsetintattr

```
int GRBsetintattr ( GRBmodel *model,
                   const char *attrname,
                   int newvalue )
```

Set the value of an integer-valued model attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of an integer-valued model attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**newvalue:** The desired new value of this attribute.

**Important note:**

Note that this method should be used for scalar attributes only (i.e., model attributes). To modify a single element of an array attribute, use [GRBsetintattrelement](#) instead.

**Example usage:**

```
error = GRBsetintattr(model, "ModelSense", -1);
```

## GRBgetintattrelement

```
int GRBgetintattrelement ( GRBmodel *model,
                           const char *attrname,
                           int element,
                           int *valueP )
```

Query a single value from an integer-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of an integer-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**element:** The index of the requested array element.

**valueP:** A pointer to the location where the requested value should be returned.

**Important note:**

Note that this method should be used for array attributes only (i.e., variable or constraint attributes). To query a scalar attribute (i.e., a model attribute), use [GRBgetintattr](#) instead.

**Example usage:**

```
int first_one;
error = GRBgetintattrelement(model, "VBasis", 0, &first_one);
```

## GRBsetintattrelement

```
int GRBsetintattrelement ( GRBmodel *model,
                           const char *attrname,
                           int element,
                           int newvalue )
```

Set a single value in an integer-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of an integer-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**element:** The index of the array element to be changed.

**newvalue:** The value to which the attribute element should be set.

**Important note:**

Note that this method should be used for array attributes only (i.e., variable or constraint attributes). To modify a scalar attribute (i.e., a model attribute), use [GRBsetintattr](#) instead.

**Example usage:**

```
error = GRBsetintattrelement(model, "VBasis", 0, GRB_BASIC);
```

## GRBgetintattrarray

```
int GRBgetintattrarray ( GRBmodel *model,
                        const char *attrname,
                        int start,
                        int len,
                        int *values )
```

Query the values of an integer-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

- model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRB-readmodel](#).
- attrname:** The name of an integer-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.
- start:** The index of the first entry in the array to retrieve.
- len:** The number of array entries to retrieve.
- values:** A pointer to the location where the array attribute should be returned. Note that the result array must be as long as the requested sub-array.

**Example usage:**

```
int cbasis[NUMCONSTRS];
error = GRBgetintattrarray(model, "CBasis", 0, NUMCONSTRS, cbasis);
```

## GRBsetintattrarray

```
int GRBsetintattrarray ( GRBmodel    *model,
                        const char  *attrname,
                        int          start,
                        int          len,
                        int          *values )
```

Set the values of an integer-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

- model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRB-readmodel](#).
- attrname:** The name of an integer-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.
- start:** The index of the first entry in the array to set.
- len:** The number of array entries to set.
- values:** A pointer to the desired new values for the specified sub-array of the attribute. Note that the values array must be as long as the sub-array to be changed.

**Example usage:**

```
int cbasis[] = {GRB_BASIC, GRB_BASIC, GRB_NONBASIC_LOWER, GRB_BASIC};
error = GRBsetintattrarray(model, "CBasis", 0, 4, cbasis);
```

## GRBgetintattrlist

```
int GRBgetintattrlist ( GRBmodel    *model,
                        const char  *attrname,
                        int          len,
                        int          *ind,
                        int          *values )
```

Query the values of an integer-valued array attribute.

### Return value:

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of an integer-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**len:** The number of attribute elements to retrieve.

**ind:** The indices of the desired attribute elements.

**values:** A pointer to the location where the requested attribute elements should be returned.

Note that the result array must be as long as the requested index list.

### Example usage:

```
int desired[] = {0, 2, 4, 6};
int cbasis[4];
error = GRBgetintattrlist(model, "CBasis", 4, desired, cbasis);
```

## GRBsetintattrlist

```
int GRBsetintattrlist ( GRBmodel    *model,
                        const char  *attrname,
                        int          len,
                        int          *ind,
                        int          *values )
```

Set the values of an integer-valued array attribute.

### Return value:

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of an integer-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**len:** The number of array entries to set.

**ind:** The indices of the array attribute elements that will be set.

**values:** A pointer to the desired new values for the specified elements of the attribute. Note that the values array must be as long as the list of indices.

**Example usage:**

```
int change[] = {0, 1, 3};
int newbas[] = {GRB_BASIC, GRB_NONBASIC_LOWER, GRB_NONBASIC_LOWER};
error = GRBsetintattrlist(model, "VBasis", 3, change, newbas);
```

## GRBgetdblattr

```
int GRBgetdblattr ( GRBmodel *model,
                   const char *attrname,
                   double *valueP )
```

Query the value of a double-valued model attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a double-valued model attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**valueP:** The location in which the current value of the requested attribute should be placed.

**Important note:**

Note that this method should be used for scalar attributes only (i.e., model attributes). To query a single element of an array attribute, use [GRBgetdblattrelement](#) instead.

**Example usage:**

```
error = GRBgetdblattr(model, "ObjCon", &objcon);
```

## GRBsetdblattr

```
int GRBsetdblattr ( GRBmodel *model,
                   const char *attrname,
                   double newvalue )
```

Set the value of a double-valued model attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a double-valued model attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**newvalue:** The desired new value of this attribute.

**Important note:**

Note that this method should be used for scalar attributes only (i.e., model attributes). To modify a single element of an array attribute, use [GRBsetdblattrelement](#) instead.

**Example usage:**

```
error = GRBsetdblattr(model, "ObjCon", 0.0);
```

**GRBgetdblattrelement**

```
int GRBgetdblattrelement ( GRBmodel    *model,
                           const char  *attrname,
                           int          element,
                           double       *valueP )
```

Query a single value from a double-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a double-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**element:** The index of the requested array element.

**values:** A pointer to the location where the requested value should be returned.

**Important note:**

Note that this method should be used for array attributes only (i.e., variable or constraint attributes). To query a scalar attribute (i.e., a model attribute), use [GRBgetdblattr](#) instead.

**Example usage:**

```
double first_one;
error = GRBgetdblattrelement(model, "X", 0, &first_one);
```

**GRBsetdblattrelement**

```
int GRBsetdblattrelement ( GRBmodel    *model,
                           const char  *attrname,
                           int          element,
                           double       newvalue )
```

Set a single value in a double-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a double-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**element:** The index of the array element to be changed.

**newvalue:** The value to which the attribute element should be set.

**Important note:**

Note that this method should be used for array attributes only (i.e., variable or constraint attributes). To modify a scalar attribute (i.e., a model attribute), use [GRBsetdblattr](#) instead.

**Example usage:**

```
error = GRBsetdblattrelement(model, "Start", 0, 1.0);
```

## GRBgetdblattrarray

```
int GRBgetdblattrarray ( GRBmodel *model,
                        const char *attrname,
                        int start,
                        int len,
                        double *values )
```

Query the values of a double-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a double-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**start:** The index of the first entry in the array to retrieve.

**len:** The number of array entries to retrieve.

**values:** A pointer to the location where the array attribute should be returned. Note that the result array must be as long as the requested sub-array.

**Example usage:**

```
double lb[NUMVARS];
error = GRBgetdblattrarray(model, "LB", 0, cols, lb);
```

## GRBsetdblattrarray

```
int GRBsetdblattrarray ( GRBmodel *model,
                        const char *attrname,
                        int start,
                        int len,
                        double *values )
```

Set the values of a double-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRB-readmodel](#).

**attrname:** The name of a double-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**start:** The index of the first entry in the array to set.

**len:** The number of array entries to set.

**values:** A pointer to the desired new values for the specified sub-array of the attribute. Note that the values array must be as long as the sub-array to be changed.

**Example usage:**

```
double start[] = {1.0, 1.0, 0.0, 1.0};
error = GRBsetdblattrarray(model, "Start", 0, 4, start);
```

**GRBgetdblattrlist**

```
int GRBgetdblattrlist ( GRBmodel    *model,
                        const char  *attrname,
                        int          len,
                        int          *ind,
                        double       *values )
```

Query the values of a double-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRB-readmodel](#).

**attrname:** The name of a double-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**len:** The number of attribute elements to retrieve.

**ind:** The indices of the desired attribute elements.

**values:** A pointer to the location where the requested attribute elements should be returned. Note that the result array must be as long as the requested index list.

**Example usage:**

```
int desired[] = {0, 2, 4, 6};
double x[4];
error = GRBgetdblattrlist(model, "X", 4, desired, cbasis);
```

**GRBsetdblattrlist**

```
int GRBsetdblattrlist ( GRBmodel    *model,
                        const char  *attrname,
                        int          len,
                        int          *ind,
                        double       *values )
```

Set the values of a double-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a double-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**len:** The number of array entries to set.

**ind:** The indices of the array attribute elements that will be set.

**values:** A pointer to the desired new values for the specified elements of the attribute. Note that the values array must be as long as the list of indices.

**Example usage:**

```
int change[] = {0, 1, 3};
double start[] = {1.0, 3.0, 2.0};
error = GRBsetdblattrlist(model, "Start", 3, change, start);
```

## GRBgetcharattrelement

```
int GRBgetcharattrelement ( GRBmodel *model,
                             const char *attrname,
                             int element,
                             char *valueP )
```

Query a single value from a character-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a character-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**element:** The index of the requested array element.

**valueP:** A pointer to the location where the requested value should be returned.

**Example usage:**

```
char first_one;
error = GRBgetcharattrelement(model, "VType", 0, &first_one);
```

## GRBsetcharattrelement

```
int GRBsetcharattrelement ( GRBmodel *model,
                             const char *attrname,
                             int element,
                             char newvalue )
```

Set a single value in a character-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRB-readmodel](#).

**attrname:** The name of a character-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**element:** The index of the array element to be changed.

**newvalue:** The value to which the attribute element should be set.

**Example usage:**

```
error = GRBsetcharattrelement(model, "VType", 0, GRB_BINARY);
```

## GRBgetcharattrarray

```
int GRBgetcharattrarray ( GRBmodel    *model,
                          const char  *attrname,
                          int          start,
                          int          len,
                          char         *values )
```

Query the values of a character-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRB-readmodel](#).

**attrname:** The name of a character-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**start:** The index of the first entry in the array to retrieve.

**len:** The number of array entries to retrieve.

**values:** A pointer to the location where the array attribute should be returned. Note that the result array must be as long as the requested sub-array.

**Example usage:**

```
char vtypes[NUMVARS];
error = GRBgetcharattrarray(model, "VType", 0, NUMVARS, vtypes);
```

## GRBsetcharattrarray

```
int GRBsetcharattrarray ( GRBmodel    *model,
                          const char  *attrname,
                          int         start,
                          int         len,
                          char        *values )
```

Set the values of a character-valued array attribute.

### Return value:

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a character-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**start:** The index of the first entry in the array to set.

**len:** The number of array entries to set.

**values:** A pointer to the desired new values for the specified sub-array of the attribute. Note that the values array must be as long as the sub-array to be changed.

### Example usage:

```
char vtypes[] = {GRB_BINARY, GRB_CONTINUOUS, GRB_INTEGER, GRB_BINARY};
error = GRBsetcharattrarray(model, "VType", 0, 4, vtypes);
```

## GRBgetcharattrlist

```
int GRBgetcharattrlist ( GRBmodel    *model,
                         const char  *attrname,
                         int         len,
                         int         *ind,
                         char        *values )
```

Query the values of a character-valued array attribute.

### Return value:

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a character-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**len:** The number of attribute elements to retrieve.

**ind:** The indices of the desired attribute elements.

**values:** A pointer to the location where the requested attribute elements should be returned.

Note that the result array must be as long as the requested index list.

### Example usage:

```

int desired[] = {0, 2, 4, 6};
char vtypes[4];
error = GRBgetcharattrlist(model, "VType", 4, desired, vtypes);

```

## GRBsetcharattrlist

```

int GRBsetcharattrlist ( GRBmodel    *model,
                        const char  *attrname,
                        int          len,
                        int          *ind,
                        char         *values )

```

Set the values of a character-valued array attribute.

### Return value:

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a character-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**len:** The number of array entries to set.

**ind:** The indices of the array attribute elements that will be set.

**values:** A pointer to the desired new values for the specified elements of the attribute. Note that the values array must be as long as the list of indices.

### Example usage:

```

int change[] = {0, 1, 3};
char vtypes[] = {GRB_BINARY, GRB_BINARY, GRB_BINARY};
error = GRBsetcharattrlist(model, "Vtype", 3, change, vtypes);

```

## GRBgetstrattr

```

int GRBgetstrattr ( GRBmodel    *model,
                   const char  *attrname,
                   char         **valueP )

```

Query the value of a string-valued model attribute.

### Return value:

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a string-valued model attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**valueP:** The location in which the current value of the requested attribute should be placed.

**Important notes:**

Note that all interface routines that return string-valued attributes are returning pointers into internal Gurobi data structures. The user should copy the contents of the pointer to a different data structure before the next call to a Gurobi library routine. The user should also be careful to never modify the data pointed to by the returned character pointer.

Note that this method should be used for scalar attributes only (i.e., model attributes). To query a single element of an array attribute, use [GRBgetstrattrelement](#) instead.

**Example usage:**

```
char *modelname;
error = GRBgetstrattr(model, "ModelName", &modelname);
```

## GRBsetstrattr

```
int GRBsetstrattr ( GRBmodel *model,
                   const char *attrname,
                   const char *newvalue )
```

Set the value of a string-valued model attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRB-readmodel](#).

**attrname:** The name of a string-valued model attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**newvalue:** The desired new value of this attribute.

**Important note:**

Note that this method should be used for scalar attributes only (i.e., model attributes). To modify a single element of an array attribute, use [GRBsetstrattrelement](#) instead.

**Example usage:**

```
error = GRBsetstrattr(model, "ModelName", "Modified name");
```

## GRBgetstrattrelement

```
int GRBgetstrattrelement ( GRBmodel *model,
                           const char *attrname,
                           int element,
                           char **valueP )
```

Query a single value from a string-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

- model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRB-readmodel](#).
- attrname:** The name of a string-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.
- element:** The index of the requested array element.
- valueP:** A pointer to the location where the requested value should be returned.

**Important notes:**

Note that all interface routines that return string-valued attributes are returning pointers into internal Gurobi data structures. The user should copy the contents of the pointer to a different data structure before the next call to a Gurobi library routine. The user should also be careful to never modify the data pointed to by the returned character pointer.

Note that this method should be used for array attributes only (i.e., variable or constraint attributes). To query a scalar attribute (i.e., a model attribute), use [GRBgetstrattr](#) instead.

**Example usage:**

```
char **varname;
error = GRBgetstrattrelement(model, "VarName", 1, varname);
```

**GRBsetstrattrelement**

```
int GRBsetstrattrelement ( GRBmodel    *model,
                           const char  *attrname,
                           int          element,
                           char        *newvalue )
```

Set a single value in a string-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

- model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRB-readmodel](#).
- attrname:** The name of a string-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.
- element:** The index of the array element to be changed.
- newvalue:** The value to which the attribute element should be set.

**Important note:**

Note that this method should be used for array attributes only (i.e., variable or constraint attributes). To modify a scalar attribute (i.e., a model attribute), use [GRBsetstrattr](#) instead.

**Example usage:**

```
error = GRBsetstrattrelement(model, "ConstrName", 0, "NewConstr");
```

## GRBgetstrattrarray

```
int GRBgetstrattrarray ( GRBmodel    *model,
                        const char  *attrname,
                        int          start,
                        int          len,
                        char         **values )
```

Query the values of a string-valued array attribute.

### Return value:

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a string-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**start:** The index of the first entry in the array to retrieve.

**len:** The number of array entries to retrieve.

**values:** A pointer to the location where the array attribute should be returned. Note that the result array must be as long as the requested sub-array.

### Important notes:

Note that all interface routines that return string-valued attributes are returning pointers into internal Gurobi data structures. The user should copy the contents of the pointer to a different data structure before the next call to a Gurobi library routine. The user should also be careful to never modify the data pointed to by the returned character pointer.

### Example usage:

```
char **varnames[NUMVARS];
error = GRBgetstrattrarray(model, "VarName", 0, NUMVARS, varnames);
```

## GRBsetstrattrarray

```
int GRBsetstrattrarray ( GRBmodel    *model,
                        const char  *attrname,
                        int          start,
                        int          len,
                        char         **values )
```

Set the values of a string-valued array attribute.

### Return value:

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a string-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**start:** The index of the first entry in the array to set.

**len:** The number of array entries to set.

**values:** A pointer to the desired new values for the specified sub-array of the attribute. Note that the values array must be as long as the sub-array to be changed.

**Example usage:**

```
char **varnames[NUMVARS];
error = GRBsetstratarray(model, "VarName", 0, NUMVARS, varnames);
```

## GRBgetstratlist

```
int GRBgetstratlist ( GRBmodel *model,
                     const char *attrname,
                     int len,
                     int *ind,
                     char **values )
```

Query the values of a string-valued array attribute.

**Return value:**

A non-zero return value indicates that a problem occurred while querying the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a string-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**len:** The number of attribute elements to retrieve.

**ind:** The indices of the desired attribute elements.

**values:** A pointer to the location where the requested attribute elements should be returned. Note that the result array must be as long as the requested index list.

**Important notes:**

Note that all interface routines that return string-valued attributes are returning pointers into internal Gurobi data structures. The user should copy the contents of the pointer to a different data structure before the next call to a Gurobi library routine. The user should also be careful to never modify the data pointed to by the returned character pointer.

**Example usage:**

```
int desired[] = {0, 2, 4, 6};
char **varnames[4];
error = GRBgetstratlist(model, "VarName", 4, desired, varnames);
```

## GRBsetstratrrlist

```
int GRBsetstratrrlist ( GRBmodel   *model,
                        const char  *attrname,
                        int          len,
                        int          *ind,
                        char         **values )
```

Set the values of a string-valued array attribute.

### Return value:

A non-zero return value indicates that a problem occurred while setting the attribute. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**model:** A loaded optimization model, typically created by routine [GRBnewmodel](#) or [GRBreadmodel](#).

**attrname:** The name of a string-valued array attribute. Available attributes are listed and described in the [Attributes](#) section of this document.

**len:** The number of array entries to set.

**ind:** The indices of the array attribute elements that will be set.

**values:** A pointer to the desired new values for the specified elements of the attribute. Note that the values array must be as long as the list of indices.

### Example usage:

```
int change[] = {0, 1, 3};
char **varnames[] = {"Var0", "Var1", "Var3"};
error = GRBsetstratrrlist(model, "VarName", 3, change, varnames);
```

## 2.7 Parameter Management and Tuning

### GRBtunemodel

```
int GRBtunemodel ( GRBmodel *model )
```

Perform an automated search for parameter settings that improve performance on a model. Upon completion, this routine stores the best parameter sets it found. The number of stored parameter sets can be determined by querying the value of the [TuneResultCount](#) attribute. The actual settings can be retrieved using [GRBgettunerresult](#)

Please refer to the [parameter tuning](#) section for details on the tuning tool.

**Return value:**

A non-zero return value indicates that a problem occurred while tuning the model. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** The model to be tuned.

**Example usage:**

```
error = GRBtunemodel(model);
if (error) goto QUIT;

error = GRBgetintattr(model, "TuneResultCount", &nresults);
if (error) goto QUIT;
```

### GRBgettunerresult

```
int GRBgettunerresult ( GRBmodel *model,
                        int n )
```

Use this routine to retrieve the results of a previous [GRBtunemodel](#) call. Calling this routine with argument *n* causes tuned parameter set *n* to be copied into the model. Parameter sets are stored in order of decreasing quality, with parameter set 0 being the best. The number of available sets is stored in attribute [TuneResultCount](#).

Once you have retrieved a tuning result, you can call [GRBoptimize](#) to use these parameter settings to optimize the model, or [GRBwrite](#) to write the changed parameters to a `.prm` file.

Please refer to the [parameter tuning](#) section for details on the tuning tool.

**Return value:**

A non-zero return value indicates that a problem occurred while retrieving a tuning result. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**model:** A model that has previously been used as the argument of [GRBtunemodel](#).

**n:** The index of the tuning result to retrieve. The best result is available as index 0. The number of stored results is available in attribute [TuneResultCount](#).

**Example usage:**

```
error = GRBtunemodel(model);
if (error) goto QUIT;
```

```

error = GRBgetintattr(model, "TuneResultCount", &nresults);
if (error) goto QUIT;

if (nresults > 0) {
    error = GRBgettunerresult(model, 0);
    if (error) goto QUIT;
}

```

## GRBgetdblparam

```

int GRBgetdblparam ( GRBenv      *env,
                    const char  *paramname,
                    double      *valueP )

```

Retrieve the value of a double-valued parameter.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the parameter. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**env:** The environment whose parameter value is being queried.

**paramname:** The name of the parameter. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**valueP:** The location in which the current value of the requested parameter should be placed.

### Example usage:

```

double cutoff;
error = GRBgetdblparam(GRBgetenv(model), "Cutoff", &cutoff);

```

## GRBgetintparam

```

int GRBgetintparam ( GRBenv      *env,
                    const char  *paramname,
                    int          *valueP )

```

Retrieve the value of an integer-valued parameter.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the parameter. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**env:** The environment whose parameter value is being queried.

**paramname:** The name of the parameter. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**valueP:** The location in which the current value of the requested parameter should be placed.

### Example usage:

```
int limit;
error = GRBgetintparam(GRBgetenv(model), "SolutionLimit", &limit);
```

## GRBgetstrparam

```
int GRBgetstrparam ( GRBenv      *env,
                    const char  *paramname,
                    char        *value )
```

Retrieve the value of a string-valued parameter.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the parameter. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**env:** The environment whose parameter value is being queried.

**paramname:** The name of the parameter. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**value:** The location in which the current value of the requested parameter should be placed.

### Example usage:

```
char logfilename[GRB_MAX_STRLEN];
error = GRBgetstrparam(GRBgetenv(model), "LogFile", logfilename);
```

## GRBsetdblparam

```
int GRBsetdblparam ( GRBenv      *env,
                    const char  *paramname,
                    double      newvalue )
```

Modify the value of a double-valued parameter.

### Return value:

A non-zero return value indicates that a problem occurred while modifying the parameter. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**env:** The environment whose parameter value is being modified.

**paramname:** The name of the parameter. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

### Important note:

Note that a model gets its own copy of the environment when it is created. Changes to the original environment have no effect on the copy. Use [GRBgetenv](#) to retrieve the environment associated with a model if you would like a parameter change to affect that model.

### Example usage:

```
error = GRBsetdblparam(GRBgetenv(model), "Cutoff", 100.0);
```

## GRBsetintparam

```
int GRBsetintparam ( GRBenv      *env,  
                    const char  *paramname,  
                    int         newvalue )
```

Modify the value of an integer-valued parameter.

### Return value:

A non-zero return value indicates that a problem occurred while modifying the parameter. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**env**: The environment whose parameter value is being modified.

**paramname**: The name of the parameter. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue**: The desired new value of the parameter.

### Important note:

Note that a model gets its own copy of the environment when it is created. Changes to the original environment have no effect on the copy. Use [GRBgetenv](#) to retrieve the environment associated with a model if you would like a parameter change to affect that model.

### Example usage:

```
error = GRBsetintparam(GRBgetenv(model), "SolutionLimit", 5);
```

## GRBsetstrparam

```
int GRBsetstrparam ( GRBenv      *env,  
                    const char  *paramname,  
                    const char  *newvalue )
```

Modify the value of a string-valued parameter.

### Return value:

A non-zero return value indicates that a problem occurred while modifying the parameter. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

### Arguments:

**env**: The environment whose parameter value is being modified.

**paramname**: The name of the parameter. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue**: The desired new value of the parameter.

### Important note:

Note that a model gets its own copy of the environment when it is created. Changes to the original environment have no effect on the copy. Use [GRBgetenv](#) to retrieve the environment associated with a model if you would like a parameter change to affect that model.

### Example usage:

```
error = GRBsetstrparam(GRBgetenv(model), "LogFile", "/tmp/new.log");
```

## GRBgetdblparaminfo

```
int GRBgetdblparaminfo ( GRBEnv      *env,  
                        const char  *paramname,  
                        double       *valueP,  
                        double       *minP,  
                        double       *maxP,  
                        double       *defaultP )
```

Retrieve information about a double-valued parameter. Specifically, retrieve the current value of the parameter, the minimum and maximum allowed values, and the default value.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving parameter information. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**env**: The environment whose parameter information is being queried.

**paramname**: The name of the parameter. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**valueP (optional)**: The location in which the current value of the specified parameter should be placed.

**minP (optional)**: The location in which the minimum allowed value of the specified parameter should be placed.

**maxP (optional)**: The location in which the maximum allowed value of the specified parameter should be placed.

**defaultP (optional)**: The location in which the default value of the specified parameter should be placed.

### Example usage:

```
error = GRBgetdblparaminfo(GRBgetenv(model), "MIPGap", &currentGap,  
                          &minAllowedGap, NULL, &defaultGap);
```

## GRBgetintparaminfo

```
int GRBgetintparaminfo ( GRBEnv      *env,  
                        const char  *paramname,  
                        int         *valueP,  
                        int         *minP,  
                        int         *maxP,  
                        int         *defaultP )
```

Retrieve information about an int-valued parameter. Specifically, retrieve the current value of the parameter, the minimum and maximum allowed values, and the default value.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving parameter information. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**env**: The environment whose parameter information is being queried.

**paramname**: The name of the parameter. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**valueP (optional)**: The location in which the current value of the specified parameter should be placed.

**minP (optional)**: The location in which the minimum allowed value of the specified parameter should be placed.

**maxP (optional)**: The location in which the maximum allowed value of the specified parameter should be placed.

**defaultP (optional)**: The location in which the default value of the specified parameter should be placed.

**Example usage:**

```
error = GRBgetintparaminfo(GRBgetenv(model), "SolutionLimit", &current,
                           &minAllowedLimit, NULL, &defaultLimit);
```

## GRBgetstrparaminfo

```
int GRBgetstrparaminfo ( GRBenv      *env,
                          const char *paramname,
                          char       *value,
                          char       *default )
```

Retrieve information about a string-valued parameter. Specifically, retrieve the current and default values of the parameter.

**Return value:**

A non-zero return value indicates that a problem occurred while retrieving parameter information. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**env**: The environment whose parameter information is being queried.

**paramname**: The name of the parameter. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**value (optional)**: The location in which the current value of the specified parameter should be placed.

**default (optional)**: The location in which the default value of the specified parameter should be placed.

**Example usage:**

```
char defaultval[GRB_MAX_STRLEN];
char currentval[GRB_MAX_STRLEN];
error = GRBgetstrparaminfo(GRBgetenv(model), "LogFile", currentval,
                           defaultval);
```

## GRBreadparams

```
int GRBreadparams ( GRBenv      *env,  
                   const char  *filename )
```

Import a set of parameter modifications from a file.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**Return value:**

A non-zero return value indicates that a problem occurred while reading the parameter file. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**env:** The environment into which the parameter changes should be imported.

**filename:** The path to the file to be read. The suffix on a parameter file should be `.prm`, optionally followed by `.zip`, `.gz`, `.bz2`, or `.7z`.

**Example usage:**

```
error = GRBreadparams(env, "/tmp/model.prm.bz2");
```

## GRBwriteparams

```
int GRBwriteparams ( GRBenv      *env,  
                   const char  *filename )
```

Write the set of changed parameter values to a file.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**Return value:**

A non-zero return value indicates that a problem occurred while writing the parameter file. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

**env:** The environment whose parameter changes are being written.

**filename:** The path to the file to be written. The suffix on a parameter file should be `.prm`, optionally followed by `.gz`, `.bz2`, or `.7z`.

**Example usage:**

```
error = GRBwriteparams(env, "/tmp/model.prm");
```

## 2.8 Monitoring Progress - Logging and Callbacks

### GRBmsg

```
void GRBmsg ( GRBenv      *env,
              const char *message )
```

Insert a message into the Gurobi log file.

#### Arguments:

**env:** The environment whose log file should receive the message.

**message:** The message to be appended to the log.

#### Example usage:

```
error = GRBmsg(env, "Add this message to the log");
```

### GRBsetcallbackfunc

```
int GRBsetcallbackfunc ( GRBmodel *model,
                        int        (*cb)(GRBmodel *model, void *cbdata, int
                                         where, void *usrdata),
                        void        *usrdata )
```

Set up a user callback function. Note that a model can only have a single callback function, so this call will replace an existing callback.

Note that a model can only have a single callback method, so this call will replace an existing callback. To disable a previously set callback, call this function with a `cb` argument of `NULL`.

When solving a model using multiple threads, note that the user callback is only ever called from a single thread, so you don't need to worry about the thread-safety of your callback.

#### Return value:

A non-zero return value indicates that a problem occurred while setting the user callback. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

#### Arguments:

**model:** The model in which the callback should be installed.

**cb:** A function pointer to the user callback function. The callback will be called regularly from the Gurobi optimizer. The `where` argument to the callback function will indicate where in the optimization process the callback was invoked. Possible values are described in the [Callback Codes](#) section. The user callback can then call a number of routines to retrieve additional details about the state of the optimization (e.g., [GRBcbget](#)), or to inject new information (e.g., [GRBcbcut](#), [GRBcb solution](#)). The user callback function should return 0 if no error was encountered, or it can return one of the Gurobi [Error Codes](#) if the user callback would like the optimization to stop and return an error result.

**usrdata:** An optional pointer to user data that will be passed back to the user callback function each time it is invoked (in the `usrdata` argument).

#### Example usage:

```
int mycallback(GRBmodel *model, void *cbdata, int where, void *usrdata);
error = GRBsetcallbackfunc(model, mycallback, NULL);
```

## GRBgetcallbackfunc

```
int GRBgetcallbackfunc ( GRBmodel *model,
                        int (**cb)(GRBmodel *model, void *cbdata,
                                   int where, void *usrdata) )
```

Retrieve the current user callback function.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the user callback. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**model:** The model in which the callback should be installed.

**cb:** A function pointer to the user callback function.

### Example usage:

```
int (*mycallback)(GRBmodel *model, void *cbdata, int where, void *usrdata);
error = GRBgetcallbackfunc(model, &mycallback);
```

## GRBcbget

```
int GRBcbget ( void *cbdata,
              int where,
              int what,
              void *resultP )
```

Retrieve additional information about the progress of the optimization. Note that this routine can only be called from within a user callback function.

### Return value:

A non-zero return value indicates that a problem occurred while retrieving the requested data. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**cbdata:** The `cbdata` argument that was passed into the user callback by the Gurobi optimizer. This argument must be passed unmodified from the user callback to `GRBcbget()`.

**where:** The `where` argument that was passed into the user callback by the Gurobi optimizer. This argument must be passed unmodified from the user callback to `GRBcbget()`.

**what:** The data requested by the user callback. Valid values are described in the [Callback Codes](#) section.

**resultP:** The location in which the requested data should be placed.

### Example usage:

```
if (where == GRB_CB_MIP) {
    double nodecount;
    error = GRBcbget(cbdata, where, GRB_CB_MIP_NODECNT, (void *) &nodecount);
    if (error) return 0;
    printf("MIP node count is %d\n", nodecount);
}
```

## GRBversion

```
void GRBversion ( int *majorP,  
                 int *minorP,  
                 int *technicalP )
```

Return the Gurobi library version number (major, minor, and technical).

### Arguments:

**majorP**: The location in which the major version number should be placed. May be `NULL`.

**minorP**: The location in which the minor version number should be placed. May be `NULL`.

**technicalP**: The location in which the technical version number should be placed. May be `NULL`.

### Example usage:

```
int major, minor, technical;  
GRBversion(&major, &minor, &technical);  
printf("Gurobi library version %d.%d.%d\n", major, minor, technical);
```

## 2.9 Modifying Solver Behavior - Callbacks

### GRBcbcut

```
int GRBcbcut ( void      *cbdata,
               int       cutlen,
               const int  *cutind,
               const double *cutval,
               char       cutsense,
               double     cutrhs )
```

Add a new cutting plane to the MIP model from within a user callback routine. Note that this routine can only be called when the `where` value on the callback routine is `GRB_CB_MIPNODE` (see the [Callback Codes](#) section for more information).

Cutting planes can be added at any node of the branch-and-cut tree. Note that cuts should be added sparingly, since they increase the size of the relaxation model that is solved at each node and can significantly degrade node processing speed.

Cutting planes are typically used to cut off the current relaxation solution. To retrieve the relaxation solution at the current node, call [GRBcbget](#) with `what = GRB_CB_MIPNODE_REL`.

When adding your own cuts, you must set parameter [PreCrush](#) to value 1. This setting shuts off a few presolve reductions that sometimes prevent cuts on the original model from being applied to the presolved model.

One very important note: you should only add cuts that are implied by the constraints in your model. If you cut off an integer solution that is feasible according to the original model constraints, *you are likely to obtain an incorrect solution to your MIP problem.*

#### Return value:

A non-zero return value indicates that a problem occurred while adding the cut. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

#### Arguments:

**cbdata:** The `cbdata` argument that was passed into the user callback by the Gurobi optimizer. This argument must be passed unmodified from the user callback to `GRBcbcut()`.

**cutlen:** The number of non-zero coefficients in the new cutting plane.

**cutind:** Variable indices for non-zero values in the new cutting plane.

**cutval:** Numerical values for non-zero values in the new cutting plane.

**cutsense:** Sense for the new cutting plane. Options are `GRB_LESS_EQUAL`, `GRB_EQUAL`, or `GRB_GREATER_EQUAL`.

**cutrhs:** Right-hand-side value for the new cutting plane.

#### Example usage:

```
if (where == GRB_CB_MIPNODE) {
    int cutind[] = {0, 1};
    double cutval[] = {1.0, 1.0};
    error = GRBcbcut(cbdata, 2, cutind, cutval, GRB_LESS_EQUAL, 1.0);
    if (error) return 0;
}
```

## GRBcblazy

```
int GRBcblazy ( void      *cbdata,
                int       lazylen,
                const int  *lazyind,
                const double *lazyval,
                char       lazysense,
                double     lazyrhs )
```

Add a new lazy constraint to the MIP model from within a user callback routine. Note that this routine can only be called when the `where` value on the callback routine is either `GRB_CB_MIPNODE` or `GRB_CB_MIPSOL` (see the [Callback Codes](#) section for more information).

Lazy constraints are typically used when the full set of constraints for a MIP model is too large to represent explicitly. By only including the constraints that are actually violated by solutions found during the branch-and-cut search, it is sometimes possible to find a proven optimal solution while only adding a fraction of the full set of constraints.

You would typically add a lazy constraint by querying the current node solution (by calling [GRBcbget](#) from a `GRB_CB_MIPSOL` or `GRB_CB_MIPNODE` callback, using `what=GRB_CB_MIPSOL_SOL` or `what=GRB_CB_MIPNODE_REL`), and then calling `GRBcblazy()` to add a constraint that cuts off the solution. Gurobi guarantees that you will have the opportunity to cut off any solutions that would otherwise be considered feasible.

Your callback should be prepared to cut off solutions that violate any of your lazy constraints, including those that have already been added. Node solutions will usually respect previously added lazy constraints, but not always.

Note that you must set the [LazyConstraints](#) parameter if you want to use lazy constraints.

### Return value:

A non-zero return value indicates that a problem occurred while adding the lazy constraint. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**cbdata:** The `cbdata` argument that was passed into the user callback by the Gurobi optimizer. This argument must be passed unmodified from the user callback to `GRBcblazy()`.

**lazylen:** The number of non-zero coefficients in the new lazy constraint.

**lazyind:** Variable indices for non-zero values in the new lazy constraint.

**lazyval:** Numerical values for non-zero values in the new lazy constraint.

**lazysense:** Sense for the new lazy constraint. Options are `GRB_LESS_EQUAL`, `GRB_EQUAL`, or `GRB_GREATER_EQUAL`.

**lazyrhs:** Right-hand-side value for the new lazy constraint.

### Example usage:

```
if (where == GRB_CB_MIPSOL) {
    int lazyind[] = {0, 1};
    double lazyval[] = {1.0, 1.0};
    error = GRBcblazy(cbdata, 2, lazyind, lazyval, GRB_LESS_EQUAL, 1.0);
    if (error) return 0;
}
```

## GRBcbsolution

```
int GRBcbsolution ( void      *cbdata,  
                   const double *solution,  
                   double      *objP )
```

Provide a new feasible solution for a MIP model from within a user callback routine. Note that this routine can only be called when the `where` value on the callback routine is `GRB_CB_MIPNODE` (see the [Callback Codes](#) section for more information).

Heuristics solutions are typically built from the current relaxation solution. To retrieve the relaxation solution at the current node, call [GRBcbget](#) with `what = GRB_CB_MIPNODE_REL`.

When providing a solution, you can specify values for any subset of the variables in the model. To leave a variable value unspecified, set the variable to `GRB_UNDEFINED` in the `solution` vector. The Gurobi MIP solver will attempt to extend the specified partial solution to a complete solution.

### Return value:

A non-zero return value indicates that a problem occurred while adding the new solution. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

### Arguments:

**cbdata:** The `cbdata` argument that was passed into the user callback by the Gurobi optimizer. This argument must be passed unmodified from the user callback to `GRBcbsolution()`.

**solution:** The solution vector. You must provide one entry for each variable in the model. Note that you can leave an entry unspecified by setting it to `GRB_UNDEFINED`. The Gurobi optimizer will attempt to find appropriate values for the unspecified variables.

**objP:** Objective value for solution that results from this call. Returns `GRB_INFINITY` if no solution is found.

### Example usage:

```
if (where == GRB_CB_MIPNODE) {  
    error = GRBcbsolution(cbdata, solution, &obj);  
    if (error) return 0;  
}
```

## GRBterminate

```
void GRBterminate ( GRBmodel *model )
```

Generate a request to terminate the current optimization. This routine can be called at any time during an optimization. When the optimization stops, the [Status](#) attribute will be equal to `GRB_INTERRUPTED`.

### Arguments:

**model:** The model to terminate.

### Example usage:

```
if (time_to_quit)  
    GRBterminate(model);
```

## 2.10 Error Handling

### GRBgeterrormsg

```
| char * GRBgeterrormsg ( GRBenv *env )
```

Retrieve the error message associated with the most recent error that occurred in an environment.

**Return value:**

A string containing the error message.

**Arguments:**

**env:** The environment in which the error occurred.

**Example usage:**

```
error = GRBgetintattr(model, "DOES_NOT_EXIST", &attr);  
if (error)  
    printf("%s\n", GRBgeterrormsg(env));
```

## 2.11 Advanced simplex routines

This section describes a set of advanced basis routines. These routines allow you to compute solutions to various linear systems involving the simplex basis matrix. Note that these should only be used by advanced users. We provide no technical support for these routines.

Before describing the routines, we should first describe the `GRBsvec` data structure that is used to input or return sparse vectors:

```
typedef struct SVector {
    int          len;
    int          *ind;
    double       *val;
} GRBsvec;
```

The `len` field gives the number of non-zero values in the vector. The `ind` and `val` fields give the index and value for each non-zero, respectively. Indices are zero-based. To give an example, the sparse vector `[0, 2.0, 0, 1.0]` would be represented as `len=2`, `ind = [1, 3]`, and `val = [2.0, 1.0]`.

The user is responsible for allocating and freeing the `ind` and `val` fields. The length of the result vector for these routines is not known in advance, so the user must allocate these arrays to hold the longest possible result (whose length is noted in the documentation for each routine).

### GRBFSolve

```
int GRBFSolve ( GRBmodel *model,
                GRBsvec  *b,
                GRBsvec  *x )
```

Computes the solution to the linear system  $Bx = b$ , where  $B$  is the current simplex basis matrix,  $b$  is an input vector, and  $x$  is the result vector.

#### Return value:

A non-zero return value indicates that a problem occurred while computing the desired vector. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling `GRBgeterrmsg`.

#### Arguments:

**model:** The model. Note that the model must have a current optimal basis, as computed by `GRBoptimize`.

**b:** The sparse right-hand side vector. It should contain one entry for each non-zero value in the input.

**x:** The sparse result vector. The user is responsible for allocating the `ind` and `val` fields to be large enough to hold as many as one non-zero entry per constraint in the model.

### GRBBSolve

```
int GRBBSolve ( GRBmodel *model,
                GRBsvec  *b,
                GRBsvec  *x )
```

Computes the solution to the linear system  $B^T x = b$ , where  $B^T$  is the transpose of the current simplex basis matrix,  $b$  is an input vector, and  $x$  is the result vector.

**Return value:**

A non-zero return value indicates that a problem occurred while computing the desired vector. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

- model:** The model. Note that the model must have a current optimal basis, as computed by [GRBoptimize](#).
- b:** The sparse right-hand side vector. It should contain one entry for each non-zero value in the input.
- x:** The sparse result vector. The user is responsible for allocating the `ind` and `val` fields to be large enough to hold as many as one non-zero entry per constraint in the model.

**GRBBinvColj**

```
int GRBBinvColj ( GRBmodel *model,
                 int      j,
                 GRBsvect *x )
```

Computes the solution to the linear system  $Bx = A_j$ , where  $B$  is the current simplex basis matrix and  $A_j$  is the column of the constraint matrix  $A$  associated with variable  $j$ .

**Return value:**

A non-zero return value indicates that a problem occurred while computing the desired vector. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

- model:** The model. Note that the model must have a current optimal basis, as computed by [GRBoptimize](#).
- j:** Indicates the index of the column of  $A$  to use as the right-hand side for the linear solve. The index  $j$  must be between 0 and `cols-1`, where `cols` is the number of columns in the model.
- x:** The sparse result vector. The user is responsible for allocating the `ind` and `val` fields to be large enough to hold as many as one non-zero entry per constraint in the model.

**GRBBinvRowi**

```
int GRBBinvRowi ( GRBmodel *model,
                 int      i,
                 GRBsvect *x )
```

Computes a single *tableau row*. More precisely, this routine returns row  $i$  from the matrix  $B^{-1}A$ , where  $B^{-1}$  is the inverse of the basis matrix and  $A$  is the constraint matrix. Note that the tableau will contain columns corresponding to the variables in the model, and also columns corresponding to artificial and slack variables associated with constraints.

**Return value:**

A non-zero return value indicates that a problem occurred while computing the desired vector. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrormsg](#).

**Arguments:**

- model:** The model. Note that the model must have a current optimal basis, as computed by [GRBoptimize](#).
- i:** The index of the desired tableau row.
- x:** The result vector. The result will contain one entry for each non-zero value. Note that the result may contain values for slack variables; the slack on row **i** will have index **cols+i**, where **cols** is the number of columns in the model. The user is responsible for allocating the **ind** and **val** fields to be large enough to hold the largest possible result. For this routine, the result could have one entry for each variable in the model, plus one entry for each constraint.

**GRBgetBasisHead**

```
int GRBgetBasisHead ( GRBmodel *model,
                     int *bhead )
```

Returns the indices of the variables that make up the current basis matrix.

**Return value:**

A non-zero return value indicates that a problem occurred while extracting the basis. Refer to the [Error Code](#) table for a list of possible return values. Details on the error can be obtained by calling [GRBgeterrmsg](#).

**Arguments:**

- model:** The model. Note that the model must have a current optimal basis, as computed by [GRBoptimize](#).
- bhead:** The constraint matrix columns that make up the current basis. The result contains one entry per constraint in *A*. If **bhead[i]=j**, then column **i** in the basis matrix *B* is column **j** from the constraint matrix *A*. Note that the basis may contain slack or artificial variables. If **bhead[i]** is greater than or equal to **cols** (the number of columns in *A*), then the corresponding basis column is the artificial or slack variable from row **bhead[i]-cols**.

This section documents the Gurobi C++ interface. This manual begins with a quick overview of the classes exposed in the interface and the most important methods on those classes. It then continues with a [comprehensive presentation of all of the available classes and methods](#).

If you are new to the Gurobi Optimizer, we suggest that you start with the [Quick Start Guide](#) or the [Example Tour](#). These documents provide concrete examples of how to use the classes and methods described here.

## Environments

The first step in using the Gurobi C++ interface is to create an environment object. Environments are represented using the `GRBEnv` class. An environment acts as the container for all data associated with a set of optimization runs. You will generally only need one environment object in your program.

## Models

You can create one or more optimization models within an environment. Each model is represented as an object of class `GRBModel`. A model consists of a set of decision variables (objects of class `GRBVar`), a linear or quadratic objective function on those variables (specified using `GRBModel::setObjective`), and a set of constraints on these variables (objects of class `GRBConstr`, `GRBQConstr`, `GRBSOS`, or `GRBGenConstr`). Each variable has an associated lower bound, upper bound, and type (continuous, binary, etc.). Each linear or quadratic constraint has an associated sense (less-than-or-equal, greater-than-or-equal, or equal), and right-hand side value. Refer to [this section](#) for more information on variables and constraints.

Linear constraints are specified by building linear expressions (objects of class `GRBLinExpr`), and then specifying relationships between these expressions (for example, requiring that one expression be equal to another). Quadratic constraints are built in a similar fashion, but using quadratic expressions (objects of class `GRBQuadExpr`) instead.

An optimization model may be specified all at once, by loading the model from a file (using the appropriate `GRBModel` constructor), or built incrementally, by first constructing an empty object of class `GRBModel` and then subsequently calling `GRBModel::addVar` or `GRBModel::addVars` to add additional variables, and `GRBModel::addConstr`, `GRBModel::addQConstr`, `GRBModel::addSOS`, or any of the `GRBModel::addGenConstrXxx` methods to add constraints. Models are dynamic entities; you can always add or remove variables or constraints.

We often refer to the *class* of an optimization model. A model with a linear objective function, linear constraints, and continuous variables is a *Linear Program (LP)*. If the objective is quadratic, the model is a *Quadratic Program (QP)*. If any of the constraints are quadratic, the model is a *Quadratically-Constrained Program (QCP)*. We'll sometimes also discuss a special case of QCP, the *Second-Order Cone Program (SOCP)*. If the model contains any integer variables, semi-continuous variables, semi-integer variables, Special Ordered Set (SOS) constraints, or general constraints, the model is a *Mixed Integer Program (MIP)*. We'll also sometimes discuss special cases of MIP, including *Mixed Integer Linear Programs (MILP)*, *Mixed Integer Quadratic Programs (MIQP)*, *Mixed*

*Integer Quadratically-Constrained Programs (MIQCP)*, and *Mixed Integer Second-Order Cone Programs (MISOCP)*. The Gurobi Optimizer handles all of these model classes.

### Solving a Model

Once you have built a model, you can call `GRBModel::optimize` to compute a solution. By default, `optimize` will use the `concurrent optimizer` to solve LP models, the barrier algorithm to solve QP and QCP models, and the branch-and-cut algorithm to solve mixed integer models. The solution is stored in a set of *attributes* of the model. These attributes can be queried using a set of attribute query methods on the `GRBModel`, `GRBVar`, `GRBConstr`, `GRBQConstr`, `GRBSOS`, and `GRBGenConstr` classes.

The Gurobi algorithms keep careful track of the state of the model, so calls to `GRBModel::optimize` will only perform further optimization if relevant data has changed since the model was last optimized. If you would like to discard previously computed solution information and restart the optimization from scratch without changing the model, you can call `GRBModel::reset`.

After a MIP model has been solved, you can call `GRBModel::fixedModel` to compute the associated *fixed* model. This model is identical to the input model, except that all integer variables are fixed to their values in the MIP solution. In some applications, it is useful to compute information on this continuous version of the MIP model (e.g., dual variables, sensitivity information, etc.).

### Multiple Solutions and Multiple Objectives

By default, the Gurobi Optimizer assumes that your goal is to find one proven optimal solution to a model with a single objective function. Gurobi provides features that allow you to relax either of these assumptions. You should refer to the section on [Solution Pools](#) for information on how to request more than one solution, or the section on [Multiple Objectives](#) for information on how to specify multiple objective functions and control the tradeoff between them.

### Infeasible Models

You have a few options if a model is found to be infeasible. You can try to diagnose the cause of the infeasibility, attempt to repair the infeasibility, or both. To obtain information that can be useful for diagnosing the cause of an infeasibility, call `GRBModel::computeIIS` to compute an Irreducible Inconsistent Subsystem (IIS). This method can be used for both continuous and MIP models, but you should be aware that the MIP version can be quite expensive. This method populates a set of IIS attributes.

To attempt to repair an infeasibility, call `GRBModel::feasRelax` to compute a feasibility relaxation for the model. This relaxation allows you to find a solution that minimizes the magnitude of the constraint violation.

### Querying and Modifying Attributes

Most of the information associated with a Gurobi model is stored in a set of attributes. Some attributes are associated with the variables of the model, some with the constraints of the model, and some with the model itself. To give a simple example, solving an optimization model causes the `X` variable attribute to be populated. Attributes such as `X` that are computed by the Gurobi optimizer cannot be modified directly by the user, while others, such as the variable lower bound (the `LB` attribute) can.

Attributes are queried using `GRBVar::get`, `GRBConstr::get`, `GRBQConstr::get`, `GRBSOS::get`, `GRBGenConstr::get`, or `GRBModel::get`, and modified using `GRBVar::set`, `GRBConstr::set`, `GRBQConstr::set`, `GRBGenConstr::set`, or `GRBModel::set`. Attributes are grouped into a set of enums

by type ([GRB\\_CharAttr](#), [GRB\\_DoubleAttr](#), [GRB\\_IntAttr](#), [GRB\\_StringAttr](#)). The `get()` and `set()` methods are overloaded, so the type of the attribute determines the type of the returned value. Thus, `constr.get(GRB.DoubleAttr.RHS)` returns a double, while `constr.get(GRB.CharAttr.Sense)` returns a char.

If you wish to retrieve attribute values for a set of variables or constraints, it is usually more efficient to use the array methods on the associated [GRBModel](#) object. Method [GRBModel::get](#) includes signatures that allow you to query or modify attribute values for arrays of variables or constraints.

The full list of attributes can be found in the [Attributes](#) section.

## Additional Model Modification Information

Most modifications to an existing model are done through the attribute interface (e.g., changes to variable bounds, constraint right-hand sides, etc.). The main exceptions are modifications to the constraint matrix and the objective function.

The constraint matrix can be modified in a few ways. The first is to call the [chgCoeffs](#) method on a [GRBModel](#) object to change individual matrix coefficients. This method can be used to modify the value of an existing non-zero, to set an existing non-zero to zero, or to create a new non-zero. The constraint matrix is also modified when you remove a variable or constraint from the model (through the [GRBModel::remove](#) method). The non-zero values associated with the deleted constraint or variable are removed along with the constraint or variable itself.

The model objective function can also be modified in a few ways. The easiest is to build an expression that captures the objective function (a [GRBLinExpr](#) or [GRBQuadExpr](#) object), and then pass that expression to method [GRBModel::setObjective](#). If you wish to modify the objective, you can simply call `setObjective` again with a new [GRBLinExpr](#) or [GRBQuadExpr](#) object.

For linear objective functions, an alternative to `setObjective` is to use the `Obj` variable attribute to modify individual linear objective coefficients.

If your variables have piecewise-linear objectives, you can specify them using the [GRBModel::setPWLObj](#) method. Call this method once for each relevant variable. The Gurobi simplex solver includes algorithmic support for convex piecewise-linear objective functions, so for continuous models you should see a substantial performance benefit from using this feature. To clear a previously specified piecewise-linear objective function, simply set the `Obj` attribute on the corresponding variable to 0.

## Lazy Updates

One important item to note about model modification in the Gurobi optimizer is that it is performed in a *lazy* fashion, meaning that modifications don't affect the model immediately. Rather, they are queued and applied later. If your program simply creates a model and solves it, you will probably never notice this behavior. However, if you ask for information about the model before your modifications have been applied, the details of the lazy update approach may be relevant to you.

As we just noted, model modifications (bound changes, right-hand side changes, objective changes, etc.) are placed in a queue. These queued modifications can be applied to the model in three different ways. The first is by an explicit call to [GRBModel::update](#). The second is by a call to [GRBModel::optimize](#). The third is by a call to [GRBModel::write](#) to write out the model. The first case gives you fine-grained control over when modifications are applied. The second and third make the assumption that you want all pending modifications to be applied before you

optimize your model or write it to disk.

Why does the Gurobi interface behave in this manner? There are a few reasons. The first is that this approach makes it much easier to perform multiple modifications to a model, since the model remains unchanged between modifications. The second is that processing model modifications can be expensive, particularly in a Compute Server environment, where modifications require communication between machines. Thus, it is useful to have visibility into exactly when these modifications are applied. In general, if your program needs to make multiple modifications to the model, you should aim to make them in phases, where you make a set of modifications, then update, then make more modifications, then update again, etc. Updating after each individual modification can be extremely expensive.

If you forget to call `update`, your program won't crash. Your query will simply return the value of the requested data from the point of the last update. If the object you tried to query didn't exist then, you'll get a `NOT_IN_MODEL` exception instead.

The semantics of lazy updates have changed in this release. While the vast majority of programs will continue to work unmodified, you can use the `UpdateMode` parameter to revert to the previous behavior if you run into an issue.

## Managing Parameters

The Gurobi optimizer provides a set of parameters that allow you to control many of the details of the optimization process. Factors like feasibility and optimality tolerances, choices of algorithms, strategies for exploring the MIP search tree, etc., can be controlled by modifying Gurobi parameters before beginning the optimization. Parameters can be of type *int*, *double*, or *string*.

The simplest way to set parameters is through the `GRBModel::set` method on the model object. Similarly, parameter values can be queried with `GRBModel::get`.

Parameters can also be set on the Gurobi environment object, using `GRBEnv::set`. Note that each model gets its own copy of the environment when it is created, so parameter changes to the original environment have no effect on existing models.

You can read a set of parameter settings from a file using `GRBEnv::readParams`, or write the set of changed parameters using `GRBEnv::writeParams`.

We also include an automated parameter tuning tool that explores many different sets of parameter changes in order to find a set that improves performance. You can call `GRBModel::tune` to invoke the tuning tool on a model. Refer to the [parameter tuning tool](#) section for more information.

The full list of Gurobi parameters can be found in the [Parameters](#) section.

## Memory Management

Memory management must always be considered in C++ programs. In particular, the Gurobi library and the user program share the same C++ heap, so the user must be aware of certain aspects of how the Gurobi library uses this heap. The basic rules for managing memory when using the Gurobi optimizer are as follows:

- As with other dynamically allocated C++ objects, `GRBEnv` or `GRBModel` objects should be freed using the associated destructors. In other words, given a `GRBModel` object `m`, you should call `delete m` when you are no longer using `m`.
- Objects that are associated with a model (e.g., `GRBConstr`, `GRBQConstr`, `GRBSOS`, `GRBGenConstr`, and `GRBVar` objects) are managed by the model. In particular, deleting a model

will delete all of the associated objects. Similarly, removing an object from a model (using [GRBModel::remove](#)) will also delete the object.

- Some Gurobi methods return an array of objects or values. For example, [GRBModel::addVars](#) returns an array of `GRBVar` objects. It is the user's responsibility to free the returned array (using `delete[]`). The reference manual indicates when a method returns a heap-allocated result.

One consequence of these rules is that you must be careful not to use an object once it has been freed. This is no doubt quite clear for environments and models, where you call the destructors explicitly, but may be less clear for constraints and variables, which are implicitly deleted when the associated model is deleted.

### Monitoring Progress - Logging and Callbacks

Progress of the optimization can be monitored through Gurobi logging. By default, Gurobi will send output to the screen. A few simple controls are available for modifying the default logging behavior. If you would like to direct output to a file as well as to the screen, specify the log file name in the [GRBEnv](#) constructor. You can modify the [LogFile](#) parameter if you wish to redirect the log to a different file after creating the environment object. The frequency of logging output can be controlled with the [DisplayInterval](#) parameter, and logging can be turned off entirely with the [OutputFlag](#) parameter. A detailed description of the Gurobi log file can be found in the [Logging](#) section.

More detailed progress monitoring can be done through the [GRBCallback](#) class. The [GRBModel::setCallback](#) method allows you to receive a periodic callback from the Gurobi optimizer. You do this by sub-classing the [GRBCallback](#) abstract class, and writing your own `callback()` method on this class. You can call [GRBCallback::getDoubleInfo](#), [GRBCallback::getIntInfo](#), [GRBCallback::getStringInfo](#), or [GRBCallback::getSolution](#) from within the callback to obtain additional information about the state of the optimization.

### Modifying Solver Behavior - Callbacks

Callbacks can also be used to modify the behavior of the Gurobi optimizer. The simplest control callback is [GRBCallback::abort](#), which asks the optimizer to terminate at the earliest convenient point. Method [GRBCallback::setSolution](#) allows you to inject a feasible solution (or partial solution) during the solution of a MIP model. Methods [GRBCallback::addCut](#) and [GRBCallback::addLazy](#) allow you to add *cutting planes* and *lazy constraints* during a MIP optimization, respectively.

### Error Handling

All of the methods in the Gurobi C++ library can throw an exception of type [GRBException](#). When an exception occurs, additional information on the error can be obtained by retrieving the error code (using method [GRBException::getErrorCode](#)), or by retrieving the exception message (using method [GRBException::getMessage](#)). The list of possible error return codes can be found in the [Error Codes](#) section.

## 3.1 GRBEnv

Gurobi environment object. Gurobi models are always associated with an environment. You must create an environment before you can create and populate a model. You will generally only need a single environment object in your program.

The methods on environment objects are mainly used to manage Gurobi parameters (e.g., [get](#), [getParamInfo](#), [set](#)).

### GRBEnv()

Constructor for `GRBEnv` object. If the constructor is called with no arguments, no log file will be written for the environment.

You have the option of constructing either a local environment, which solves Gurobi models on the local machine, a client environment for a Gurobi compute server, which will solve Gurobi models on a server machine, or an Instant Cloud environment, which will launch a Gurobi Cloud server and solve models on that server. Choose the appropriate signature for the type of environment you wish to launch.

Note that the `GRBEnv` constructor will check the current working directory for a file named `gurobi.env`, and it will attempt to read parameter settings from this file if it exists. The file should be in [PRM](#) format (briefly, each line should contain a parameter name, followed by the desired value for that parameter).

In general, you should aim to create a single Gurobi environment object in your program, even if you plan to work with multiple models. Reusing one environment is much more efficient than creating and destroying multiple environments.

```
GRBEnv GRBEnv ( )
```

Create a Gurobi environment (with logging disabled).

**Return value:**

An environment object (with no associated log file).

```
GRBEnv GRBEnv ( const string& logFileName )
```

Create a Gurobi environment (with logging enabled).

**Arguments:**

`logFileName`: The desired log file name.

**Return value:**

An environment object.

```
GRBEnv GRBEnv ( const string& logFileName,  
                const string& computeserver,  
                int          port,  
                const string& password,  
                int          priority,  
                double       timeout )
```

Create a client Gurobi environment on a compute server.

**Arguments:**

- logFileName:** The name of the log file for this environment. Pass an empty string for no log file.
- computeserver:** A comma-separated list of Gurobi compute servers. You can refer to compute server machines using their names or their IP addresses.
- port:** The port number used to connect to the compute server. You should pass a -1 value, which indicates that the default port should be used, unless your server administrator has changed our recommended port settings.
- password:** The password for gaining access to the specified compute servers. Pass an empty string if no password is required.
- priority:** The priority of the job. Priorities must be between -100 and 100, with a default value of 0 (by convention). Higher priority jobs are chosen from the server job queue before lower priority jobs. A job with priority 100 runs immediately, bypassing the job queue and ignoring the job limit on the server. You should exercise caution with priority 100 jobs, since they can severely overload a server, which can cause jobs to fail, and in extreme cases can cause the server to crash.
- timeout:** Job timeout (in seconds). If the job doesn't reach the front of the queue before the specified timeout, the constructor will throw a `JOB_REJECTED` exception. Use a negative value to indicate that the call should never timeout.

**Return value:**

An environment object.

```
GRBEnv GRBEnv ( const string& logFileName,  
               const string& accessID,  
               const string& secretKey,  
               const string& pool )
```

Create a Gurobi Instant Cloud environment.

**Arguments:**

- logfile:** The name of the log file for this environment. May be `NULL` (or an empty string), in which case no log file is created.
- accessID:** The access ID for your Gurobi Instant Cloud license. This can be retrieved from the Gurobi Instant Cloud website. When used in combination with your `secretKey`, this allows you to launch Instant Cloud instances and submit jobs to them.
- secretKey:** The secret key for your Gurobi Instant Cloud license. This can be retrieved from the Gurobi Instant Cloud website. When used in combination with your `accessID`, this allows you to launch Instant Cloud instances and submit jobs to them. Note that you should keep your secret key private.
- pool:** The machine pool. Machine pools allow you to create fixed configurations on the Instant Cloud website (capturing things like type of machine, geographic region, etc.), and then launch and share machines from client programs without having to restart the configuration information each time you launch a machine. May be `NULL` (or an empty string), in which case your job will be launched in the default pool associated with your cloud license.

**Return value:**

An environment object.

## GRBEnv::get()

Query the value of a parameter.

```
| double get ( GRB_DoubleParam param )
```

Query the value of a double-valued parameter.

### Arguments:

**param:** The parameter being queried. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

### Return value:

The current value of the requested parameter.

```
| int get ( GRB_IntParam param )
```

Query the value of an int-valued parameter.

### Arguments:

**param:** The parameter being queried. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

### Return value:

The current value of the requested parameter.

```
| const string get ( GRB_StringParam param )
```

Query the value of a string-valued parameter.

### Arguments:

**param:** The parameter being queried. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

### Return value:

The current value of the requested parameter.

## GRBEnv::getErrMsg()

Query the error message for the most recent exception associated with this environment.

```
| const string getErrMsg ( )
```

### Return value:

The error string.

## GRBEnv::getParamInfo()

Obtain information about a parameter.

```
void getParamInfo ( GRB_DoubleParam param,
                   double*          valP,
                   double*          minP,
                   double*          maxP,
                   double*          *defP )
```

Obtain detailed information about a double parameter.

### Arguments:

**param:** The parameter of interest. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**valP:** The current value of the parameter.

**minP:** The minimum allowed value of the parameter.

**maxP:** The maximum allowed value of the parameter.

**defP:** The default value of the parameter.

```
void getParamInfo ( GRB_IntParam param,
                   int*          valP,
                   int*          minP,
                   int*          maxP,
                   int*          defP )
```

Obtain detailed information about an integer parameter.

### Arguments:

**param:** The parameter of interest. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**valP:** The current value of the parameter.

**minP:** The minimum allowed value of the parameter.

**maxP:** The maximum allowed value of the parameter.

**defP:** The default value of the parameter.

```
void getParamInfo ( GRB_StringParam param,
                   string*          valP,
                   string*          defP )
```

Obtain detailed information about a string parameter.

### Arguments:

**param:** The parameter of interest. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**valP:** The current value of the parameter.

**defP:** The default value of the parameter.

## GRBEnv::message()

Write a message to the console and the log file.

```
| void message ( const string& message )
```

### Arguments:

**message:** Print a message to the console and to the log file. Note that this call has no effect unless the `OutputFlag` parameter is set.

## GRBEnv::readParams()

Read new parameter settings from a file.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

```
| void readParams ( const string& paramfile )
```

### Arguments:

**paramfile:** Name of the file containing parameter settings. Parameters should be listed one per line, with the parameter name first and the desired value second. For example:

```
# Gurobi parameter file  
Threads 1  
MIPGap 0
```

Blank lines and lines that begin with the hash symbol are ignored.

## GRBEnv::resetParams()

Reset all parameters to their default values.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

```
| void resetParams ( )
```

## GRBEnv::set()

Set the value of a parameter.

### Important notes:

Note that a model gets its own copy of the environment when it is created. Changes to the original environment have no effect on the copy. Use [GRBModel::set](#) to change a parameter on an existing model.

```
| void set ( GRB_DoubleParam param,  
            double          newvalue )
```

Set the value of a double-valued parameter.

**Arguments:**

**param:** The parameter being modified. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

```
void set ( GRB_IntParam param,  
           int          newvalue )
```

Set the value of an int-valued parameter.

**Arguments:**

**param:** The parameter being modified. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

```
void set ( GRB_StringParam param,  
           const string&    newvalue )
```

Set the value of a string-valued parameter.

**Arguments:**

**param:** The parameter being modified. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

```
void set ( const string& param,  
           const string& newvalue )
```

Set the value of any parameter using strings alone.

**Arguments:**

**param:** The name of the parameter being modified. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

## GRBEnv::writeParams()

Write all non-default parameter settings to a file.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

```
void writeParams ( const string& paramfile )
```

**Arguments:**

**paramfile:** Name of the file to which non-default parameter settings should be written. The previous contents are overwritten.

## 3.2 GRBModel

Gurobi model object. Commonly used methods include [addVar](#) (adds a new decision variable to the model), [addConstr](#) (adds a new constraint to the model), [optimize](#) (optimizes the current model), and [get](#) (retrieves the value of an attribute).

### GRBModel()

Constructor for `GRBModel`. The simplest version creates an empty model. You can then call [addVar](#) and [addConstr](#) to populate the model with variables and constraints. The more complex constructors can read a model from a file, or make a copy of an existing model.

```
| GRBModel GRBModel ( const GRBEnv& env )
```

Model constructor.

**Arguments:**

`env`: Environment for new model.

**Return value:**

New model object. Model initially contains no variables or constraints.

```
| GRBModel GRBModel ( const GRBEnv& env,  
                    const string& filename )
```

Read a model from a file. Note that the type of the file is encoded in the file name suffix. Valid suffixes are `.mps`, `.rew`, `.lp`, `.rlp`, `.ilp`, or `.opb`. The files can be compressed, so additional suffixes of `.zip`, `.gz`, `.bz2`, or `.7z` are accepted.

**Arguments:**

`env`: Environment for new model.

`modelName`: Name of the file containing the model.

**Return value:**

New model object.

```
| GRBModel GRBModel ( const GRBModel& model )
```

Create a copy of an existing model.

**Arguments:**

`model`: Model to copy.

**Return value:**

New model object. Model is a clone of the input model.

### GRBModel::addConstr()

Add a single linear constraint to a model. Multiple signatures are available.

```
GRBConstr addConstr (  const GRBLinExpr& lhsExpr,
                        char          sense,
                        const GRBLinExpr& rhsExpr,
                        string        name="" )
```

Add a single linear constraint to a model.

**Arguments:**

**lhsExpr:** Left-hand side expression for new linear constraint.

**sense:** Sense for new linear constraint (GRB\_LESS\_EQUAL, GRB\_EQUAL, or GRB\_GREATER\_EQUAL).

**rhsExpr:** Right-hand side expression for new linear constraint.

**name (optional):** Name for new constraint.

**Return value:**

New constraint object.

```
GRBConstr addConstr (  const GRBLinExpr& lhsExpr,
                        char          sense,
                        GRBVar        rhsVar,
                        string        name="" )
```

Add a single linear constraint to a model.

**Arguments:**

**lhsExpr:** Left-hand side expression for new linear constraint.

**sense:** Sense for new linear constraint (GRB\_LESS\_EQUAL, GRB\_EQUAL, or GRB\_GREATER\_EQUAL).

**rhsVar:** Right-hand side variable for new linear constraint.

**name (optional):** Name for new constraint.

**Return value:**

New constraint object.

```
GRBConstr addConstr (  const GRBLinExpr& lhsExpr,
                        char          sense,
                        double        rhsVal,
                        string        name="" )
```

Add a single linear constraint to a model.

**Arguments:**

**lhsExpr:** Left-hand side expression for new linear constraint.

**sense:** Sense for new linear constraint (GRB\_LESS\_EQUAL, GRB\_EQUAL, or GRB\_GREATER\_EQUAL).

**rhsVal:** Right-hand side value for new linear constraint.

**name (optional):** Name for new constraint.

**Return value:**

New constraint object.

```
GRBConstr addConstr ( GRBVar lhsVar,  
                       char    sense,  
                       GRBVar  rhsVar,  
                       string  name="" )
```

Add a single linear constraint to a model.

**Arguments:**

**lhsVar:** Left-hand side variable for new linear constraint.

**sense:** Sense for new linear constraint (GRB\_LESS\_EQUAL, GRB\_EQUAL, or GRB\_GREATER\_EQUAL).

**rhsVar:** Right-hand side variable for new linear constraint.

**name (optional):** Name for new constraint.

**Return value:**

New constraint object.

```
GRBConstr addConstr ( GRBVar lhsVar,  
                       char    sense,  
                       double  rhsVal,  
                       string  name="" )
```

Add a single linear constraint to a model.

**Arguments:**

**lhsVar:** Left-hand side variable for new linear constraint.

**sense:** Sense for new linear constraint (GRB\_LESS\_EQUAL, GRB\_EQUAL, or GRB\_GREATER\_EQUAL).

**rhsVal:** Right-hand side value for new linear constraint.

**name (optional):** Name for new constraint.

**Return value:**

New constraint object.

```
GRBConstr addConstr ( GRBTempConstr& tc,  
                       string      name="" )
```

Add a single linear constraint to a model.

**Arguments:**

**tc:** Temporary constraint object, created using an overloaded comparison operator. See [GRBTempConstr](#) for more information.

**name (optional):** Name for new constraint.

**Return value:**

New constraint object.

## GRBModel::addConstrs()

Add new linear constraints to a model.

We recommend that you build your model one constraint at a time (using [addConstr](#)), since it introduces no significant overhead and we find that it produces simpler code. Feel free to use these methods if you disagree, though.

```
GRBConstr* addConstrs ( int count )
```

Add count new linear constraints to a model.

**Arguments:**

**count:** Number of constraints to add to the model. The new constraints are all of the form  $0 \leq 0$ .

**Return value:**

Array of new constraint objects. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
GRBConstr* addConstrs ( const GRBLinExpr* lhsExprs,
                       const char*      senses,
                       const double*     rhsVals,
                       const string*     names,
                       int                count )
```

Add count new linear constraints to a model.

**Arguments:**

**lhsExprs:** Left-hand side expressions for the new linear constraints.

**senses:** Senses for new linear constraints (GRB\_LESS\_EQUAL, GRB\_EQUAL, or GRB\_GREATER\_EQUAL).

**rhsVals:** Right-hand side values for the new linear constraints.

**names:** Names for new constraints.

**count:** Number of constraints to add.

**Return value:**

Array of new constraint objects. Note that the result is heap-allocated, and must be returned to the heap by the user.

## GRBModel::addGenConstrXxx()

Each of the functions described below adds a new *general constraint* to a model.

Mathematical programming has traditionally defined a set of fundamental constraint types: variable bound constraints, linear constraints, quadratic constraints, integrality constraints, and SOS constraints. These are typically treated directly by the underlying solver (although not always), and are fundamental to the overall algorithm.

Gurobi accepts a number of additional constraint types, which we collectively refer to as *general constraints*. These are typically *not* treated directly by the solver. Rather, they are transformed by presolve into mathematically equivalent sets of constraints (and variables), chosen from among the fundamental types listed above. These general constraints are provided as a convenience to users. If such constraints appear in your model, but if you prefer to reformulate them yourself using fundamental constraint types instead, you can certainly do so. However, note that Gurobi can sometimes exploit information contained in the other constraints in the model to build a more efficient formulation than what you might create.

The additional constraint types that fall under this *general constraint* umbrella are:

- MAX ([addGenConstrMax](#)): set a decision variable equal to the maximum value from among a set of decision variables

- MIN ([addGenConstrMin](#)): set a decision variable equal to the minimum value from among a set of decision variables
- ABS ([addGenConstrAbs](#)): set a decision variable equal to the absolute value of some other decision variable
- AND ([addGenConstrAnd](#)): set a binary variable equal to one if and only if all of a set of binary decision variables are equal to one
- OR ([addGenConstrOr](#)): set a binary variable equal to one if and only if at least one variable out of a set of binary decision variables is equal to one
- INDICATOR ([addGenConstrIndicator](#)): a given binary variable may only take a certain value if a given linear constraint is satisfied

Please refer to [this section](#) for additional details on general constraints.

### GRBModel::addGenConstrMax()

Add a new general constraint of type `GRB_GENCONSTR_MAX` to a model.

A MAX constraint  $r = \max\{x_1, \dots, x_n, c\}$  states that the resultant variable  $r$  should be equal to the maximum of the operand variables  $x_1, \dots, x_n$  and the constant  $c$ .

```
GRBGenConstr addGenConstrMax ( GRBVar      resvar,
                               const GRBVar* vars,
                               int         len,
                               double      constant=-GRB_INFINITY,
                               string       name="" )
```

#### Arguments:

**resvar:** The resultant variable of the new constraint.

**vars:** Array of variables that are the operands of the new constraint.

**len:** Number of operands in the new constraint (length of `vars` array).

**constant (optional):** The additional constant operand of the new constraint.

**name (optional):** Name for the new general constraint.

#### Return value:

New general constraint.

### GRBModel::addGenConstrMin()

Add a new general constraint of type `GRB_GENCONSTR_MIN` to a model.

A MIN constraint  $r = \min\{x_1, \dots, x_n, c\}$  states that the resultant variable  $r$  should be equal to the minimum of the operand variables  $x_1, \dots, x_n$  and the constant  $c$ .

```
GRBGenConstr addGenConstrMin ( GRBVar      resvar,
                               const GRBVar* vars,
                               int         len,
                               double      constant=GRB_INFINITY,
                               string       name="" )
```

**Arguments:**

**resvar:** The resultant variable of the new constraint.  
**vars:** Array of variables that are the operands of the new constraint.  
**len:** Number of operands in the new constraint (length of **vars** array).  
**constant (optional):** The additional constant operand of the new constraint.  
**name (optional):** Name for the new general constraint.

**Return value:**

New general constraint.

**GRBModel::addGenConstrAbs()**

Add a new general constraint of type `GRB_GENCONSTR_ABS` to a model.

An ABS constraint  $r = \text{abs}\{x\}$  states that the resultant variable  $r$  should be equal to the absolute value of the argument variable  $x$ .

```
GRBGenConstr addGenConstrAbs ( GRBVar resvar,
                               GRBVar argvar,
                               string name="" )
```

**Arguments:**

**resvar:** The resultant variable of the new constraint.  
**argvar:** The argument variable of the new constraint.  
**name (optional):** Name for the new general constraint.

**Return value:**

New general constraint.

**GRBModel::addGenConstrAnd()**

Add a new general constraint of type `GRB_GENCONSTR_AND` to a model.

An AND constraint  $r = \text{and}\{x_1, \dots, x_n\}$  states that the binary resultant variable  $r$  should be 1 if and only if all of the operand variables  $x_1, \dots, x_n$  are equal to 1. If any of the operand variables is 0, then the resultant should be 0 as well.

Note that all variables participating in such a constraint will be forced to be binary; independently of how they were created.

```
GRBGenConstr addGenConstrAnd ( GRBVar resvar,
                               const GRBVar* vars,
                               int len,
                               string name="" )
```

**Arguments:**

**resvar:** The resultant binary variable of the new constraint.  
**vars:** Array of binary variables that are the operands of the new constraint.  
**len:** Number of operands in the new constraint (length of **vars** array).  
**name (optional):** Name for the new general constraint.

**Return value:**

New general constraint.

## GRBModel::addGenConstrOr()

Add a new general constraint of type `GRB_GENCONSTR_OR` to a model.

An OR constraint  $r = \text{or}\{x_1, \dots, x_n\}$  states that the binary resultant variable  $r$  should be 1 if and only if any of the operand variables  $x_1, \dots, x_n$  is equal to 1. If all operand variables are 0, then the resultant should be 0 as well.

Note that all variables participating in such a constraint will be forced to be binary; independently of how they were created.

```
GRBGenConstr  addGenConstrOr (  GRBVar          resvar,
                               const GRBVar*    vars,
                               int              len,
                               string          name="" )
```

### Arguments:

**resvar:** The resultant binary variable of the new constraint.

**vars:** Array of binary variables that are the operands of the new constraint.

**len:** Number of operands in the new constraint (length of `vars` array).

**name (optional):** Name for the new general constraint.

### Return value:

New general constraint.

## GRBModel::addGenConstrIndicator()

Add a new general constraint of type `GRB_GENCONSTR_INDICATOR` to a model.

An INDICATOR constraint  $z = f \rightarrow a^T x \leq b$  states that if the binary indicator variable  $z$  is equal to  $f \in \{0, 1\}$ , then the linear constraint  $a^T x \leq b$  should hold. On the other hand, if  $z = 1 - f$ , the linear constraint may be violated. The sense of the linear constraint can also be specified to be  $=$  or  $\geq$ .

Note that the indicator variable  $z$  of a constraint will be forced to be binary; independently of how it was created.

Multiple signatures are available.

```
GRBGenConstr  addGenConstrIndicator (  GRBVar          binvar,
                                       int              binval,
                                       const GRBLinExpr&  expr,
                                       char              sense,
                                       double            rhs,
                                       string            name="" )
```

### Arguments:

**binvar:** The binary indicator variable.

**binval:** The value for the binary indicator variable that would force the linear constraint to be satisfied (0 or 1).

**expr:** Left-hand side expression for the linear constraint triggered by the indicator.

**sense:** Sense for the linear constraint. Options are `GRB_LESS_EQUAL`, `GRB_EQUAL`, or `GRB_GREATER_EQUAL`.

**rhs:** Right-hand-side value for the linear constraint.  
**name (optional):** Name for the new general constraint.

**Return value:**

New general constraint.

```
GRBGenConstr addGenConstrIndicator ( GRBVar          binvar,  
                                     int            binval,  
                                     const GRBTempConstr& constr,  
                                     string          name="" )
```

**Arguments:**

**binvar:** The binary indicator variable.

**binval:** The value for the binary indicator variable that would force the linear constraint to be satisfied (0 or 1).

**constr:** Temporary constraint object defining the linear constraint that is triggered by the indicator. The temporary constraint object is created using an overloaded comparison operator. See [GRBTempConstr](#) for more information.

**name (optional):** Name for the new general constraint.

**Return value:**

New general constraint.

## GRBModel::addQConstr()

Add a quadratic constraint to a model. Multiple signatures are available.

Important note: the algorithms that Gurobi uses to solve quadratically constrained problems can only handle certain types of quadratic constraints. Constraints of the following forms are always accepted:

- $x^T Q x + q^T x \leq b$ , where  $Q$  is Positive Semi-Definite (PSD)
- $x^T x \leq y^2$ , where  $x$  is a vector of variables, and  $y$  is a non-negative variable (a Second-Order Cone)
- $x^T x \leq yz$ , where  $x$  is a vector of variables, and  $y$  and  $z$  are non-negative variables (a rotated Second-Order Cone)

If you add a constraint that isn't in one of these forms (and Gurobi presolve is unable to transform the constraint into one of these forms), you'll get an error when you try to solve the model. Constraints where the quadratic terms only involve binary variables will always be transformed into one of these forms.

```
GRBQConstr addQConstr ( const GRBQuadExpr& lhsExpr,  
                       char                sense,  
                       const GRBQuadExpr& rhsExpr,  
                       string              name="" )
```

Add a quadratic constraint to a model.

**Arguments:**

**lhsExpr**: Left-hand side expression for new quadratic constraint.  
**sense**: Sense for new quadratic constraint (GRB\_LESS\_EQUAL or GRB\_GREATER\_EQUAL).  
**rhsExpr**: Right-hand side expression for new quadratic constraint.  
**name (optional)**: Name for new constraint.

**Return value:**

New quadratic constraint object.

```
GRBQConstr addQConstr ( const GRBQuadExpr& lhsExpr,  
                        char               sense,  
                        GRBVar            rhsVar,  
                        string             name="" )
```

Add a quadratic constraint to a model.

**Arguments:**

**lhsExpr**: Left-hand side expression for new quadratic constraint.  
**sense**: Sense for new quadratic constraint (GRB\_LESS\_EQUAL or GRB\_GREATER\_EQUAL).  
**rhsVar**: Right-hand side variable for new quadratic constraint.  
**name (optional)**: Name for new constraint.

**Return value:**

New quadratic constraint object.

```
GRBQConstr addQConstr ( GRBTempConstr& tc,  
                        string          name="" )
```

Add a quadratic constraint to a model.

**Arguments:**

**tc**: Temporary constraint object, created using an overloaded comparison operator. See [GRBTempConstr](#) for more information.  
**name (optional)**: Name for new constraint.

**Return value:**

New quadratic constraint object.

## GRBModel::addRange()

Add a single range constraint to a model. A range constraint states that the value of the input expression must be between the specified **lower** and **upper** bounds in any solution.

Note that range constraints are stored internally as equality constraints. We add an extra variable to the model to capture the range information. Thus, the **Sense** attribute on a range constraint will always be **GRB\_EQUAL**.

```
GRBConstr addRange ( const GRBLinExpr& expr,  
                    double           lower,  
                    double           upper,  
                    string            name="" )
```

**Arguments:**

**expr**: Linear expression for new range constraint.

**lower:** Lower bound for linear expression.  
**upper:** Upper bound for linear expression.  
**name (optional):** Name for new constraint.

**Return value:**

New constraint object.

## GRBModel::addRanges()

Add new range constraints to a model. A range constraint states that the value of the input expression must be between the specified **lower** and **upper** bounds in any solution.

```
GRBConstr* addRanges ( const GRBLinExpr* exprs,  
                      const double* lower,  
                      const double* upper,  
                      const string* names,  
                      int count )
```

**Arguments:**

**exprs:** Linear expressions for the new range constraints.  
**lower:** Lower bounds for linear expressions.  
**upper:** Upper bounds for linear expressions.  
**name:** Names for new range constraints.  
**count:** Number of range constraints to add.

**Return value:**

Array of new constraint objects. Note that the result is heap-allocated, and must be returned to the heap by the user.

## GRBModel::addSOS()

Add an SOS constraint to the model. Please refer to [this section](#) for details on SOS constraints.

```
GRBSOS addSOS ( const GRBVar* vars,  
               const double* weights,  
               int len,  
               int type )
```

**Arguments:**

**vars:** Array of variables that participate in the SOS constraint.  
**weights:** Weights for the variables in the SOS constraint.  
**len:** Number of members in the new SOS set (length of **vars** and **weights** arrays).  
**type:** SOS type (can be `GRB_SOS_TYPE1` or `GRB_SOS_TYPE2`).

**Return value:**

New SOS constraint.

## GRBModel::addVar()

Add a single decision variable to a model.

```
GRBVar addVar ( double lb,  
                double ub,  
                double obj,  
                char type,  
                string name="" )
```

Add a variable; non-zero entries will be added later.

### Arguments:

**lb**: Lower bound for new variable.

**ub**: Upper bound for new variable.

**obj**: Objective coefficient for new variable.

**type**: Variable type for new variable (GRB\_CONTINUOUS, GRB\_BINARY, GRB\_INTEGER, GRB\_SEMICON, or GRB\_SEMIINT).

**name (optional)**: Name for new variable.

### Return value:

New variable object.

```
GRBVar addVar ( double lb,  
                double ub,  
                double obj,  
                char type,  
                int numnz,  
                const GRBConstr* constrs,  
                const double* coeffs,  
                string name="" )
```

Add a variable, and the associated non-zero coefficients.

### Arguments:

**lb**: Lower bound for new variable.

**ub**: Upper bound for new variable.

**obj**: Objective coefficient for new variable.

**type**: Variable type for new variable (GRB\_CONTINUOUS, GRB\_BINARY, GRB\_INTEGER, GRB\_SEMICON, or GRB\_SEMIINT).

**numnz**: Number of constraints in which this new variable participates.

**constrs**: Array of constraints in which the variable participates.

**coeffs**: Array of coefficients for each constraint in which the variable participates.

**name (optional)**: Name for new variable.

### Return value:

New variable object.

```
GRBVar addVar ( double lb,
                double ub,
                double obj,
                char type,
                const GRBColumn& col,
                string name="" )
```

Add a variable, and the associated non-zero coefficients.

**Arguments:**

**lb:** Lower bound for new variable.

**ub:** Upper bound for new variable.

**obj:** Objective coefficient for new variable.

**type:** Variable type for new variable (GRB\_CONTINUOUS, GRB\_BINARY, GRB\_INTEGER, GRB\_SEMICONT, or GRB\_SEMIINT).

**col:** GRBColumn object for specifying a set of constraints to which new variable belongs.

**name (optional):** Name for new variable.

**Return value:**

New variable object.

## GRBModel::addVars()

Add new decision variables to a model.

```
GRBVar* addVars ( int count,
                  char type=GRB_CONTINUOUS )
```

Add `count` new decision variables to a model. All associated attributes take their default values, except the variable `type`, which is specified as an argument.

**Arguments:**

**count:** Number of variables to add.

**type (optional):** Variable type for new variables (GRB\_CONTINUOUS, GRB\_BINARY, GRB\_INTEGER, GRB\_SEMICONT, or GRB\_SEMIINT).

**Return value:**

Array of new variable objects. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
GRBVar* addVars ( const double* lb,
                  const double* ub,
                  const double* obj,
                  const char* type,
                  const string* names,
                  int count )
```

Add `count` new decision variables to a model. This signature allows you to use arrays to hold the various variable attributes (lower bound, upper bound, etc.).

**Arguments:**

**lb:** Lower bounds for new variables. Can be NULL, in which case the variables get lower bounds of 0.0.

**ub:** Upper bounds for new variables. Can be NULL, in which case the variables get infinite upper bounds.

**obj:** Objective coefficients for new variables. Can be NULL, in which case the variables get objective coefficients of 0.0.

**type:** Variable types for new variables (GRB\_CONTINUOUS, GRB\_BINARY, GRB\_INTEGER, GRB\_SEMICON, or GRB\_SEMIINT). Can be NULL, in which case the variables are assumed to be continuous.

**names:** Names for new variables. Can be NULL, in which case all variables are given default names.

**count:** The number of variables to add.

**Return value:**

Array of new variable objects. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
GRBVar* addVars (  const double*    lb,
                  const double*    ub,
                  const double*    obj,
                  const char*      type,
                  const string*     names,
                  const GRBColumn*  cols,
                  int               count )
```

Add new decision variables to a model. This signature allows you to specify the set of constraints to which each new variable belongs using an array of GRBColumn objects.

**Arguments:**

**lb:** Lower bounds for new variables. Can be NULL, in which case the variables get lower bounds of 0.0.

**ub:** Upper bounds for new variables. Can be NULL, in which case the variables get infinite upper bounds.

**obj:** Objective coefficients for new variables. Can be NULL, in which case the variables get objective coefficients of 0.0.

**type:** Variable types for new variables (GRB\_CONTINUOUS, GRB\_BINARY, GRB\_INTEGER, GRB\_SEMICON, or GRB\_SEMIINT). Can be NULL, in which case the variables are assumed to be continuous.

**names:** Names for new variables. Can be NULL, in which case all variables are given default names.

**cols:** GRBColumn objects for specifying a set of constraints to which each new column belongs.

**count:** The number of variables to add.

**Return value:**

Array of new variable objects. Note that the result is heap-allocated, and must be returned to the heap by the user.

**GRBModel::chgCoeff()**

Change one coefficient in the model. The desired change is captured using a GRBVar object, a GRBConstr object, and a desired coefficient for the specified variable in the specified constraint. If

you make multiple changes to the same coefficient, the last one will be applied.

Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel::update](#)), optimize the model (using [GRBModel::optimize](#)), or write the model to disk (using [GRBModel::write](#)).

```
void chgCoeff ( GRBConstr  constr,  
                GRBVar    var,  
                double    newvalue )
```

**Arguments:**

**constr:** Constraint for coefficient to be changed.

**var:** Variable for coefficient to be changed.

**newvalue:** Desired new value for coefficient.

### GRBModel::chgCoeffs()

Change a list of coefficients in the model. Each desired change is captured using a `GRBVar` object, a `GRBConstr` object, and a desired coefficient for the specified variable in the specified constraint. The entries in the input arrays each correspond to a single desired coefficient change. If you make multiple changes to the same coefficient, the last one will be applied.

Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel::update](#)), optimize the model (using [GRBModel::optimize](#)), or write the model to disk (using [GRBModel::write](#)).

```
void chgCoeffs ( const GRBConstr*  constrs,  
                 const GRBVar*    vars,  
                 const double*    vals,  
                 int               len )
```

**Arguments:**

**constrs:** Constraints for coefficients to be changed.

**vars:** Variables for coefficients to be changed.

**vals:** Desired new values for coefficients.

**len:** Number of coefficients to change (length of `vars`, `constrs`, and `vals` arrays).

### GRBModel::computeIIS()

Compute an Irreducible Inconsistent Subsystem (IIS). An IIS is a subset of the constraints and variable bounds of the original model. If all constraints in the model except those in the IIS are removed, the model is still infeasible. However, further removing any one member of the IIS produces a feasible result.

This method populates the `IISCONSTR`, `IISQCONSTR`, and `IISGENCONSTR` constraint attributes, the `IISOS` attribute, and the `IISLB`, and `IISUB` variable attributes. You can also obtain information about the results of the IIS computation by writing a `.ilp` format file (see [GRBModel::write](#)). This file contains only the IIS from the original model.

Note that this method can be used to compute IISs for both continuous and MIP models.

```
void computeIIS ( )
```

## GRBModel::discardConcurrentEnvs()

Discard concurrent environments for a model.

The concurrent environments created by [getConcurrentEnv](#) will be used by every subsequent call to the concurrent optimizer until the concurrent environments are discarded.

```
| void discardConcurrentEnvs ( )
```

## GRBModel::feasRelax()

Modifies the `GRBModel` object to create a feasibility relaxation. Note that you need to call [optimize](#) on the result to compute the actual relaxed solution.

The feasibility relaxation is a model that, when solved, minimizes the amount by which the solution violates the bounds and linear constraints of the original model. This method provides a number of options for specifying the relaxation.

If you specify `relaxobjtype=0`, the objective of the feasibility relaxation is to minimize the sum of the weighted magnitudes of the bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the cost per unit violation in the lower bounds, upper bounds, and linear constraints, respectively.

If you specify `relaxobjtype=1`, the objective of the feasibility relaxation is to minimize the weighted sum of the squares of the bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the coefficients on the squares of the lower bound, upper bound, and linear constraint violations, respectively.

If you specify `relaxobjtype=2`, the objective of the feasibility relaxation is to minimize the weighted count of bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the cost of violating a lower bound, upper bound, and linear constraint, respectively.

To give an example, if a constraint with `rhspen` value `p` is violated by 2.0, it would contribute `2*p` to the feasibility relaxation objective for `relaxobjtype=0`, it would contribute `2*2*p` for `relaxobjtype=1`, and it would contribute `p` for `relaxobjtype=2`.

The `minrelax` argument is a boolean that controls the type of feasibility relaxation that is created. If `minrelax=false`, optimizing the returned model gives a solution that minimizes the cost of the violation. If `minrelax=true`, optimizing the returned model finds a solution that minimizes the original objective, but only from among those solutions that minimize the cost of the violation. Note that `feasRelax` must solve an optimization problem to find the minimum possible relaxation when `minrelax=true`, which can be quite expensive.

There are two signatures for this method. The more complex one takes a list of variables and constraints, as well as penalties associated with relaxing the corresponding lower bounds, upper bounds, and constraints. If a variable or constraint is not included in one of these lists, the associated bounds or constraints may not be violated. The simpler signature takes a pair of boolean arguments, `vrelax` and `crelax`, that indicate whether variable bounds and/or constraints can be violated. If `vrelax/crelax` is `true`, then every bound/constraint is allowed to be violated, respectively, and the associated cost is 1.0.

Note that this is a destructive method: it modifies the model on which it is invoked. If you don't want to modify your original model, use the [GRBModel constructor](#) to create a copy before invoking this method.

```
double feasRelax ( int      relaxobjtype,
                  bool     minrelax,
                  int      vlen,
                  int      clen,
                  const GRBVar* vars,
                  double*  lbpen,
                  double*  ubpen,
                  const GRBConstr* constr,
                  double*  rhspen )
```

Create a feasibility relaxation model.

**Arguments:**

- relaxobjtype:** The cost function used when finding the minimum cost relaxation.
- minrelax:** The type of feasibility relaxation to perform.
- vlen:** The length of the list of variables whose bounds are allowed to be violated.
- clen:** The length of the list of linear constraints that are allowed to be violated.
- vars:** Variables whose bounds are allowed to be violated.
- lbpen:** Penalty for violating a variable lower bound. One entry for each variable in argument `vars`.
- ubpen:** Penalty for violating a variable upper bound. One entry for each variable in argument `vars`.
- constr:** Linear constraints that are allowed to be violated.
- rhspen:** Penalty for violating a linear constraint. One entry for each variable in argument `constr`.

**Return value:**

Zero if `minrelax` is false. If `minrelax` is true, the return value is the objective value for the relaxation performed. If the value is less than 0, it indicates that the method failed to create the feasibility relaxation.

```
double feasRelax ( int  relaxobjtype,
                  bool  minrelax,
                  bool  vrelax,
                  bool  crelax )
```

Simplified method for creating a feasibility relaxation model.

**Arguments:**

- relaxobjtype:** The cost function used when finding the minimum cost relaxation.
- minrelax:** The type of feasibility relaxation to perform.
- vrelax:** Indicates whether variable bounds can be relaxed (with a cost of 1.0 for any violations).
- crelax:** Indicates whether linear constraints can be relaxed (with a cost of 1.0 for any violations).

**Return value:**

Zero if `minrelax` is false. If `minrelax` is true, the return value is the objective value for the relaxation performed. If the value is less than 0, it indicates that the method failed to create the feasibility relaxation.

## GRBModel::fixedModel()

Create the fixed model associated with a MIP model. The MIP model must have a solution loaded (e.g., after a call to the `optimize` method). In the fixed model, each integer variable is fixed to the value that variable takes in the MIP solution.

```
| GRBModel fixedModel ( )
```

**Return value:**

Fixed model associated with calling object.

## GRBModel::get()

Query the value(s) of a parameter or attribute. Use this method for parameters, for scalar model attributes, or for arrays of constraint or variable attributes.

```
| double get ( GRB_DoubleParam param )
```

Query the value of a double-valued parameter.

**Arguments:**

`param`: The parameter being queried.

**Return value:**

The current value of the requested parameter.

```
| int get ( GRB_IntParam param )
```

Query the value of an int-valued parameter.

**Arguments:**

`param`: The parameter being queried.

**Return value:**

The current value of the requested parameter.

```
| string get ( GRB_StringParam param )
```

Query the value of a string-valued parameter.

**Arguments:**

`param`: The parameter being queried.

**Return value:**

The current value of the requested parameter.

```
| char* get ( GRB_CharAttr attr,  
             const GRBVar* vars,  
             int count )
```

Query a char-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** An array of variables whose attribute values are being queried.

**count:** The number of variable attributes to retrieve.

**Return value:**

The current values of the requested attribute for each input variable. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
char* get ( GRB_CharAttr attr,
            const GRBConstr* constrs,
            int count )
```

Query a char-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** An array of constraints whose attribute values are being queried.

**count:** The number of constraint attributes to retrieve.

**Return value:**

The current values of the requested attribute for each input constraint. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
char* get ( GRB_CharAttr attr,
            const GRBQConstr* qconstrs,
            int count )
```

Query a char-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** An array of quadratic constraints whose attribute values are being queried.

**count:** The number of quadratic constraint attributes to retrieve.

**Return value:**

The current values of the requested attribute for each input quadratic constraint. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
double get ( GRB_DoubleAttr attr )
```

Query the value of a double-valued model attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
double* get ( GRB_DoubleAttr attr,
              const GRBVar* vars,
              int count )
```

Query a double-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** An array of variables whose attribute values are being queried.

**count:** The number of variable attributes to retrieve.

**Return value:**

The current values of the requested attribute for each input variable. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
double* get ( GRB_DoubleAttr attr,
              const GRBConstr* constrs,
              int count )
```

Query a double-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** An array of constraints whose attribute values are being queried.

**count:** The number of constraint attributes to retrieve.

**Return value:**

The current values of the requested attribute for each input constraint. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
double* get ( GRB_DoubleAttr attr,
              const GRBQConstr* qconstrs,
              int count )
```

Query a double-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** An array of quadratic constraints whose attribute values are being queried.

**count:** The number of quadratic constraint attributes to retrieve.

**Return value:**

The current values of the requested attribute for each input quadratic constraint. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
int get ( GRB_IntAttr attr )
```

Query the value of an int-valued model attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
int* get ( GRB_IntAttr attr,
           const GRBVar* vars,
           int count )
```

Query an int-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** An array of variables whose attribute values are being queried.

**count:** The number of variable attributes to retrieve.

**Return value:**

The current values of the requested attribute for each input variable. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
int* get ( GRB_IntAttr      attr,
           const GRBConstr* constrs,
           int              count )
```

Query an int-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** An array of constraints whose attribute values are being queried.

**count:** The number of constraint attributes to retrieve.

**Return value:**

The current values of the requested attribute for each input constraint. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
string get ( GRB_StringAttr attr )
```

Query the value of a string-valued model attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
string* get ( GRB_StringAttr attr,
              const GRBVar*   vars,
              int              count )
```

Query a string-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** An array of variables whose attribute values are being queried.

**count:** The number of variable attributes to retrieve.

**Return value:**

The current values of the requested attribute for each input variable. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
string* get ( GRB_StringAttr attr,
              const GRBConstr* constrs,
              int              count )
```

Query a string-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** An array of constraints whose attribute values are being queried.

**count:** The number of constraint attributes to retrieve.

**Return value:**

The current values of the requested attribute for each input constraint. Note that the result is heap-allocated, and must be returned to the heap by the user.

```
string* get ( GRB_StringAttr attr,
              const GRBQConstr* qconstrs,
              int count )
```

Query a string-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** An array of quadratic constraints whose attribute values are being queried.

**count:** The number of quadratic constraint attributes to retrieve.

**Return value:**

The current values of the requested attribute for each input quadratic constraint. Note that the result is heap-allocated, and must be returned to the heap by the user.

## GRBModel::getCoeff()

Query the coefficient of variable `var` in linear constraint `constr` (note that the result can be zero).

```
double getCoeff ( GRBConstr constr,
                  GRBVar var )
```

**Arguments:**

**constr:** The requested constraint.

**var:** The requested variable.

**Return value:**

The current value of the requested coefficient.

## GRBModel::getCol()

Retrieve the list of constraints in which a variable participates, and the associated coefficients. The result is returned as a [GRBColumn](#) object.

```
GRBColumn getCol ( GRBVar var )
```

**Arguments:**

**var:** The variable of interest.

**Return value:**

A [GRBColumn](#) object that captures the set of constraints in which the variable participates.

## GRBModel::getConcurrentEnv()

Create/retrieve a concurrent environment for a model.

This method provides fine-grained control over the concurrent optimizer. By creating your own concurrent environments and setting appropriate parameters on these environments (e.g., the [Method](#) parameter), you can control exactly which strategies the concurrent optimizer employs. For example, if you create two concurrent environments, and set `Method` to primal simplex for one and dual simplex for the other, subsequent concurrent optimizer runs will use the two simplex algorithms rather than the default choices.

Note that you must create contiguously numbered concurrent environments, starting with `num=0`. For example, if you want three concurrent environments, they must be numbered 0, 1, and 2.

Once you create concurrent environments, they will be used for every subsequent concurrent optimization on that model. Use [discardConcurrentEnvs](#) to revert back to default concurrent optimizer behavior.

```
| GRBEnv  getConcurrentEnv ( int num )
```

### Arguments:

`num`: The concurrent environment number.

### Return value:

The concurrent environment for the model.

## GRBModel::getConstrByName()

Retrieve a linear constraint from its name. If multiple linear constraints have the same name, this method chooses one arbitrarily.

```
| GRBConstr getConstrByName ( const string& name )
```

### Arguments:

`name`: The name of the desired linear constraint.

### Return value:

The requested linear constraint.

## GRBModel::getConstrs()

Retrieve an array of all linear constraints in the model.

```
| GRBConstr* getConstrs ( )
```

### Return value:

An array of all linear constraints in the model. Note that this array is heap-allocated, and must be returned to the heap by the user.

## GRBModel::getEnv()

Query the environment associated with the model. Note that each model makes its own copy of the environment when it is created. To change parameters for a model, for example, you should use this method to obtain the appropriate environment object.

```
GRBEnv getEnv ( )
```

### Return value:

The environment for the model.

## GRBModel::getGenConstrMax()

Retrieve the data of a general constraint of type MAX. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with a NULL value for the `vars` argument. The routine returns the total number of operand variables in the specified general constraint in `lenP`. That allows you to make certain that the `vars` array is of sufficient size to hold the result of the second call.

See also [addGenConstrMax](#) for a description of the semantics of this general constraint type.

```
void getGenConstrMax ( GRBGenConstr genc,  
                      GRBVar*      resvarP,  
                      GRBVar*      vars,  
                      int*         lenP,  
                      double*      constantP )
```

### Arguments:

**genc:** The index of the general constraint.

Any combination of the following four arguments can be NULL.

**resvarP:** Pointer to store the resultant variable of the constraint.

**vars:** Array to store the operand variables of the constraint.

**lenP:** Pointer to store the number of operand variables of the constraint.

**constantP:** Pointer to store the additional constant operand of the constraint.

## GRBModel::getGenConstrMin()

Retrieve the data of a general constraint of type MIN. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with a NULL value for the `vars` argument. The routine returns the total number of operand variables in the specified general constraint in `lenP`. That allows you to make certain that the `vars` array is of sufficient size to hold the result of the second call.

See also [addGenConstrMin](#) for a description of the semantics of this general constraint type.

```
void getGenConstrMin ( GRBGenConstr genc,
                      GRBVar*      resvarP,
                      GRBVar*      vars,
                      int*          lenP,
                      double*       constantP )
```

**Arguments:**

- genc:** The index of the general constraint.
- Any combination of the following four arguments can be NULL.
- resvarP:** Pointer to store the resultant variable of the constraint.
- vars:** Array to store the operand variables of the constraint.
- lenP:** Pointer to store the number of operand variables of the constraint.
- constantP:** Pointer to store the additional constant operand of the constraint.

### GRBModel::getGenConstrAbs()

Retrieve the data of a general constraint of type ABS. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [addGenConstrAbs](#) for a description of the semantics of this general constraint type.

```
void getGenConstrAbs ( GRBGenConstr genc,
                      GRBVar*      resvarP,
                      GRBVar*      argvarP )
```

**Arguments:**

- genc:** The index of the general constraint.
- Any combination of the following two arguments can be NULL.
- resvarP:** Pointer to store the resultant variable of the constraint.
- argvarP:** Pointer to store the argument variable of the constraint.

### GRBModel::getGenConstrAnd()

Retrieve the data of a general constraint of type AND. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with a NULL value for the **vars** argument. The routine returns the total number of operand variables in the specified general constraint in **lenP**. That allows you to make certain that the **vars** array is of sufficient size to hold the result of the second call.

See also [addGenConstrAnd](#) for a description of the semantics of this general constraint type.

```
void getGenConstrAnd ( GRBGenConstr genc,
                      GRBVar*      resvarP,
                      GRBVar*      vars,
                      int*          lenP )
```

**Arguments:**

**genc**: The index of the general constraint.

Any combination of the following three arguments can be NULL.

**resvarP**: Pointer to store the resultant variable of the constraint.

**vars**: Array to store the operand variables of the constraint.

**lenP**: Pointer to store the number of operand variables of the constraint.

### GRBModel::getGenConstrOr()

Retrieve the data of a general constraint of type OR. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with a NULL value for the **vars** argument. The routine returns the total number of operand variables in the specified general constraint in **lenP**. That allows you to make certain that the **vars** array is of sufficient size to hold the result of the second call.

See also [addGenConstrOr](#) for a description of the semantics of this general constraint type.

```
void getGenConstrOr ( GRBGenConstr  genc,  
                    GRBVar*      resvarP,  
                    GRBVar*      vars,  
                    int*         lenP )
```

#### Arguments:

**genc**: The index of the general constraint.

Any combination of the following three arguments can be NULL.

**resvarP**: Pointer to store the resultant variable of the constraint.

**vars**: Array to store the operand variables of the constraint.

**lenP**: Pointer to store the number of operand variables of the constraint.

### GRBModel::getGenConstrIndicator()

Retrieve the data of a general constraint of type INDICATOR. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [addGenConstrIndicator](#) for a description of the semantics of this general constraint type.

```
void getGenConstrIndicator ( GRBGenConstr  genc,  
                            GRBVar*      binvarP,  
                            int*         binvalP,  
                            GRBLinExpr*  exprP,  
                            char*       senseP,  
                            double*     rhsP )
```

#### Arguments:

**genc**: The index of the general constraint.

Any combination of the following five arguments can be NULL.

**binvarP**: Pointer to store the binary indicator variable of the constraint.  
**binvalP**: Pointer to store the value that the indicator variable has to take in order to trigger the linear constraint.  
**exprP**: Pointer to a [GRBLinExpr](#) object to store the left-hand-side expression of the linear constraint that is triggered by the indicator.  
**senseP**: Pointer to store the sense for the linear constraint. Options are `GRB_LESS_EQUAL`, `GRB_EQUAL`, or `GRB_GREATER_EQUAL`.  
**rhsP**: Pointer to store the right-hand-side value for the linear constraint.

## GRBModel::getGenConstrs()

Retrieve an array of all general constraints in the model.

```
| GRBGenConstr*  getGenConstrs ( )
```

**Return value:**

An array of all general constraints in the model. Note that this array is heap-allocated, and must be returned to the heap by the user.

## GRBModel::getObjective()

Retrieve a quadratic model objective.

Note that the constant and linear portions of the objective can also be retrieved using the [ObjCon](#) and [Obj](#) attributes.

```
| GRBQuadExpr  getObjective ( )
```

**Return value:**

The model objective.

## GRBModel::getPWLObj()

Retrieve the piecewise-linear objective function for a variable. The return value gives the number of points that define the function, and the  $x$  and  $y$  arguments give the coordinates of the points, respectively. The  $x$  and  $y$  arguments must be large enough to hold the result. Call this method with NULL values for  $x$  and  $y$  if you just want the number of points.

Refer to the description of [setPWLObj](#) for additional information on what the values in  $x$  and  $y$  mean.

```
| int  getPWLObj (  GRBVar    var,  
                    double[]  x,  
                    double[]  y )
```

**Arguments:**

**var**: The variable whose objective function is being retrieved.

**x**: The  $x$  values for the points that define the piecewise-linear function. These will always be in non-decreasing order.

$y$ : The  $y$  values for the points that define the piecewise-linear function.

**Return value:**

The number of points that define the piecewise-linear objective function.

### GRBModel::getQCRow()

Retrieve the left-hand side expression from a quadratic constraint. The result is returned as a [GRBQuadExpr](#) object.

```
| GRBQuadExpr getQCRow ( GRBQConstr qconstr )
```

**Arguments:**

`qconstr`: The quadratic constraint of interest.

**Return value:**

A [GRBQuadExpr](#) object that captures the left-hand side of the quadratic constraint.

### GRBModel::getQConstrs()

Retrieve an array of all quadratic constraints in the model.

```
| GRBQConstr* getQConstrs ( )
```

**Return value:**

An array of all quadratic constraints in the model. Note that this array is heap-allocated, and must be returned to the heap by the user.

### GRBModel::getRow()

Retrieve a list of variables that participate in a constraint, and the associated coefficients. The result is returned as a [GRBLinExpr](#) object.

```
| GRBLinExpr getRow ( GRBConstr constr )
```

**Arguments:**

`constr`: The constraint of interest.

**Return value:**

A [GRBLinExpr](#) object that captures the set of variables that participate in the constraint.

### GRBModel::getSOS()

Retrieve the list of variables that participate in an SOS constraint, and the associated coefficients. The return value is the length of this list. If you would like to allocate space for the result before retrieving the result, call the method first with NULL array arguments to determine the appropriate array lengths.

```
int  getSOS (  GRBSOS   sos,
               GRBVar*  vars,
               double*   weights,
               int*      typeP )
```

**Arguments:**

**sos:** The SOS set of interest.

**vars:** A list of variables that participate in **sos**.

**weights:** The SOS weights for each participating variable.

**typeP:** The type of the SOS set (either `GRB_SOS_TYPE1` or `GRB_SOS_TYPE2`).

**Return value:**

The length of the result arrays.

## GRBModel::getSOSs()

Retrieve an array of all SOS constraints in the model.

```
GRBSOS* getSOSs ( )
```

**Return value:**

An array of all SOS constraints in the model. Note that this array is heap-allocated, and must be returned to the heap by the user.

## GRBModel::getTuneResult()

Use this method to retrieve the results of a previous [tune](#) call. Calling this method with argument **n** causes tuned parameter set **n** to be copied into the model. Parameter sets are stored in order of decreasing quality, with parameter set 0 being the best. The number of available sets is stored in attribute [TuneResultCount](#).

Once you have retrieved a tuning result, you can call [optimize](#) to use these parameter settings to optimize the model, or [write](#) to write the changed parameters to a `.prm` file.

Please refer to the [parameter tuning](#) section for details on the tuning tool.

```
void getTuneResult ( int n )
```

**n:** The index of the tuning result to retrieve. The best result is available as index 0. The number of stored results is available in attribute [TuneResultCount](#).

## GRBModel::getVarByName()

Retrieve a variable from its name. If multiple variables have the same name, this method chooses one arbitrarily.

```
GRBVar getVarByName ( const string& name )
```

**Arguments:**

**name:** The name of the desired variable.

**Return value:**

The requested variable.

**GRBModel::getVars()**

Retrieve an array of all variables in the model.

```
| GRBVar* getVars ( )
```

**Return value:**

An array of all variables in the model. Note that this array is heap-allocated, and must be returned to the heap by the user.

**GRBModel::optimize()**

Optimize the model. The algorithm used for the optimization depends on the model type (simplex or barrier for a continuous model; branch-and-cut for a MIP model). Upon successful completion, this method will populate the solution related attributes of the model. See the [Attributes](#) section for more information on attributes.

Please consult [this section](#) for a discussion of some of the practical issues associated with solving a precisely defined mathematical model using finite-precision floating-point arithmetic.

Note that this method will process all pending model modifications.

```
| void optimize ( )
```

**GRBModel::optimizeasync()**

Optimize a model asynchronously. This routine returns immediately. Your program can perform other computations while optimization proceeds in the background. To check the state of the asynchronous optimization, query the [Status](#) attribute for the model. A value of `IN_PROGRESS` indicates that the optimization has not yet completed. When you are done with your foreground tasks, you must call [sync](#) to sync your foreground program with the asynchronous optimization task.

Note that the set of Gurobi calls that you are allowed to make while optimization is running in the background is severely limited. Specifically, you can only perform attribute queries, and only for a few attributes (listed below). Any other calls on the running model, *or on any other models that were built within the same Gurobi environment*, will fail with error code `OPTIMIZATION_IN_PROGRESS`.

Note that there are no such restrictions on models built in other environments. Thus, for example, you could create multiple environments, and then have a single foreground program launch multiple simultaneous asynchronous optimizations, each in its own environment.

As already noted, you are allowed to query the value of the [Status](#) attribute while an asynchronous optimization is in progress. The other attributes that can be queried are: [ObjVal](#), [ObjBound](#), [IterCount](#), [NodeCount](#), and [BarIterCount](#). In each case, the returned value reflects progress in the optimization to that point. Any attempt to query the value of an attribute not on this list will return an `OPTIMIZATION_IN_PROGRESS` error.

```
| void optimizeasync ( )
```

## GRBModel::presolve()

Perform presolve on a model.

```
| GRBModel presolve ( )
```

**Return value:**

Presolved version of original model.

## GRBModel::read()

This method is the general entry point for importing data from a file into a model. It can be used to read basis files for continuous models, start vectors for MIP models, or parameter settings. The type of data read is determined by the file suffix. File formats are described in the [File Format](#) section.

Note that this is **not** the method to use if you want to read a new model from a file. For that, use the [GRBModel constructor](#). One variant of the constructor takes the name of the file that contains the new model as its argument.

```
| void read ( const string& filename )
```

**Arguments:**

**filename:** Name of the file to read. The suffix on the file must be either `.bas` (for an LP basis), `.mst` or `.sol` (for a MIP start), `.hnt` (for MIP hints), `.ord` (for a priority order), or `.prm` (for a parameter file). The suffix may optionally be followed by `.zip`, `.gz`, `.bz2`, or `.7z`.

## GRBModel::remove()

Remove a variable, constraint, or SOS from a model.

```
| void remove ( GRBConstr constr )
```

Remove a linear constraint from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel::update](#)), optimize the model (using [GRBModel::optimize](#)), or write the model to disk (using [GRBModel::write](#)).

**Arguments:**

**constr:** The linear constraint to remove.

```
| void remove ( GRBGenConstr genconstr )
```

Remove a general constraint from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel::update](#)), optimize the model (using [GRBModel::optimize](#)), or write the model to disk (using [GRBModel::write](#)).

**Arguments:**

**genconstr:** The general constraint to remove.

```
| void remove ( GRBQConstr qconstr )
```

Remove a quadratic constraint from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel::update](#)), optimize the model (using [GRBModel::optimize](#)), or write the model to disk (using [GRBModel::write](#)).

**Arguments:**

**qconstr:** The quadratic constraint to remove.

```
| void remove ( GRBSOS sos )
```

Remove an SOS constraint from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel::update](#)), optimize the model (using [GRBModel::optimize](#)), or write the model to disk (using [GRBModel::write](#)).

**Arguments:**

**sos:** The SOS constraint to remove.

```
| void remove ( GRBVar var )
```

Remove a variable from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel::update](#)), optimize the model (using [GRBModel::optimize](#)), or write the model to disk (using [GRBModel::write](#)).

**Arguments:**

**var:** The variable to remove.

## **GRBModel::reset()**

Reset the model to an unsolved state, discarding any previously computed solution information.

```
| void reset ( )
```

## **GRBModel::setCallback()**

Set the callback object for a model. The `callback()` method on this object will be called periodically from the Gurobi solver. You will have the opportunity to obtain more detailed information about the state of the optimization from this callback. See the documentation for [GRBCallback](#) for additional information.

Note that a model can only have a single callback method, so this call will replace an existing callback. To disable a previously set callback, call this method with a `NULL` argument.

```
| void setCallback ( GRBCallback* cb )
```

## GRBModel::set()

Set the value(s) of a parameter or attribute. Use this method for parameters, for scalar model attributes, and for arrays of constraint or variable attributes.

```
void set ( GRB_DoubleParam param,  
           double          newvalue )
```

Set the value of a double-valued parameter.

The difference between setting a parameter on a model and setting it on an environment (i.e., through [GRBEnv::set](#)) is that the former modifies the parameter for a single model, while the latter modifies the parameter for every model that is subsequently built using that environment (and leaves the parameter unchanged for models that were previously built using that environment).

### Arguments:

**param:** The parameter being modified.

**newvalue:** The desired new value for the parameter.

```
void set ( GRB_IntParam  param,  
           int           newvalue )
```

Set the value of an int-valued parameter.

The difference between setting a parameter on a model and setting it on an environment (i.e., through [GRBEnv::set](#)) is that the former modifies the parameter for a single model, while the latter modifies the parameter for every model that is subsequently built using that environment (and leaves the parameter unchanged for models that were previously built using that environment).

### Arguments:

**param:** The parameter being modified.

**newvalue:** The desired new value for the parameter.

```
void set ( GRB_StringParam param,  
           string          newvalue )
```

Set the value of a string-valued parameter.

The difference between setting a parameter on a model and setting it on an environment (i.e., through [GRBEnv::set](#)) is that the former modifies the parameter for a single model, while the latter modifies the parameter for every model that is subsequently built using that environment (and leaves the parameter unchanged for models that were previously built using that environment).

### Arguments:

**param:** The parameter being modified.

**newvalue:** The desired new value for the parameter.

```
void set ( GRB_CharAttr  attr,  
           const GRBVar* vars,  
           char*         newvalues,  
           int           count )
```

Set a char-valued variable attribute for an array of variables.

### Arguments:

**attr:** The attribute being modified.  
**vars:** An array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.  
**count:** The number of variable attributes to set.

```
void set ( GRB_CharAttr attr,  
          const GRBConstr* constrs,  
          char* newvalues,  
          int count )
```

Set a char-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** An array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.  
**count:** The number of constraint attributes to set.

```
void set ( GRB_CharAttr attr,  
          const GRBQConstr* qconstrs,  
          char* newvalues,  
          int count )
```

Set a char-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** An array of quadratic constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input quadratic constraint.  
**count:** The number of quadratic constraint attributes to set.

```
void set ( GRB_DoubleAttr attr,  
          double newvalue )
```

Set the value of a double-valued model attribute.

**Arguments:**

**attr:** The attribute being modified.  
**newvalue:** The desired new value for the attribute.

```
void set ( GRB_DoubleAttr attr,  
          const GRBVar* vars,  
          double* newvalues,  
          int count )
```

Set a double-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being modified.  
**vars:** An array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.  
**count:** The number of variable attributes to set.

```
void set ( GRB_DoubleAttr attr,
           const GRBConstr* constrs,
           double* newvalues,
           int count )
```

Set a double-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** An array of constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

**count:** The number of constraint attributes to set.

```
void set ( GRB_DoubleAttr attr,
           const GRBQConstr* qconstrs,
           double* newvalues,
           int count )
```

Set a double-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** An array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

**count:** The number of quadratic constraint attributes to set.

```
void set ( GRB_IntAttr attr,
           int newvalue )
```

Set the value of an int-valued model attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value for the attribute.

```
void set ( GRB_IntAttr attr,
           const GRBVar* vars,
           int* newvalues,
           int count )
```

Set an int-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** An array of variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

**count:** The number of variable attributes to set.

```
void set ( GRB_IntAttr attr,
           const GRBConstr* constrs,
           int* newvalues,
           int count )
```

Set an int-valued constraint attribute for an array of constraints.

**Arguments:**

- attr:** The attribute being modified.
- constrs:** An array of constraints whose attribute values are being modified.
- newvalues:** The desired new values for the attribute for each input constraint.
- count:** The number of constraint attributes to set.

```
void set ( GRB_StringAttr attr,  
           string          newvalue )
```

Set the value of a string-valued model attribute.

**Arguments:**

- attr:** The attribute being modified.
- newvalue:** The desired new value for the attribute.

```
void set ( GRB_StringAttr attr,  
           const GRBVar*   vars,  
           string*        newvalues,  
           int             count )
```

Set a string-valued variable attribute for an array of variables.

**Arguments:**

- attr:** The attribute being modified.
- vars:** An array of variables whose attribute values are being modified.
- newvalues:** The desired new values for the attribute for each input variable.
- count:** The number of variable attributes to set.

```
void set ( GRB_StringAttr attr,  
           const GRBConstr* constrs,  
           string*        newvalues,  
           int             count )
```

Set a string-valued constraint attribute for an array of constraints.

**Arguments:**

- attr:** The attribute being modified.
- constrs:** An array of constraints whose attribute values are being modified.
- newvalues:** The desired new values for the attribute for each input constraint.
- count:** The number of constraint attributes to set.

```
void set ( GRB_StringAttr attr,  
           const GRBQConstr* qconstrs,  
           string*        newvalues,  
           int             count )
```

Set a string-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

- attr:** The attribute being modified.
- constrs:** An array of quadratic constraints whose attribute values are being modified.
- newvalues:** The desired new values for the attribute for each input quadratic constraint.
- count:** The number of quadratic constraint attributes to set.

## GRBModel::setObjective()

Set the model objective equal to a linear or quadratic expression.

Note that you can also modify the linear portion of a model objective using the `Obj` variable attribute. If you wish to mix and match these two approaches, please note that this method replaces the entire existing objective, while the `Obj` attribute can be used to modify individual linear terms.

```
void setObjective ( GRBLinExpr  linexpr,  
                   int          sense=0 )
```

### Arguments:

**linexpr**: New linear model objective.

**sense (optional)**: Optimization sense (GRB\_MINIMIZE for minimization, GRB\_MAXIMIZE for maximization). Omit this argument to use the `ModelSense` attribute value to determine the sense.

```
void setObjective ( GRBQuadExpr  quadexpr,  
                   int          sense=0 )
```

### Arguments:

**quadexpr**: New quadratic model objective.

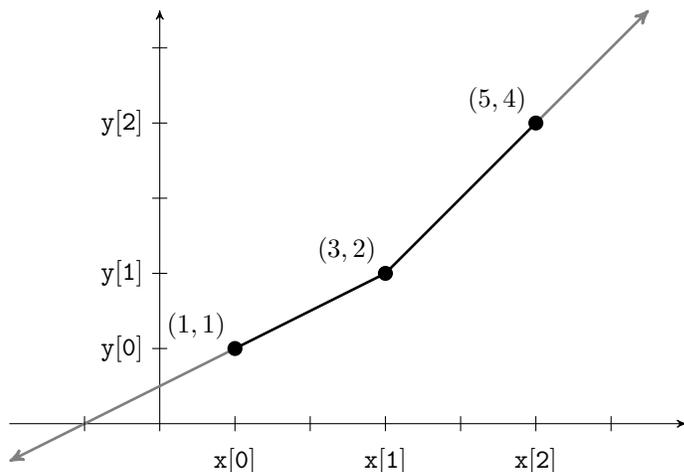
**sense (optional)**: Optimization sense (GRB\_MINIMIZE for minimization, GRB\_MAXIMIZE for maximization). Omit this argument to use the `ModelSense` attribute value.

## GRBModel::setPWLObj()

Set a piecewise-linear objective function for a variable.

The arguments to this method specify a list of points that define a piecewise-linear objective function for a single variable. Specifically, the  $x$  and  $y$  arguments give coordinates for the vertices of the function.

For example, suppose we want to define the function  $f(x)$  shown below:



The vertices of the function occur at the points (1, 1), (3, 2) and (5, 4), so `npoints` is 3, `x` is {1, 3, 5}, and `y` is {1, 2, 4}. With these arguments we define  $f(1) = 1$ ,  $f(3) = 2$  and  $f(5) = 4$ . Other objective values are linearly interpolated between neighboring points. The first pair and last pair of points each define a ray, so values outside the specified `x` values are extrapolated from these points. Thus, in our example,  $f(-1) = 0$  and  $f(6) = 5$ .

More formally, a set of  $n$  points

$$\mathbf{x} = \{x_1, \dots, x_n\}, \quad \mathbf{y} = \{y_1, \dots, y_n\}$$

define the following piecewise-linear function:

$$f(v) = \begin{cases} y_1 + \frac{y_2 - y_1}{x_2 - x_1}(v - x_1), & \text{if } v \leq x_1, \\ y_i + \frac{y_{i+1} - y_i}{x_{i+1} - x_i}(v - x_i), & \text{if } v \geq x_i \text{ and } v \leq x_{i+1}, \\ y_n + \frac{y_n - y_{n-1}}{x_n - x_{n-1}}(v - x_n), & \text{if } v \geq x_n. \end{cases}$$

The `x` entries must appear in non-decreasing order. Two points can have the same `x` coordinate — this can be useful for specifying a discrete jump in the objective function.

Note that a piecewise-linear objective can change the type of a model. Specifically, including a non-convex piecewise linear objective function in a continuous model will transform that model into a MIP. This can significantly increase the cost of solving the model.

Setting a piecewise-linear objective for a variable will set the `Obj attribute` on that variable to 0. Similarly, setting the `Obj` attribute will delete the piecewise-linear objective on that variable.

Each variable can have its own piecewise-linear objective function. They must be specified individually, even if multiple variables share the same function.

```
void setPWLObj ( GRBvar   var,
                 int      npoints,
                 double[] x,
                 double[] y )
```

Set the piecewise-linear objective function for a variable.

**Arguments:**

**var:** The variable whose objective function is being set.

**npoints:** Number of points that define the piecewise-linear function.

**x:** The `x` values for the points that define the piecewise-linear function. Must be in non-decreasing order.

**y:** The `y` values for the points that define the piecewise-linear function.

## GRBModel::sync()

Wait for a previous asynchronous optimization call to complete.

Calling `optimizeasync` returns control to the calling routine immediately. The caller can perform other computations while optimization proceeds, and can check on the progress of the optimization by querying various model attributes. The `sync` call forces the calling program to wait until the asynchronous optimization call completes. You *must* call `sync` before the corresponding model object is deleted.

The `sync` call throws an exception if the optimization itself ran into any problems. In other words, exceptions thrown by this method are those that `optimize` itself would have thrown, had the original method not been asynchronous.

Note that you need to call `sync` even if you know that the asynchronous optimization has already completed.

```
| void sync ( )
```

### **GRBModel::terminate()**

Generate a request to terminate the current optimization. This method can be called at any time during an optimization.

```
| void terminate ( )
```

### **GRBModel::tune()**

Perform an automated search for parameter settings that improve performance. Upon completion, this method stores the best parameter sets it found. The number of stored parameter sets can be determined by querying the value of the [TuneResultCount](#) attribute. The actual settings can be retrieved using [getTuneResult](#)

Please refer to the [parameter tuning](#) section for details on the tuning tool.

```
| void tune ( )
```

### **GRBModel::update()**

Process any pending model modifications.

```
| void update ( )
```

### **GRBModel::write()**

This method is the general entry point for writing model data to a file. It can be used to write optimization models, IIS submodels, solutions, basis vectors, MIP start vectors, or parameter settings. The type of file written is determined by the file suffix. File formats are described in the [File Format](#) section.

Note that writing a model to a file will process all pending model modifications. However, writing other model information (solutions, bases, etc.) will not.

```
| void write ( const string& filename )
```

#### **Arguments:**

**filename:** Name of the file to write. The file type is encoded in the file name suffix. Valid suffixes for writing the model itself are `.mps`, `.rew`, `.lp`, or `.rlp`. An IIS can be written by using an `.ilp` suffix. Use `.sol` for a solution file, `.mst` for a MIP start, `.hnt` for MIP hints, `.bas` for a basis file, or `.prm` for a parameter file. The suffix may optionally be followed by `.gz`, `.bz2`, or `.7z`, which produces a compressed result.

### 3.3 GRBVar

Gurobi variable object. Variables are always associated with a particular model. You create a variable object by adding a variable to a model (using `GRBModel::addVar`), rather than by using a `GRBVar` constructor.

The methods on variable objects are used to get and set variable attributes. For example, solution information can be queried by calling `get( GRB_DoubleAttr_X)`. Note that you can also query attributes for a set of variables at once. This is done using the attribute query method on the `GRBModel` object (`GRBModel::get`).

#### **GRBVar::get()**

Query the value of a variable attribute.

```
| char get ( GRB_CharAttr attr )
```

Query the value of a char-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| double get ( GRB_DoubleAttr attr )
```

Query the value of a double-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| int get ( GRB_IntAttr attr )
```

Query the value of an int-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| string get ( GRB_StringAttr attr )
```

Query the value of a string-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

## GRBVar::sameAs()

```
bool sameAs ( GRBVar var2 )
```

Check whether two variable objects refer to the same variable.

**Arguments:**

**var2:** The other variable.

**Return value:**

Boolean result indicates whether the two variable objects refer to the same model variable.

## GRBVar::set()

Set the value of a variable attribute.

```
void set ( GRB_CharAttr attr,  
           char          newvalue )
```

Set the value of a char-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB_DoubleAttr attr,  
           double         newvalue )
```

Set the value of a double-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB_IntAttr  attr,  
           int          newvalue )
```

Set the value of an int-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB_StringAttr attr,  
           const string&  newvalue )
```

Set the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

## 3.4 GRBConstr

Gurobi constraint object. Constraints are always associated with a particular model. You create a constraint object by adding a constraint to a model (using `GRBModel::addConstr`), rather than by using a `GRBConstr` constructor.

The methods on constraint objects are used to get and set constraint attributes. For example, constraint right-hand sides can be queried by calling `get( GRB_DoubleAttr_RHS)`. Note that you can also query attributes for a set of constraints at once. This is done using the attribute query method on the `GRBModel` object (`GRBModel::get`).

### `GRBConstr::get()`

Query the value of a constraint attribute.

```
| char get ( GRB_CharAttr attr )
```

Query the value of a char-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| double get ( GRB_DoubleAttr attr )
```

Query the value of a double-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| int get ( GRB_IntAttr attr )
```

Query the value of an int-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| string get ( GRB_StringAttr attr )
```

Query the value of a string-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

## GRBConstr::sameAs()

```
bool sameAs ( GRBConstr constr2 )
```

Check whether two constraint objects refer to the same constraint.

**Arguments:**

**constr2:** The other constraint.

**Return value:**

Boolean result indicates whether the two constraint objects refer to the same model constraint.

## GRBConstr::set()

Set the value of a constraint attribute.

```
void set ( GRB_CharAttr attr,  
           char          newvalue )
```

Set the value of a char-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB_DoubleAttr attr,  
           double         newvalue )
```

Set the value of a double-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB_IntAttr attr,  
           int          newvalue )
```

Set the value of an int-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB_StringAttr attr,  
           const string&   newvalue )
```

Set the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

## 3.5 GRBQConstr

Gurobi quadratic constraint object. Quadratic constraints are always associated with a particular model. You create a quadratic constraint object by adding a constraint to a model (using [GRBModel::addQConstr](#)), rather than by using a `GRBQConstr` constructor.

The methods on quadratic constraint objects are used to get and set quadratic constraint attributes. For example, quadratic constraint right-hand sides can be queried by calling `get(GRB_DoubleAttr_QCRHS)`. Note, however, that it is generally more efficient to query attributes for a set of constraints at once. This is done using the attribute query method on the `GRBModel` object ([GRBModel::get](#)).

### GRBQConstr::get()

Query the value of a quadratic constraint attribute.

```
| char get ( GRB_CharAttr attr )
```

Query the value of a char-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| double get ( GRB_DoubleAttr attr )
```

Query the value of a double-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| int get ( GRB_IntAttr attr )
```

Query the value of an int-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| string get ( GRB_StringAttr attr )
```

Query the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

## GRBQConstr::set()

Set the value of a quadratic constraint attribute.

```
void set ( GRB_CharAttr attr,  
           char          newvalue )
```

Set the value of a char-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB_DoubleAttr attr,  
           double         newvalue )
```

Set the value of a double-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB_StringAttr attr,  
           const string&   newvalue )
```

Set the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

## 3.6 GRBSOS

Gurobi SOS constraint object. SOS constraints are always associated with a particular model. You create an SOS object by adding an SOS constraint to a model (using [GRBModel::addSOS](#)), rather than by using a `GRBSOS` constructor. Similarly, SOS constraints are removed using the [GRBModel::remove](#) method.

An SOS constraint can be of type 1 or 2 (`GRB_SOS_TYPE1` or `GRB_SOS_TYPE2`). A type 1 SOS constraint is a set of variables for which at most one variable in the set may take a value other than zero. A type 2 SOS constraint is an ordered set of variables where at most two variables in the set may take non-zero values. If two take non-zero values, they must be contiguous in the ordered set.

SOS constraint objects have one attribute, `ISSOS`, which can be queried with the [GRBSOS::get](#) method.

### **GRBSOS::get()**

Query the value of an SOS attribute.

```
| int get ( GRB_IntAttr attr )
```

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

## 3.7 GRBGenConstr

Gurobi general constraint object. General constraints are always associated with a particular model. You create a general constraint object by adding a constraint to a model (using one of the `GRBModel::addGenConstrXxx`) methods, rather than by using a `GRBGenConstr` constructor.

The methods on general constraint objects are used to get and set general constraint attributes. For example, general constraint types can be queried by calling `get(GRB_IntAttr_GenConstrType)`. Note, however, that it is generally more efficient to query attributes for a set of constraints at once. This is done using the attribute query method on the `GRBModel` object (`GRBModel::get`).

### GRBGenConstr::get()

Query the value of a general constraint attribute.

```
| int get ( GRB_IntAttr attr )
```

Query the value of an int-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| string get ( GRB_StringAttr attr )
```

Query the value of a string-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

### GRBGenConstr::set()

Set the value of a general constraint attribute.

```
| void set ( GRB_StringAttr attr,  
            const string& newvalue )
```

Set the value of a string-valued attribute.

**Arguments:**

`attr`: The attribute being modified.

`newvalue`: The desired new value of the attribute.

## 3.8 GRBExpr

Abstract base class for the [GRBLinExpr](#) and [GRBQuadExpr](#) classes. Expressions are used to build objectives and constraints. They are temporary objects that typically have short lifespans.

### **GRBExpr::getValue()**

Compute the value of an expression for the current solution.

```
| double getValue ( )
```

**Return value:**

Value of the expression for the current solution.

## 3.9 GRBLinExpr

Gurobi linear expression object. A linear expression consists of a constant term, plus a list of coefficient-variable pairs that capture the linear terms. Linear expressions are used to build constraints. They are temporary objects that typically have short lifespans.

The `GRBLinExpr` class is a sub-class of the abstract base class `GRBExpr`.

You generally build linear expressions using overloaded operators. For example, if `x` is a `GRBVar` object, then `x + 1` is a `GRBLinExpr` object. Expressions can be built from constants (e.g., `expr = 0`), variables (e.g., `expr = 1 * x + 2 * y`), or from other expressions (e.g., `expr2 = 2 * expr1 + x`, or `expr3 = expr1 + 2 * expr2`). You can also modify existing expressions (e.g., `expr += x`, or `expr2 -= expr1`).

Another option for building expressions is to use the `addTerms` method, which adds an array of new terms at once. Terms can also be removed from an expression, using `remove`.

Note that the cost of building expressions depends heavily on the approach you use. While you can generally ignore this issue when building small expressions, you should be aware of a few efficiency issues when building large expressions:

- You should avoid using `expr = expr + x` in a loop. It will lead to runtimes that are quadratic in the number of terms in the expression.
- Using `expr += x` (or `expr -= x`) is much more efficient than `expr = expr + x`. Building a large expression by looping over `+=` statements is reasonably efficient, but it isn't the most efficient approach.
- The most efficient way to build a large expression is to make a single call to `addTerms`.

Individual terms in a linear expression can be queried using the `getVar`, `getCoeff`, and `getConstant` methods. You can query the number of terms in the expression using the `size` method.

Note that a linear expression may contain multiple terms that involve the same variable. These duplicate terms are merged when creating a constraint from an expression, but they may be visible when inspecting individual terms in the expression (e.g., when using `getVar`).

### GRBLinExpr()

Linear expression constructor. Create a constant expression or an expression with one term.

```
GRBLinExpr GRBLinExpr ( double constant=0.0 )
```

Create a constant linear expression.

**Arguments:**

`constant` (optional): Constant value for expression.

**Return value:**

A constant expression object.

```
GRBLinExpr GRBLinExpr ( GRBVar var,  
                        double coeff=1.0 )
```

Create an expression with one term.

**Arguments:**

**var:** Variable for expression term.

**coeff (optional):** Coefficient for expression term.

**Return value:**

An expression object containing one linear term.

### GRBLinExpr::addTerms()

Add new terms into a linear expression.

```
void addTerms ( const double* coeffs,  
                const GRBVar* vars,  
                int count )
```

**Arguments:**

**coeffs:** Coefficients for new terms.

**vars:** Variables for new terms.

**count:** Number of terms to add to the expression.

### GRBLinExpr::clear()

Set a linear expression to 0.

You should use the overloaded `expr = 0` instead. The `clear` method is mainly included for consistency with our interfaces to non-overloaded languages.

```
void clear ( )
```

### GRBLinExpr::getConstant()

Retrieve the constant term from a linear expression.

```
double getConstant ( )
```

**Return value:**

Constant from expression.

### GRBLinExpr::getCoeff()

Retrieve the coefficient from a single term of the expression.

```
double getCoeff ( int i )
```

**Arguments:**

**i:** Index for coefficient of interest.

**Return value:**

Coefficient for the term at index `i` in the expression.

## GRBLinExpr::getValue()

Compute the value of a linear expression for the current solution.

```
| double getValue ( )
```

**Return value:**

Value of the expression for the current solution.

## GRBLinExpr::getVar()

Retrieve the variable object from a single term of the expression.

```
| GRBVar getVar ( int i )
```

**Arguments:**

**i**: Index for term of interest.

**Return value:**

Variable for the term at index **i** in the expression.

## GRBLinExpr::operator=

Set an expression equal to another expression.

```
| GRBLinExpr operator= ( const GRBLinExpr& rhs )
```

**Arguments:**

**rhs**: Source expression.

**Return value:**

New expression object.

## GRBLinExpr::operator+

Add one expression into another, producing a result expression.

```
| GRBLinExpr operator+ ( const GRBLinExpr& rhs )
```

**Arguments:**

**rhs**: Expression to add.

**Return value:**

Expression object which is equal the sum of the invoking expression and the argument expression.

### **GRBLinExpr::operator-**

Subtract one expression from another, producing a result expression.

```
| GRBLinExpr operator- ( const GRBLinExpr& rhs )
```

#### **Arguments:**

**rhs:** Expression to subtract.

#### **Return value:**

Expression object which is equal the invoking expression minus the argument expression.

### **GRBLinExpr::operator+=**

Add an expression into the invoking expression.

```
| void operator+= ( const GRBLinExpr& expr )
```

#### **Arguments:**

**expr:** Expression to add.

### **GRBLinExpr::operator-=**

Subtract an expression from the invoking expression.

```
| void operator-= ( const GRBLinExpr& expr )
```

#### **Arguments:**

**expr:** Expression to subtract.

### **GRBLinExpr::operator\*=**

Multiply the invoking expression by a constant.

```
| void operator*= ( double multiplier )
```

#### **Arguments:**

**multiplier:** Constant multiplier.

## GRBLinExpr::remove()

Remove a term from a linear expression.

```
| void remove ( int i )
```

Remove the term stored at index `i` of the expression.

**Arguments:**

`i`: The index of the term to be removed.

```
| boolean remove ( GRBVar var )
```

Remove all terms associated with variable `var` from the expression.

**Arguments:**

`var`: The variable whose term should be removed.

**Return value:**

Returns `true` if the variable appeared in the linear expression (and was removed).

## GRBLinExpr::size()

Retrieve the number of terms in the linear expression (not including the constant).

```
| unsigned int size ( )
```

**Return value:**

Number of terms in the expression.

## 3.10 GRBQuadExpr

Gurobi quadratic expression object. A quadratic expression consists of a linear expression, plus a list of coefficient-variable-variable triples that capture the quadratic terms. Quadratic expressions are used to build quadratic objective functions and quadratic constraints. They are temporary objects that typically have short lifespans.

The `GRBQuadExpr` class is a sub-class of the abstract base class `GRBExpr`.

You generally build quadratic expressions using overloaded operators. For example, if `x` is a `GRBVar` object, then `x * x` is a `GRBQuadExpr` object. Expressions can be built from constants (e.g., `expr = 0`), variables (e.g., `expr = 1 * x * x + 2 * x * y`), or from other expressions (e.g., `expr2 = 2 * expr1 + x * x`, or `expr3 = expr1 + 2 * expr2`). You can also modify existing expressions (e.g., `expr += x * x`, or `expr2 -= expr1`).

The other option for building expressions is to start with an empty expression (using the `GRBQuadExpr` constructor), and then add terms. Terms can be added individually (using `addTerm`) or in groups (using `addTerms`). Terms can also be removed from an expression (using `remove`).

Note that the cost of building expressions depends heavily on the approach you use. While you can generally ignore this issue when building small expressions, you should be aware of a few efficiency issues when building large expressions:

- You should avoid using `expr = expr + x*x` in a loop. It will lead to runtimes that are quadratic in the number of terms in the expression.
- Using `expr += x*x` (or `expr -= x*x`) is much more efficient than `expr = expr + x*x`. Building a large expression by looping over `+=` statements is reasonably efficient, but it isn't the most efficient approach.
- The most efficient way to build a large expression is to make a single call `addTerms`.

Individual terms in a quadratic expression can be queried using the `getVar1`, `getVar2`, and `getCoeff` methods. You can query the number of quadratic terms in the expression using the `size` method. To query the constant and linear terms associated with a quadratic expression, first obtain the linear portion of the quadratic expression using `getLinExpr`, and then use the `getConstant`, `getCoeff`, or `getVar` on the resulting `GRBLinExpr` object.

Note that a quadratic expression may contain multiple terms that involve the same variable pair. These duplicate terms are merged when creating the model objective from an expression, but they may be visible when inspecting individual terms in the expression (e.g., when using `getVar1` and `getVar2`).

### GRBQuadExpr()

Quadratic expression constructor. Create a constant expression or an expression with one term.

```
GRBQuadExpr GRBQuadExpr ( double constant=0.0 )
```

Create a constant quadratic expression.

**Arguments:**

`constant` (optional): Constant value for expression.

**Return value:**

A constant expression object.

```
GRBQuadExpr GRBQuadExpr ( GRBVar var,
                          double coeff=1.0 )
```

Create an expression with one term.

**Arguments:**

**var:** Variable for expression term.

**coeff (optional):** Coefficient for expression term.

**Return value:**

An expression object containing one quadratic term.

```
GRBQuadExpr GRBQuadExpr ( GRBLinExpr linexpr )
```

Initialize a quadratic expression from an existing linear expression.

**Arguments:**

**orig:** Existing linear expression to copy.

**Return value:**

Quadratic expression object whose initial value is taken from the input linear expression.

**GRBQuadExpr::addTerm()**

Add a single new term into a quadratic expression.

```
void addTerm ( double coeff,
              GRBVar var )
```

Add a new linear term into a quadratic expression.

**Arguments:**

**coeff:** Coefficient for new linear term.

**var:** Variable for new linear term.

```
void addTerm ( double coeff,
              GRBVar var1,
              GRBVar var2 )
```

Add a new quadratic term into a quadratic expression.

**Arguments:**

**coeff:** Coefficient for new quadratic term.

**var1:** Variable for new quadratic term.

**var2:** Variable for new quadratic term.

## GRBQuadExpr::addTerms()

Add new terms into a quadratic expression.

```
void addTerms ( const double* coeffs,
                const GRBVar* vars,
                int count )
```

Add new linear terms into a quadratic expression.

### Arguments:

- coeffs:** Coefficients for new linear terms.
- vars:** Variables for new linear terms.
- count:** Number of linear terms to add to the quadratic expression.

```
void addTerms ( const double* coeffs,
                const GRBVar* vars1,
                const GRBVar* vars2,
                int count )
```

Add new quadratic terms into a quadratic expression.

### Arguments:

- coeffs:** Coefficients for new quadratic terms.
- vars1:** First variables for new quadratic terms.
- vars2:** Second variables for new quadratic terms.
- count:** Number of quadratic terms to add to the quadratic expression.

## GRBQuadExpr::clear()

Set a quadratic expression to 0.

You should use the overloaded `expr = 0` instead. The `clear` method is mainly included for consistency with our interfaces to non-overloaded languages.

```
void clear ( )
```

## GRBQuadExpr::getCoeff()

Retrieve the coefficient from a single quadratic term of the quadratic expression.

```
double getCoeff ( int i )
```

### Arguments:

- i:** Index for coefficient of interest.

### Return value:

Coefficient for the quadratic term at index `i` in the quadratic expression.

## GRBQuadExpr::getLinExpr()

A quadratic expression is represented as a linear expression, plus a list of quadratic terms. This method retrieves the linear expression associated with the quadratic expression.

```
| GRBLinExpr getLinExpr ( )
```

**Return value:**

Linear expression associated with the quadratic expression.

## GRBQuadExpr::getValue()

Compute the value of a quadratic expression for the current solution.

```
| double getValue ( )
```

**Return value:**

Value of the expression for the current solution.

## GRBQuadExpr::getVar1()

Retrieve the first variable object associated with a single quadratic term from the expression.

```
| GRBVar getVar1 ( int i )
```

**Arguments:**

**i:** Index for term of interest.

**Return value:**

First variable for the quadratic term at index **i** in the quadratic expression.

## GRBQuadExpr::getVar2()

Retrieve the second variable object associated with a single quadratic term from the expression.

```
| GRBVar getVar2 ( int i )
```

**Arguments:**

**i:** Index for term of interest.

**Return value:**

Second variable for the quadratic term at index **i** in the quadratic expression.

### GRBQuadExpr::operator=

Set a quadratic expression equal to another quadratic expression.

```
| GRBQuadExpr operator= ( const GRBQuadExpr& rhs )
```

**Arguments:**

**rhs:** Source quadratic expression.

**Return value:**

New quadratic expression object.

### GRBQuadExpr::operator+

Add one expression into another, producing a result expression.

```
| GRBQuadExpr operator+ ( const GRBQuadExpr& rhs )
```

**Arguments:**

**rhs:** Expression to add.

**Return value:**

Expression object which is equal the sum of the invoking expression and the argument expression.

### GRBQuadExpr::operator-

Subtract one expression from another, producing a result expression.

```
| GRBQuadExpr operator- ( const GRBQuadExpr& rhs )
```

**Arguments:**

**rhs:** Expression to subtract.

**Return value:**

Expression object which is equal the invoking expression minus the argument expression.

### GRBQuadExpr::operator+=

Add an expression into the invoking expression.

```
| void operator+= ( const GRBQuadExpr& expr )
```

**Arguments:**

**expr:** Expression to add.

## GRBQuadExpr::operator-=

Subtract an expression from the invoking expression.

```
| void operator-= ( const GRBQuadExpr& expr )
```

### Arguments:

**expr:** Expression to subtract.

## GRBQuadExpr::operator\*=

Multiply the invoking expression by a constant.

```
| void operator*= ( double multiplier )
```

### Arguments:

**multiplier:** Constant multiplier.

## GRBQuadExpr::remove()

Remove a quadratic term from a quadratic expression.

```
| void remove ( int i )
```

Remove the quadratic term stored at index *i* of the expression.

### Arguments:

**i:** The index of the term to be removed.

```
| boolean remove ( GRBVar var )
```

Remove all quadratic terms associated with variable *var* from the quadratic expression.

### Arguments:

**var:** The variable whose term should be removed.

### Return value:

Returns `true` if the variable appeared in the quadratic expression (and was removed).

## GRBQuadExpr::size()

Retrieve the number of quadratic terms in the quadratic expression.

```
| unsigned int size ( )
```

### Return value:

Number of quadratic terms in the expression.

### 3.11 GRBTempConstr

Gurobi temporary constraint object. Objects of this class are created as intermediate results when building constraints using overloaded operators. There are no member functions on this class. Instead, `GRBTempConstr` objects are created by a set of non-member functions: `==`, `<=`, and `>=`. You will generally never store objects of this class in your own variables.

Consider the following examples:

```
model.addConstr(x + y <= 1);  
model.addQConstr(x*x + y*y <= 1);
```

The overloaded `<=` operator creates an object of type `GRBTempConstr`, which is then immediately passed to method [GRBModel::addConstr](#) or [GRBModel::addQConstr](#).

## 3.12 GRBColumn

Gurobi column object. A column consists of a list of coefficient, constraint pairs. Columns are used to represent the set of constraints in which a variable participates, and the associated coefficients. They are temporary objects that typically have short lifespans.

You generally build columns by starting with an empty column (using the [GRBColumn](#) constructor), and then adding terms. Terms can be added individually, using [addTerm](#), or in groups, using [addTerms](#). Terms can also be removed from a column, using [remove](#).

Individual terms in a column can be queried using the [getConstr](#), and [getCoeff](#) methods. You can query the number of terms in the column using the [size](#) method.

### GRBColumn()

Column constructor. Create an empty column.

```
| GRBColumn GRBColumn ( )
```

**Return value:**

An empty column object.

### GRBColumn::addTerm()

Add a single term into a column.

```
| void addTerm ( double    coeff,  
                GRBConstr constr )
```

**Arguments:**

**coeff:** Coefficient for new term.

**constr:** Constraint for new term.

### GRBColumn::addTerms()

Add new terms into a column.

```
| void addTerms ( const double*   coeffs,  
                 const GRBConstr* constra,  
                 int             count )
```

Add a list of terms into a column.

**Arguments:**

**coeffs:** Coefficients for new terms.

**constra:** Constraints for new terms.

**count:** Number of terms to add to the column.

### GRBColumn::clear()

Remove all terms from a column.

```
| void clear ( )
```

## GRBColumn::getCoeff()

Retrieve the coefficient from a single term in the column.

```
| double getCoeff ( int i )
```

### Return value:

Coefficient for the term at index *i* in the column.

## GRBColumn::getConstr()

Retrieve the constraint object from a single term in the column.

```
| GRBConstr getConstr ( int i )
```

### Return value:

Constraint for the term at index *i* in the column.

## GRBColumn::remove()

Remove a single term from a column.

```
| void remove ( int i )
```

Remove the term stored at index *i* of the column.

### Arguments:

*i*: The index of the term to be removed.

```
| boolean remove ( GRBConstr constr )
```

Remove the term associated with constraint *constr* from the column.

### Arguments:

*constr*: The constraint whose term should be removed.

### Return value:

Returns `true` if the constraint appeared in the column (and was removed).

## GRBColumn::size()

Retrieve the number of terms in the column.

```
| unsigned int size ( )
```

### Return value:

Number of terms in the column.

### 3.13 GRBCallback

Gurobi callback class. This is an abstract class. To implement a callback, you should create a subclass of this class and implement a `callback()` method. If you pass an object of this subclass to method `GRBModel::setCallback` before calling `GRBModel::optimize`, the `callback()` method of the class will be called periodically. Depending on where the callback is called from, you can obtain various information about the progress of the optimization.

Note that this class contains one protected `int` member variable: `where`. You can query this variable from your `callback()` method to determine where the callback was called from.

Gurobi callbacks can be used both to monitor the progress of the optimization and to modify the behavior of the Gurobi optimizer. A simple user callback function might call the `GRBCallback::getIntInfo` or `GRBCallback::getDoubleInfo` methods to produce a custom display, or perhaps to terminate optimization early (using `GRBCallback::abort`). More sophisticated MIP callbacks might use `GRBCallback::getNodeRel` or `GRBCallback::getSolution` to retrieve values from the solution to the current node, and then use `GRBCallback::addCut` or `GRBCallback::addLazy` to add a constraint to cut off that solution, or `GRBCallback::setSolution` to import a heuristic solution built from that solution.

When solving a model using multiple threads, note that the user callback is only ever called from a single thread, so you don't need to worry about the thread-safety of your callback.

You can look at the `callback_c++.cpp` example for details of how to use Gurobi callbacks.

#### GRBCallback()

Callback constructor.

```
| GRBCallback GRBCallback ( )
```

**Return value:**

A callback object.

#### GRBCallback::abort()

Abort optimization. When the optimization stops, the `Status` attribute will be equal to `GRB_INTERRUPTED`.

```
| void abort ( )
```

#### GRBCallback::addCut()

Add a cutting plane to the MIP model from within a callback function. Note that this method can only be invoked when the `where` member variable is equal to `GRB_CB_MIPNODE` (see the [Callback Codes](#) section for more information).

Cutting planes can be added at any node of the branch-and-cut tree. However, they should be added sparingly, since they increase the size of the relaxation model that is solved at each node and can significantly degrade node processing speed.

Cutting planes are typically used to cut off the current relaxation solution. To retrieve the relaxation solution at the current node, you should first call `getNodeRel`.

When adding your own cuts, you must set parameter [PreCrush](#) to value 1. This setting shuts off a few presolve reductions that sometimes prevent cuts on the original model from being applied to the presolved model.

Note that cutting planes added through this method must truly be cutting planes — they can cut off continuous solutions, but they may not cut off integer solutions that respect the original constraints of the model. Ignoring this restriction will lead to incorrect solutions.

```
void addCut (  const GRBLinExpr&  lhsExpr,
               char              sense,
               double            rhsVal )
```

**Arguments:**

**lhsExpr**: Left-hand side expression for new cutting plane.

**sense**: Sense for new cutting plane (GRB\_LESS\_EQUAL, GRB\_EQUAL, or GRB\_GREATER\_EQUAL).

**rhsVal**: Right-hand side value for new cutting plane.

```
void addCut (  GRBTempConstr&  tc )
```

**Arguments:**

**tc**: Temporary constraint object, created using an overloaded comparison operator. See [GRBTempConstr](#) for more information.

## GRBCallback::addLazy()

Add a lazy constraint to the MIP model from within a callback function. Note that this method can only be invoked when the **where** member variable is equal to GRB\_CB\_MIPNODE or GRB\_CB\_MIPSOL (see the [Callback Codes](#) section for more information).

Lazy constraints are typically used when the full set of constraints for a MIP model is too large to represent explicitly. By only including the constraints that are actually violated by solutions found during the branch-and-cut search, it is sometimes possible to find a proven optimal solution while only adding a fraction of the full set of constraints.

You would typically add a lazy constraint by first querying the current node solution (by calling [getSolution](#) from a GRB\_CB\_MIPSOL callback, or [getNodeRel](#) from a GRB\_CB\_MIPNODE callback), and then calling [addLazy\(\)](#) to add a constraint that cuts off the solution. Gurobi guarantees that you will have the opportunity to cut off any solutions that would otherwise be considered feasible.

Your callback should be prepared to cut off solutions that violate any of your lazy constraints, including those that have already been added. Node solutions will usually respect previously added lazy constraints, but not always.

Note that you must set the [LazyConstraints](#) parameter if you want to use lazy constraints.

```
void addLazy (  const GRBLinExpr&  lhsExpr,
               char              sense,
               double            rhsVal )
```

**Arguments:**

**lhsExpr**: Left-hand side expression for new lazy constraint.

**sense:** Sense for new lazy constraint (GRB\_LESS\_EQUAL, GRB\_EQUAL, or GRB\_GREATER\_EQUAL).  
**rhsVal:** Right-hand side value for new lazy constraint.

```
| void addLazy ( GRBTempConstr& tc )
```

**Arguments:**

**tc:** Temporary constraint object, created using an overloaded comparison operator. See [GRBTempConstr](#) for more information.

### GRBCallback::getDoubleInfo()

Request double-valued callback information. The available information depends on the value of the **where** member. For information on possible values of **where**, and the double-valued information that can be queried for different values of **where**, please refer to the [Callback](#) section.

```
| double getDoubleInfo ( int what )
```

**Arguments:**

**what:** Information requested (refer the list of Gurobi [Callback Codes](#) for possible values).

**Return value:**

Value of requested callback information.

### GRBCallback::getIntInfo()

Request int-valued callback information. The available information depends on the value of the **where** member. For information on possible values of **where**, and the int-valued information that can be queried for different values of **where**, please refer to the [Callback](#) section.

```
| int getIntInfo ( int what )
```

**Arguments:**

**what:** Information requested (refer to the list of Gurobi [Callback Codes](#) for possible values).

**Return value:**

Value of requested callback information.

### GRBCallback::getNodeRel()

Retrieve values from the node relaxation solution at the current node. Only available when the **where** member variable is equal to GRB\_CB\_MIPNODE, and GRB\_CB\_MIPNODE\_STATUS is equal to GRB\_OPTIMAL.

```
| double getNodeRel ( GRBVar v )
```

**Arguments:**

**v:** The variable whose value is desired.

**Return value:**

The value of the specified variable in the node relaxation for the current node.

```
double* getNodeRel ( const GRBVar* xvars,
                    int           len )
```

**Arguments:**

**xvars:** The list of variables whose values are desired.

**len:** The number of variables in the list.

**Return value:**

The values of the specified variables in the node relaxation for the current node. Note that the result is heap-allocated, and must be returned to the heap by the user.

**GRBCallback::getSolution()**

Retrieve values from the current solution vector. Only available when the **where** member variable is equal to GRB\_CB\_MIPSOL.

```
double getSolution ( GRBVar v )
```

**Arguments:**

**v:** The variable whose value is desired.

**Return value:**

The value of the specified variable in the current solution vector.

```
double* getSolution ( const GRBVar* xvars,
                    int           len )
```

**Arguments:**

**xvars:** The list of variables whose values are desired.

**len:** The number of variables in the list.

**Return value:**

The values of the specified variables in the current solution. Note that the result is heap-allocated, and must be returned to the heap by the user.

**GRBCallback::getStringInfo()**

Request string-valued callback information. The available information depends on the value of the **where** member. For information on possible values of **where**, and the string-valued information that can be queried for different values of **where**, please refer to the [Callback](#) section.

```
string getStringInfo ( int what )
```

**Arguments:**

**what:** Information requested (refer to the list of Gurobi [Callback Codes](#) for possible values).

**Return value:**

Value of requested callback information.

## GRBCallback::setSolution()

Import solution values for a heuristic solution. Only available when the **where** member variable is equal to `GRB_CB_MIPNODE`.

When you specify a heuristic solution from a callback, variables initially take undefined values. You should use this method to specify variable values. You can make multiple calls to `setSolution` from one callback invocation to specify values for multiple sets of variables. At the end of the callback, if values have been specified for any variables, the Gurobi optimizer will try to compute a feasible solution from the specified values, possibly filling in values for variables whose values were left undefined.

```
void setSolution ( GRBVar v,  
                  double val )
```

**Arguments:**

**v:** The variable whose values is being set.  
**val:** The value of the variable in the new solution.

```
void setSolution ( const GRBVar* xvars,  
                  const double* sol,  
                  int len )
```

**Arguments:**

**xvars:** The variables whose values are being set.  
**sol:** The values of the variables in the new solution.  
**len:** The number of variables.

## 3.14 GRBException

Gurobi exception object. Exceptions can be thrown by nearly every method in the Gurobi C++ API.

### GRBException()

Exception constructor.

```
| GRBException GRBException ( int errcode=0 )
```

Create a Gurobi exception.

**Arguments:**

`errcode` (optional): Error code for exception.

**Return value:**

An exception object.

```
| GRBException GRBException ( string errmsg,  
                             int errcode=0 )
```

Create a Gurobi exception.

**Arguments:**

`errmsg`: Error message for exception.

`errcode` (optional): Error code for exception.

**Return value:**

An exception object.

### GRBException::getErrorCode()

Retrieve the error code associated with a Gurobi exception.

```
| int getErrorCode ( )
```

**Return value:**

The error code associated with the exception.

### GRBException::getMessage()

Retrieve the error message associated with a Gurobi exception.

```
| const string getMessage ( )
```

**Return value:**

The error message associated with the exception.

## 3.15 Non-Member Functions

Several Gurobi C++ interface functions aren't member functions on a particular object.

### **operator==**

Create an equality constraint

```
GRBTempConstr operator== ( GRBQuadExpr lhsExpr,  
                           GRBQuadExpr rhsExpr )
```

**Arguments:**

**lhsExpr:** Left-hand side of equality constraint.

**rhsExpr:** Right-hand side of equality constraint.

**Return value:**

A constraint of type [GRBTempConstr](#). The result is typically immediately passed to [GRBModel::addConstr](#).

### **operator<=**

Create an inequality constraint

```
GRBTempConstr operator<= ( GRBQuadExpr lhsExpr,  
                           GRBQuadExpr rhsExpr )
```

**Arguments:**

**lhsExpr:** Left-hand side of inequality constraint.

**rhsExpr:** Right-hand side of inequality constraint.

**Return value:**

A constraint of type [GRBTempConstr](#). The result is typically immediately passed to [GRBModel::addConstr](#) or [GRBModel::addQConstr](#).

### **operator>=**

Create an inequality constraint

```
GRBTempConstr operator>= ( GRBQuadExpr lhsExpr,  
                           GRBQuadExpr rhsExpr )
```

**Arguments:**

**lhsExpr:** Left-hand side of inequality constraint.

**rhsExpr:** Right-hand side of inequality constraint.

**Return value:**

A constraint of type [GRBTempConstr](#). The result is typically immediately passed to [GRBModel::addConstr](#) or [GRBModel::addQConstr](#).

## operator+

Overloaded operator on expression objects.

```
GRBLinExpr operator+ ( const GRBLinExpr& expr1,  
                      const GRBLinExpr& expr2 )
```

Add a pair of expressions.

**Arguments:**

**expr1:** First expression to be added.

**expr2:** Second expression to be added.

**Return value:**

Sum expression.

```
GRBLinExpr operator+ ( const GRBLinExpr& expr )
```

Allow plus sign to be used before an expression.

**Arguments:**

**expr:** Expression.

**Return value:**

Result expression.

```
GRBLinExpr operator+ ( GRBVar x,  
                      GRBVar y )
```

Add a pair of variables.

**Arguments:**

**x:** First variable to be added.

**y:** Second variable to be added.

**Return value:**

Sum expression.

```
GRBQuadExpr operator+ ( const GRBQuadExpr& expr1,  
                      const GRBQuadExpr& expr2 )
```

Add a pair of expressions.

**Arguments:**

**expr1:** First expression to be added.

**expr2:** Second expression to be added.

**Return value:**

Sum expression.

```
GRBQuadExpr operator+ ( const GRBQuadExpr& expr )
```

Allow plus sign to be used before an expression.

**Arguments:**

**expr:** Expression.

**Return value:**

Result expression.

**operator-**

Overloaded operator on expression objects.

```
GRBLinExpr operator- ( const GRBLinExpr& expr1,  
                      const GRBLinExpr& expr2 )
```

Subtract one expression from another.

**Arguments:**

**expr1:** Start expression.

**expr2:** Expression to be subtracted.

**Return value:**

Difference expression.

```
GRBLinExpr operator- ( const GRBLinExpr& expr )
```

Negate an expression.

**Arguments:**

**expr:** Expression.

**Return value:**

Negation of expression.

```
GRBQuadExpr operator- ( const GRBQuadExpr& expr1,  
                       const GRBQuadExpr& expr2 )
```

Subtract one expression from another.

**Arguments:**

**expr1:** Start expression.

**expr2:** Expression to be subtracted.

**Return value:**

Difference expression.

```
GRBQuadExpr operator- ( const GRBQuadExpr& expr )
```

Negate an expression.

**Arguments:**

**expr:** Expression.

**Return value:**

Negation of expression.

## operator\*

Overloaded operator on expression objects.

```
GRBLinExpr operator* ( GRBVar x,  
                       double a )
```

Multiply a variable and a constant.

**Arguments:**

**x:** Variable.

**a:** Constant multiplier.

**Return value:**

Expression that represents the result of multiplying the variable by a constant.

```
GRBLinExpr operator* ( double a,  
                       GRBVar x )
```

Multiply a variable and a constant.

**Arguments:**

**a:** Constant multiplier.

**x:** Variable.

**Return value:**

Expression that represents the result of multiplying the variable by a constant.

```
GRBLinExpr operator* ( const GRBLinExpr& expr,  
                       double a )
```

Multiply an expression and a constant.

**Arguments:**

**expr:** Expression.

**a:** Constant multiplier.

**Return value:**

Expression that represents the result of multiplying the expression by a constant.

```
GRBLinExpr operator* ( double a,  
                       const GRBLinExpr& expr )
```

Multiply an expression and a constant.

**Arguments:**

**a:** Constant multiplier.

**expr:** Expression.

**Return value:**

Expression that represents the result of multiplying the expression by a constant.

```
GRBQuadExpr operator* ( const GRBQuadExpr& expr,  
                        double a )
```

Multiply an expression and a constant.

**Arguments:**

**expr:** Expression.  
**a:** Constant multiplier.

**Return value:**

Expression that represents the result of multiplying the expression by a constant.

```
GRBQuadExpr operator* ( double          a,
                       const GRBQuadExpr& expr )
```

Multiply an expression and a constant.

**Arguments:**

**a:** Constant multiplier.  
**expr:** Expression.

**Return value:**

Expression that represents the result of multiplying the expression by a constant.

```
GRBQuadExpr operator* ( GRBVar  x,
                       GRBVar  y )
```

Multiply a pair of variables.

**Arguments:**

**x:** First variable.  
**y:** Second variable.

**Return value:**

Expression that represents the result of multiplying the argument variables.

```
GRBQuadExpr operator* ( GRBVar          var,
                       const GRBLinExpr& expr )
```

Multiply an expression and a variable.

**Arguments:**

**var:** Variable.  
**expr:** Expression.

**Return value:**

Expression that represents the result of multiplying the expression by a variable.

```
GRBQuadExpr operator* ( const GRBLinExpr& expr,
                       GRBVar          var )
```

Multiply an expression and a variable.

**Arguments:**

**var:** Variable.  
**expr:** Expression.

**Return value:**

Expression that represents the result of multiplying the expression by a variable.

```
GRBQuadExpr operator* ( const GRBLinExpr& expr1,
                       const GRBLinExpr& expr2 )
```

Multiply a pair of expressions.

**Arguments:**

**expr1:** First expression.

**expr2:** Second expression.

**Return value:**

Expression that represents the result of multiplying the argument expressions.

**operator/**

Overloaded operator to divide a variable or expression by a constant.

```
GRBLinExpr operator/ ( GRBVar x,  
                       double a )
```

**Arguments:**

**x:** Variable.

**a:** Constant divisor.

**Return value:**

Expression that represents the result of dividing the variable by a constant.

```
GRBLinExpr operator/ ( const GRBLinExpr& expr,  
                       double a )
```

**Arguments:**

**expr:** Expression.

**a:** Constant divisor.

**Return value:**

Expression that represents the result of dividing the expression by a constant.

```
GRBLinExpr operator/ ( const GRBQuadExpr& expr,  
                       double a )
```

**Arguments:**

**expr:** Expression.

**a:** Constant divisor.

**Return value:**

Expression that represents the result of dividing the expression by a constant.

## 3.16 Attribute Enums

These `enums` are used to get or set Gurobi attributes. The complete list of attributes can be found in the [Attributes](#) section.

### **GRB\_CharAttr**

This enum is used to get or set char-valued attributes (through [GRBModel::get](#) or [GRBModel::set](#)). Please refer to the [Attributes](#) section to see a list of all char attributes and their functions.

### **GRB\_DoubleAttr**

This enum is used to get or set double-valued attributes (through [GRBModel::get](#) or [GRBModel::set](#)). Please refer to the [Attributes](#) section to see a list of all double attributes and their functions.

### **GRB\_IntAttr**

This enum is used to get or set int-valued attributes (through [GRBModel::get](#) or [GRBModel::set](#)). Please refer to the [Attributes](#) section to see a list of all int attributes and their functions.

### **GRB\_StringAttr**

This enum is used to get or set string-valued attributes (through [GRBModel::get](#) or [GRBModel::set](#)). Please refer to the [Attributes](#) section to see a list of all string attributes and their functions.

## 3.17 Parameter Enums

These `enums` are used to get or set Gurobi parameters. The complete of parameters can be found in the [Parameters](#) section.

### **GRB\_DoubleParam**

This enum is used to get or set double-valued parameters (through [GRBModel::get](#), [GRBModel::set](#), [GRBEnv::get](#), or [GRBEnv::set](#)). Please refer to the [Parameters](#) section to see a list of all double parameters and their functions.

### **GRB\_IntParam**

This enum is used to get or set int-valued parameters (through [GRBModel::get](#), [GRBModel::set](#), [GRBEnv::get](#), or [GRBEnv::set](#)). Please refer to the [Parameters](#) section to see a list of all int parameters and their functions.

### **GRB\_StringParam**

This enum is used to get or set string-valued parameters (through [GRBModel::get](#), [GRBModel::set](#), [GRBEnv::get](#), or [GRBEnv::set](#)). Please refer to the [Parameters](#) section to see a list of all int parameters and their functions.

This section documents the Gurobi Java interface. This manual begins with a quick overview of the classes exposed in the interface and the most important methods on those classes. It then continues with a [comprehensive presentation of all of the available classes and methods](#).

If you are new to the Gurobi Optimizer, we suggest that you start with the [Quick Start Guide](#) or the [Example Tour](#). These documents provide concrete examples of how to use the classes and methods described here.

## Environments

The first step in using the Gurobi Java interface is to create an environment object. Environments are represented using the `GRBEnv` class. An environment acts as the container for all data associated with a set of optimization runs. You will generally only need one environment object in your program.

## Models

You can create one or more optimization models within an environment. Each model is represented as an object of class `GRBModel`. A model consists of a set of decision variables (objects of class `GRBVar`), a linear or quadratic objective function on these variables (specified using `GRBModel.setObjective`), and a set of constraints on these variables (objects of class `GRBConstr`, `GRBQConstr`, `GRBSOS`, or `GRBGenConstr`). Each variable has an associated lower bound, upper bound, and type (continuous, binary, etc.). Each linear or quadratic constraint has an associated sense (less-than-or-equal, greater-than-or-equal, or equal), and right-hand side value. Refer to [this section](#) for more information on variables and constraints.

Linear constraints are specified by building linear expressions (objects of class `GRBLinExpr`), and then specifying relationships between these expressions (for example, requiring that one expression be equal to another). Quadratic constraints are built in a similar fashion, but using quadratic expressions (objects of class `GRBQuadExpr`) instead.

An optimization model may be specified all at once, by loading the model from a file (using the appropriate `GRBModel` constructor), or built incrementally, by first constructing an empty object of class `GRBModel` and then subsequently calling `GRBModel.addVar` or `GRBModel.addVars` to add additional variables, and `GRBModel.addConstr`, `GRBModel.addQConstr`, `GRBModel.addSOS`, or any of the `GRBModel.addGenConstrXxx` methods to add additional constraints. Models are dynamic entities; you can always add or remove variables or constraints.

We often refer to the *class* of an optimization model. A model with a linear objective function, linear constraints, and continuous variables is a *Linear Program (LP)*. If the objective is quadratic, the model is a *Quadratic Program (QP)*. If any of the constraints are quadratic, the model is a *Quadratically-Constrained Program (QCP)*. We'll sometimes also discuss a special case of QCP, the *Second-Order Cone Program (SOCP)*. If the model contains any integer variables, semi-continuous variables, semi-integer variables, Special Ordered Set (SOS) constraints, or general constraints, the model is a *Mixed Integer Program (MIP)*. We'll also sometimes discuss special cases of MIP, including *Mixed Integer Linear Programs (MILP)*, *Mixed Integer Quadratic Programs (MIQP)*, *Mixed*

*Integer Quadratically-Constrained Programs (MIQCP)*, and *Mixed Integer Second-Order Cone Programs (MISOCP)*. The Gurobi Optimizer handles all of these model classes.

### Solving a Model

Once you have built a model, you can call `GRBModel.optimize` to compute a solution. By default, `optimize` will use the `concurrent optimizer` to solve LP models, the barrier algorithm to solve QP and QCP models, and the branch-and-cut algorithm to solve mixed integer models. The solution is stored in a set of *attributes* of the model. These attributes can be queried using a set of attribute query methods on the `GRBModel`, `GRBVar`, `GRBConstr`, `GRBQConstr`, `GRBSOS`, and `GRBGenConstr`, and classes.

The Gurobi algorithms keep careful track of the state of the model, so calls to `GRBModel.optimize` will only perform further optimization if relevant data has changed since the model was last optimized. If you would like to discard previously computed solution information and restart the optimization from scratch without changing the model, you can call `GRBModel.reset`.

After a MIP model has been solved, you can call `GRBModel.fixedModel` to compute the associated *fixed* model. This model is identical to the input model, except that all integer variables are fixed to their values in the MIP solution. In some applications, it is useful to compute information on this continuous version of the MIP model (e.g., dual variables, sensitivity information, etc.).

### Multiple Solutions and Multiple Objectives

By default, the Gurobi Optimizer assumes that your goal is to find one proven optimal solution to a model with a single objective function. Gurobi provides features that allow you to relax either of these assumptions. You should refer to the section on [Solution Pools](#) for information on how to request more than one solution, or the section on [Multiple Objectives](#) for information on how to specify multiple objective functions and control the tradeoff between them.

### Infeasible Models

You have a few options if a model is found to be infeasible. You can try to diagnose the cause of the infeasibility, attempt to repair the infeasibility, or both. To obtain information that can be useful for diagnosing the cause of an infeasibility, call `GRBModel.computeIIS` to compute an Irreducible Inconsistent Subsystem (IIS). This method can be used for both continuous and MIP models, but you should be aware that the MIP version can be quite expensive. This method populates a set of IIS attributes.

To attempt to repair an infeasibility, call `GRBModel.feasRelax` to compute a feasibility relaxation for the model. This relaxation allows you to find a solution that minimizes the magnitude of the constraint violation.

### Querying and Modifying Attributes

Most of the information associated with a Gurobi model is stored in a set of attributes. Some attributes are associated with the variables of the model, some with the constraints of the model, and some with the model itself. To give a simple example, solving an optimization model causes the `X` variable attribute to be populated. Attributes such as `X` that are computed by the Gurobi optimizer cannot be modified directly by the user, while others, such as the variable lower bound (the `LB` attribute) can.

Attributes are queried using `GRBVar.get`, `GRBConstr.get`, `GRBQConstr.get`, `GRBSOS.get`, `GRBGenConstr.get`, or `GRBModel.get`, and modified using `GRBVar.set`, `GRBConstr.set`, `GRBQConstr.set`, `GRBGenConstr.set`, or `GRBModel.set`. Attributes are grouped into a set of enums by

type ([GRB.CharAttr](#), [GRB.DoubleAttr](#), [GRB.IntAttr](#), [GRB.StringAttr](#)). The `get()` and `set()` methods are overloaded, so the type of the attribute determines the type of the returned value. Thus, `constr.get(GRB.DoubleAttr.RHS)` returns a double, while `constr.get(GRB.CharAttr.Sense)` returns a char.

If you wish to retrieve attribute values for a set of variables or constraints, it is usually more efficient to use the array methods on the associated [GRBModel](#) object. Method [GRBModel.get](#) includes signatures that allow you to query or modify attribute values for one-, two-, and three-dimensional arrays of variables or constraints.

The full list of attributes can be found in the [Attributes](#) section.

## Additional Model Modification Information

Most modifications to an existing model are done through the attribute interface (e.g., changes to variable bounds, constraint right-hand sides, etc.). The main exceptions are modifications to the constraint matrix and to the objective function.

The constraint matrix can be modified in a few ways. The first is to call the [chgCoeff](#) method on a [GRBModel](#) object to change individual matrix coefficients. This method can be used to modify the value of an existing non-zero, to set an existing non-zero to zero, or to create a new non-zero. The constraint matrix is also modified when you remove a variable or constraint from the model (through the [GRBModel.remove](#) method). The non-zero values associated with the deleted constraint or variable are removed along with the constraint or variable itself.

The model objective function can also be modified in a few ways. The easiest is to build an expression that captures the objective function (a [GRBLinExpr](#) or [GRBQuadExpr](#) object), and then pass that expression to method [GRBModel.setObjective](#). If you wish to modify the objective, you can simply call `setObjective` again with a new [GRBLinExpr](#) or [GRBQuadExpr](#) object.

For linear objective functions, an alternative to `setObjective` is to use the `Obj` variable attribute to modify individual linear objective coefficients.

If your variables have piecewise-linear objectives, you can specify them using the [GRBModel.setPWLObj](#) method. Call this method once for each relevant variable. The Gurobi simplex solver includes algorithmic support for convex piecewise-linear objective functions, so for continuous models you should see a substantial performance benefit from using this feature. To clear a previously specified piecewise-linear objective function, simply set the `Obj` attribute on the corresponding variable to 0.

## Lazy Updates

One important item to note about model modification in the Gurobi optimizer is that it is performed in a *lazy* fashion, meaning that modifications don't affect the model immediately. Rather, they are queued and applied later. If your program simply creates a model and solves it, you will probably never notice this behavior. However, if you ask for information about the model before your modifications have been applied, the details of the lazy update approach may be relevant to you.

As we just noted, model modifications (bound changes, right-hand side changes, objective changes, etc.) are placed in a queue. These queued modifications can be applied to the model in three different ways. The first is by an explicit call to [GRBModel.update](#). The second is by a call to [GRBModel.optimize](#). The third is by a call to [GRBModel.write](#) to write out the model. The first case gives you fine-grained control over when modifications are applied. The second and third make the assumption that you want all pending modifications to be applied before you optimize

your model or write it to disk.

Why does the Gurobi interface behave in this manner? There are a few reasons. The first is that this approach makes it much easier to perform multiple modifications to a model, since the model remains unchanged between modifications. The second is that processing model modifications can be expensive, particularly in a Compute Server environment, where modifications require communication between machines. Thus, it is useful to have visibility into exactly when these modifications are applied. In general, if your program needs to make multiple modifications to the model, you should aim to make them in phases, where you make a set of modifications, then update, then make more modifications, then update again, etc. Updating after each individual modification can be extremely expensive.

If you forget to call `update`, your program won't crash. Your query will simply return the value of the requested data from the point of the last update. If the object you tried to query didn't exist then, you'll get a `NOT_IN_MODEL` exception instead.

The semantics of lazy updates have changed in this release. While the vast majority of programs will continue to work unmodified, you can use the `UpdateMode` parameter to revert to the previous behavior if you run into an issue.

## Managing Parameters

The Gurobi optimizer provides a set of parameters that allow you to control many of the details of the optimization process. Factors like feasibility and optimality tolerances, choices of algorithms, strategies for exploring the MIP search tree, etc., can be controlled by modifying Gurobi parameters before beginning the optimization. Parameters can be of type *int*, *double*, or *string*.

The simplest way to set parameters is through the `GRBModel.set` method on the model object. Similarly, parameter values can be queried with `GRBModel.get`.

Parameters can also be set on the Gurobi environment object, using `GRBEnv.set`. Note that each model gets its own copy of the environment when it is created, so parameter changes to the original environment have no effect on existing models.

You can read a set of parameter settings from a file using `GRBEnv.readParams`, or write the set of changed parameters using `GRBEnv.writeParams`.

We also include an automated parameter tuning tool that explores many different sets of parameter changes in order to find a set that improves performance. You can call `GRBModel.tune` to invoke the tuning tool on a model. Refer to the [parameter tuning tool](#) section for more information.

The full list of Gurobi parameters can be found in the [Parameters](#) section.

## Memory Management

Users typically do not need to concern themselves with memory management in Java, since it is handled automatically by the garbage collector. The Gurobi Java interface utilizes the same garbage collection mechanism as other Java programs, but there are a few specifics of our memory management that users should be aware of.

In general, Gurobi objects live in the same Java heap as other Java objects. When they are no longer referenced, they become candidates for garbage collection, and are returned to the pool of free space at the next invocation of the garbage collector. Two important exceptions are the `GRBEnv` and `GRBModel` objects. A `GRBModel` object has a small amount of memory associated with it in the Java heap, but the majority of the space associated with a model lives in the heap of the Gurobi native code library (the Gurobi DLL in Windows, or the Gurobi shared library in Linux or Mac). The Java heap manager is unaware of the memory associated with the model in

the native code library, so it does not consider this memory usage when deciding whether to invoke the garbage collector. When the garbage collector eventually collects the Java `GRBModel` object, the memory associated with the model in the Gurobi native code library will be freed, but this collection may come later than you might want. Similar considerations apply to the `GRBEnv` object.

If you are writing a Java program that makes use of multiple Gurobi models or environments, we recommend that you call `GRBModel.dispose` when you are done using the associated `GRBModel` object, and `GRBEnv.dispose` when you are done using the associated `GRBEnv` object and after you have called `GRBModel.dispose` on all of the models created using that `GRBEnv` object.

## Native Code

As noted earlier, the Gurobi Java interface is a thin layer that sits on top of our native code library (the Gurobi DLL on Windows, and the Gurobi shared library on Linux or Mac). Thus, an application that uses the Gurobi Java library will load the Gurobi native code library at runtime. In order for this happen, you need to make sure that two things are true. First, you need to make sure that the native code library is available in the search path of the target machine (`PATH` on Windows, `LD_LIBRARY_PATH` on Linux, or `DYLD_LIBRARY_PATH` on Mac). These paths are set up as part of the installation of the Gurobi Optimizer, but may not be configured appropriately on a machine where the full Gurobi Optimizer has not been installed. Second, you need to be sure that the Java JVM and the Gurobi native library use the same object format. In particular, you need to use the 32-bit Gurobi native library with a 32-bit Java JVM, and similarly the 64-bit Gurobi native library with a 64-bit Java JVM.

## Monitoring Progress - Logging and Callbacks

Progress of the optimization can be monitored through Gurobi logging. By default, Gurobi will send output to the screen. A few simple controls are available for modifying the default logging behavior. If you would like to direct output to a file as well as to the screen, specify the log file name in the `GRBEnv` constructor. You can modify the `LogFile` parameter if you wish to redirect the log to a different file after creating the environment object. The frequency of logging output can be controlled with the `DisplayInterval` parameter, and logging can be turned off entirely with the `OutputFlag` parameter. A detailed description of the Gurobi log file can be found in the [Logging](#) section.

More detailed progress monitoring can be done through the `GRBCallback` class. The `GRBModel.setCallback` method allows you to receive a periodic callback from the Gurobi optimizer. You do this by sub-classing the `GRBCallback` abstract class, and writing your own `Callback()` method on this class. You can call `GRBCallback.getDoubleInfo`, `GRBCallback.getIntInfo`, `GRBCallback.getStringInfo`, or `GRBCallback.getSolution` from within the callback to obtain additional information about the state of the optimization.

## Modifying Solver Behavior - Callbacks

Callbacks can also be used to modify the behavior of the Gurobi optimizer. The simplest control callback is `GRBCallback.abort`, which asks the optimizer to terminate at the earliest convenient point. Method `GRBCallback.setSolution` allows you to inject a feasible solution (or partial solution) during the solution of a MIP model. Methods `GRBCallback.addCut` and `GRBCallback.addLazy` allow you to add *cutting planes* and *lazy constraints* during a MIP optimization, respectively.

## Error Handling

All of the methods in the Gurobi Java library can throw an exception of type [GRBException](#). When an exception occurs, additional information on the error can be obtained by retrieving the error code (using method [GRBException.getErrorCode](#)), or by retrieving the exception message (using method [GRBException.getMessage](#) from the parent class). The list of possible error return codes can be found in the [Error Codes](#) section.

## 4.1 GRBEnv

Gurobi environment object. Gurobi models are always associated with an environment. You must create an environment before can you create and populate a model. You will generally only need a single environment object in your program.

The methods on environment objects are mainly used to manage Gurobi parameters (e.g., [get](#), [getParamInfo](#), [set](#)).

While the Java garbage collector will eventually collect an unused `GRBEnv` object, an environment will hold onto resources (Gurobi licenses, file descriptors, etc.) until that collection occurs. If your program creates multiple `GRBEnv` objects, we recommend that you call `GRBEnv.dispose` when you are done using one.

### GRBEnv()

Environment constructor.

Constructor for `GRBEnv` object. If the constructor is called with no arguments, no log file will be written for the environment.

You have the option of constructing either a local environment, which solves Gurobi models on the local machine, or a client environment for a Gurobi compute server, which will solve Gurobi models on a server machine. For the latter, choose the signature that allows you to specify the names of the Gurobi compute servers and the priority of the associated job.

Note that the `GRBEnv` constructor will check the current working directory for a file named `gurobi.env`, and it will attempt to read parameter settings from this file if it exists. The file should be in [PRM](#) format (briefly, each line should contain a parameter name, followed by the desired value for that parameter).

In general, you should aim to create a single Gurobi environment object in your program, even if you plan to work with multiple models. Reusing one environment is much more efficient than creating and destroying multiple environments.

```
| GRBEnv GRBEnv ( )
```

Create a Gurobi environment (with logging disabled).

**Return value:**

An environment object (with no associated log file).

```
| GRBEnv GRBEnv ( String logFileName )
```

Create a Gurobi environment (with logging enabled).

**Arguments:**

`logFileName`: The desired log file name.

**Return value:**

An environment object.

```
GRBEnv GRBEnv ( String logFileName,  
                String computeserver,  
                int port,  
                String password,  
                int priority,  
                double timeout )
```

Create a client Gurobi environment on a compute server.

**Arguments:**

**logFileName:** The name of the log file for this environment. Pass an empty string for no log file.

**computeserver:** A comma-separated list of Gurobi compute servers. You can refer to compute server machines using their names or their IP addresses.

**port:** The port number used to connect to the compute server. You should pass a -1 value, which indicates that the default port should be used, unless your server administrator has changed our recommended port settings.

**password:** The password for gaining access to the specified compute servers. Pass an empty string if no password is required.

**priority:** The priority of the job. Priorities must be between -100 and 100, with a default value of 0 (by convention). Higher priority jobs are chosen from the server job queue before lower priority jobs. A job with priority 100 runs immediately, bypassing the job queue and ignoring the job limit on the server. You should exercise caution with priority 100 jobs, since they can severely overload a server, which can cause jobs to fail, and in extreme cases can cause the server to crash.

**timeout:** Job timeout (in seconds). If the job doesn't reach the front of the queue before the specified timeout, the constructor will throw a `JOB_REJECTED` exception. Use a negative value to indicate that the call should never timeout.

**Return value:**

An environment object.

```
GRBEnv GRBEnv ( String logFileName,  
                String accessID,  
                String secretKey,  
                String pool )
```

Create a Gurobi environment on Gurobi Instant Cloud

**Arguments:**

**logfile**name: The name of the log file for this environment. May be `NULL` (or an empty string), in which case no log file is created.

**accessID:** The access ID for your Gurobi Instant Cloud license. This can be retrieved from the Gurobi Instant Cloud website. When used in combination with your `secretKey`, this allows you to launch Instant Cloud instances and submit jobs to them.

**secretKey:** The secret key for your Gurobi Instant Cloud license. This can be retrieved from the Gurobi Instant Cloud website. When used in combination with your `accessID`, this allows you to launch Instant Cloud instances and submit jobs to them. Note that you should keep your secret key private.

**pool:** The machine pool. Machine pools allow you to create fixed configurations on the Instant Cloud website (capturing things like type of machine, geographic region, etc.), and then launch and share machines from client programs without having to restate the configuration information each time you launch a machine. May be `null` (or an empty string), in which case your job will be launched in the default pool associated with your cloud license.

**Return value:**

An environment object.

## **GRBEnv.dispose()**

Release the resources associated with a `GRBEnv` object. While the Java garbage collector will eventually reclaim these resources, we recommend that you call the `dispose` method when you are done using an environment if your program creates more than one.

The `dispose` method on a `GRBEnv` should be called only after you have called `dispose` on all of the models that were created within that environment. You should not attempt to use a `GRBEnv` object after calling `dispose`.

```
| void dispose ( )
```

## **GRBEnv.get()**

Query the value of a parameter.

```
| double get ( GRB.DoubleParam param )
```

Query the value of a double-valued parameter.

**Arguments:**

**param:** The parameter being queried. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**Return value:**

The current value of the requested parameter.

```
| int get ( GRB.IntParam param )
```

Query the value of an int-valued parameter.

**Arguments:**

**param:** The parameter being queried. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**Return value:**

The current value of the requested parameter.

```
String get ( GRB.StringParam param )
```

Query the value of a string-valued parameter.

**Arguments:**

**param:** The parameter being queried. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**Return value:**

The current value of the requested parameter.

### GRBEnv.getErrorMsg()

Query the error message for the most recent exception associated with this environment.

```
String getErrorMsg ( )
```

**Return value:**

The error string.

### GRBEnv.getParamInfo()

Obtain information about a parameter.

```
void getParamInfo ( GRB.DoubleParam param,  
                   double[] info )
```

Obtain detailed information about a double parameter.

**Arguments:**

**param:** The parameter of interest. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**info:** The returned information. The result will contain four entries: the current value of the parameter, the minimum allowed value, the maximum allowed value, and the default value.

```
void getParamInfo ( GRB.IntParam param,  
                   int[] info )
```

Obtain detailed information about an integer parameter.

**Arguments:**

**param:** The parameter of interest. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**info:** The returned information. The result will contain four entries: the current value of the parameter, the minimum allowed value, the maximum allowed value, and the default value.

```
void getParamInfo ( GRB.StringParam param,  
                   String[] info )
```

Obtain detailed information about a string parameter.

**Arguments:**

**param:** The parameter of interest. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**info:** The returned information. The result will contain two entries: the current value of the parameter and the default value.

## GRBEnv.message()

Write a message to the console and the log file.

```
void message ( String message )
```

**Arguments:**

**message:** Print a message to the console and to the log file. Note that this call has no effect unless the `OutputFlag` parameter is set.

## GRBEnv.readParams()

Read new parameter settings from a file.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

```
void readParams ( String paramfile )
```

**Arguments:**

**paramfile:** Name of the file containing parameter settings. Parameters should be listed one per line, with the parameter name first and the desired value second. For example:

```
# Gurobi parameter file  
Threads 1  
MIPGap 0
```

Blank lines and lines that begin with the hash symbol are ignored.

## GRBEnv.release()

Release the license associated with this environment. You will no longer be able to call [optimize](#) on models created with this environment after the license has been released.

```
void release ( )
```

## GRBEnv.resetParams()

Reset all parameters to their default values.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

```
| void resetParams ( )
```

## GRBEnv.set()

Set the value of a parameter.

### Important notes:

Note that a model gets its own copy of the environment when it is created. Changes to the original environment have no effect on the copy. Use [GRBModel.set](#) to change a parameter on an existing model.

```
| void set ( GRB.DoubleParam param,  
            double          newvalue )
```

Set the value of a double-valued parameter.

### Arguments:

**param:** The parameter being modified. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

```
| void set ( GRB.IntParam  param,  
            int           newvalue )
```

Set the value of an int-valued parameter.

### Arguments:

**param:** The parameter being modified. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

```
| void set ( GRB.StringParam param,  
            String          newvalue )
```

Set the value of a string-valued parameter.

### Arguments:

**param:** The parameter being modified. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

```
void set ( String param,  
          String newvalue )
```

Set the value of any parameter using strings alone.

**Arguments:**

**param:** The name of the parameter being modified. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

## GRBEnv.writeParams()

Write all non-default parameter settings to a file.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

```
void writeParams ( String paramfile )
```

**Arguments:**

**paramfile:** Name of the file to which non-default parameter settings should be written. The previous contents are overwritten.

## 4.2 GRBModel

Gurobi model object. Commonly used methods include [addVar](#) (adds a new decision variable to the model), [addConstr](#) (adds a new constraint to the model), [optimize](#) (optimizes the current model), and [get](#) (retrieves the value of an attribute).

While the Java garbage collector will eventually collect an unused `GRBModel` object, the vast majority of the memory associated with a model is stored outside of the Java heap. As a result, the garbage collector can't see this memory usage, and thus it can't take this quantity into account when deciding whether collection is necessary. We recommend that you call [GRBModel.dispose](#) when you are done using a model.

### GRBModel()

Constructor for `GRBModel`. The simplest version creates an empty model. You can then call [addVar](#) and [addConstr](#) to populate the model with variables and constraints. The more complex constructors can read a model from a file, or make a copy of an existing model.

```
| GRBModel GRBModel ( GRBEnv env )
```

Model constructor.

**Arguments:**

`env`: Environment for new model.

**Return value:**

New model object. Model initially contains no variables or constraints.

```
| GRBModel GRBModel ( GRBEnv env,  
                      String filename )
```

Read a model from a file. Note that the type of the file is encoded in the file name suffix. Valid suffixes are `.mps`, `.rew`, `.lp`, `.rlp`, `.ilp`, or `.opb`. The files can be compressed, so additional suffixes of `.zip`, `.gz`, `.bz2`, or `.7z` are accepted.

**Arguments:**

`env`: Environment for new model.

`modelName`: Name of the file containing the model.

**Return value:**

New model object.

```
| GRBModel GRBModel ( GRBModel model )
```

Create a copy of an existing model.

**Arguments:**

`model`: Model to copy.

**Return value:**

New model object. Model is a clone of the input model.

## GRBModel.addConstr()

Add a single linear constraint to a model. Multiple signatures are available.

```
GRBConstr addConstr ( GRBLinExpr lhsExpr,  
                      char         sense,  
                      GRBLinExpr rhsExpr,  
                      String       name )
```

Add a single linear constraint to a model.

### Arguments:

**lhsExpr**: Left-hand side expression for new linear constraint.

**sense**: Sense for new linear constraint (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhsExpr**: Right-hand side expression for new linear constraint.

**name**: Name for new constraint.

### Return value:

New constraint object.

```
GRBConstr addConstr ( GRBLinExpr lhsExpr,  
                      char         sense,  
                      GRBVar       rhsVar,  
                      String       name )
```

Add a single linear constraint to a model.

### Arguments:

**lhsExpr**: Left-hand side expression for new linear constraint.

**sense**: Sense for new linear constraint (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhsVar**: Right-hand side variable for new linear constraint.

**name**: Name for new constraint.

### Return value:

New constraint object.

```
GRBConstr addConstr ( GRBLinExpr lhsExpr,  
                      char         sense,  
                      double       rhsVal,  
                      String       name )
```

Add a single linear constraint to a model.

### Arguments:

**lhsExpr**: Left-hand side expression for new linear constraint.

**sense**: Sense for new linear constraint (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhsVal**: Right-hand side value for new linear constraint.

**name**: Name for new constraint.

### Return value:

New constraint object.

```
GRBConstr addConstr ( GRBVar    lhsVar,  
                      char      sense,  
                      GRBLinExpr rhsExpr,  
                      String     name )
```

Add a single linear constraint to a model.

**Arguments:**

**lhsVar:** Left-hand side variable for new linear constraint.

**sense:** Sense for new linear constraint (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhsExpr:** Right-hand side expression for new linear constraint.

**name:** Name for new constraint.

**Return value:**

New constraint object.

```
GRBConstr addConstr ( GRBVar lhsVar,  
                      char    sense,  
                      GRBVar  rhsVar,  
                      String   name )
```

Add a single linear constraint to a model.

**Arguments:**

**lhsVar:** Left-hand side variable for new linear constraint.

**sense:** Sense for new linear constraint (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhsVar:** Right-hand side variable for new linear constraint.

**name:** Name for new constraint.

**Return value:**

New constraint object.

```
GRBConstr addConstr ( GRBVar lhsVar,  
                      char    sense,  
                      double  rhsVal,  
                      String   name )
```

Add a single linear constraint to a model.

**Arguments:**

**lhsVar:** Left-hand side variable for new linear constraint.

**sense:** Sense for new linear constraint (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhsVal:** Right-hand side value for new linear constraint.

**name:** Name for new constraint.

**Return value:**

New constraint object.

```
GRBConstr addConstr ( double lhsVal,  
                      char   sense,  
                      GRBVar  rhsVar,  
                      String  name )
```

Add a single linear constraint to a model.

**Arguments:**

**lhsVal:** Left-hand side value for new linear constraint.

**sense:** Sense for new linear constraint (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhsVar:** Right-hand side variable for new linear constraint.

**name:** Name for new constraint.

**Return value:**

New constraint object.

```
GRBConstr addConstr ( double   lhsVal,  
                      char     sense,  
                      GRBLinExpr rhsExpr,  
                      String    name )
```

Add a single linear constraint to a model.

**Arguments:**

**lhsVal:** Left-hand side value for new linear constraint.

**sense:** Sense for new linear constraint (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhsExpr:** Right-hand side expression for new linear constraint.

**name:** Name for new constraint.

**Return value:**

New constraint object.

## GRBModel.addConstrs()

Add new linear constraints to a model.

We recommend that you build your model one constraint at a time (using [addConstr](#)), since it introduces no significant overhead and we find that it produces simpler code. Feel free to use these methods if you disagree, though.

```
GRBConstr[] addConstrs ( int count )
```

Add count new linear constraints to a model. The new constraints are all of the form  $0 \leq 0$ .

**Arguments:**

**count:** Number of constraints to add.

**Return value:**

Array of new constraint objects.

```
GRBConstr[] addConstrs ( GRBLinExpr[] lhsExprs,
                        char[] senses,
                        double[] rhsVals,
                        String[] names )
```

Add new linear constraints to a model. The number of added constraints is determined by the length of the input arrays (which must be consistent across all arguments).

**Arguments:**

**lhsExprs:** Left-hand side expressions for the new linear constraints.

**senses:** Senses for new linear constraints (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhsVals:** Right-hand side values for the new linear constraints.

**names:** Names for new constraints.

**Return value:**

Array of new constraint objects.

```
GRBConstr[] addConstrs ( GRBLinExpr[] lhsExprs,
                        char[] senses,
                        GRBLinExpr[] rhsExprs,
                        int start,
                        int len,
                        String[] names )
```

Add new linear constraints to a model. This signature allows you to use arrays to hold the various constraint attributes (left-hand side, sense, etc.), without forcing you to add one constraint for each entry in the array. The **start** and **len** arguments allow you to specify which constraints to add.

**Arguments:**

**lhsExprs:** Left-hand side expressions for the new linear constraints.

**senses:** Senses for new linear constraints (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhs:** Right-hand side expressions for the new linear constraints.

**start:** The first constraint in the list to add.

**len:** The number of variables to add.

**names:** Names for new constraints.

**Return value:**

Array of new constraint objects.

## GRBModel.addGenConstrXxx()

Each of the functions described below adds a new *general constraint* to a model.

Mathematical programming has traditionally defined a set of fundamental constraint types: variable bound constraints, linear constraints, quadratic constraints, integrality constraints, and SOS constraints. These are typically treated directly by the underlying solver (although not always), and are fundamental to the overall algorithm.

Gurobi accepts a number of additional constraint types, which we collectively refer to as *general constraints*. These are typically *not* treated directly by the solver. Rather, they are transformed

by presolve into mathematically equivalent sets of constraints (and variables), chosen from among the fundamental types listed above. These general constraints are provided as a convenience to users. If such constraints appear in your model, but if you prefer to reformulate them yourself using fundamental constraint types instead, you can certainly do so. However, note that Gurobi can sometimes exploit information contained in the other constraints in the model to build a more efficient formulation than what you might create.

The additional constraint types that fall under this *general constraint* umbrella are:

- MAX ([addGenConstrMax](#)): set a decision variable equal to the maximum value from among a set of decision variables
- MIN ([addGenConstrMin](#)): set a decision variable equal to the minimum value from among a set of decision variables
- ABS ([addGenConstrAbs](#)): set a decision variable equal to the absolute value of some other decision variable
- AND ([addGenConstrAnd](#)): set a binary variable equal to one if and only if all of a set of binary decision variables are equal to one
- OR ([addGenConstrOr](#)): set a binary variable equal to one if and only if at least one variable out of a set of binary decision variables is equal to one
- INDICATOR ([addGenConstrIndicator](#)): a given binary variable may only take a certain value if a given linear constraint is satisfied

Please refer to [this section](#) for additional details on general constraints.

### **GRBModel.addGenConstrMax()**

Add a new general constraint of type `GRB.GENCONSTR_MAX` to a model.

A MAX constraint  $r = \max\{x_1, \dots, x_n, c\}$  states that the resultant variable  $r$  should be equal to the maximum of the operand variables  $x_1, \dots, x_n$  and the constant  $c$ .

```
GRBGenConstr addGenConstrMax ( GRBVar    resvar,  
                               GRBVar[]  vars,  
                               double     constant,  
                               String     name )
```

#### **Arguments:**

**resvar:** The resultant variable of the new constraint.

**vars:** Array of variables that are the operands of the new constraint.

**constant:** The additional constant operand of the new constraint.

**name:** Name for the new general constraint.

#### **Return value:**

New general constraint.

### GRBModel.addGenConstrMin()

Add a new general constraint of type `GRB.GENCONSTR_MIN` to a model.

A MIN constraint  $r = \min\{x_1, \dots, x_n, c\}$  states that the resultant variable  $r$  should be equal to the minimum of the operand variables  $x_1, \dots, x_n$  and the constant  $c$ .

```
GRBGenConstr addGenConstrMin ( GRBVar  resvar,  
                               GRBVar[] vars,  
                               double   constant,  
                               String   name )
```

#### Arguments:

**resvar:** The resultant variable of the new constraint.

**vars:** Array of variables that are the operands of the new constraint.

**constant:** The additional constant operand of the new constraint.

**name:** Name for the new general constraint.

#### Return value:

New general constraint.

### GRBModel.addGenConstrAbs()

Add a new general constraint of type `GRB.GENCONSTR_ABS` to a model.

An ABS constraint  $r = \text{abs}\{x\}$  states that the resultant variable  $r$  should be equal to the absolute value of the argument variable  $x$ .

```
GRBGenConstr addGenConstrAbs ( GRBVar  resvar,  
                               GRBVar  argvar,  
                               String   name )
```

#### Arguments:

**resvar:** The resultant variable of the new constraint.

**argvar:** The argument variable of the new constraint.

**name:** Name for the new general constraint.

#### Return value:

New general constraint.

### GRBModel.addGenConstrAnd()

Add a new general constraint of type `GRB.GENCONSTR_AND` to a model.

An AND constraint  $r = \text{and}\{x_1, \dots, x_n\}$  states that the binary resultant variable  $r$  should be 1 if and only if all of the operand variables  $x_1, \dots, x_n$  are equal to 1. If any of the operand variables is 0, then the resultant should be 0 as well.

Note that all variables participating in such a constraint will be forced to be binary; independently of how they were created.

```
GRBGenConstr addGenConstrAnd ( GRBVar  resvar,  
                               GRBVar[] vars,  
                               String   name )
```

**Arguments:**

- resvar:** The resultant variable of the new constraint.
- vars:** Array of variables that are the operands of the new constraint.
- name:** Name for the new general constraint.

**Return value:**

New general constraint.

**GRBModel.addGenConstrOr()**

Add a new general constraint of type `GRB.GENCONSTR_OR` to a model.

An OR constraint  $r = \text{or}\{x_1, \dots, x_n\}$  states that the binary resultant variable  $r$  should be 1 if and only if any of the operand variables  $x_1, \dots, x_n$  is equal to 1. If all operand variables are 0, then the resultant should be 0 as well.

Note that all variables participating in such a constraint will be forced to be binary; independently of how they were created.

```
GRBGenConstr addGenConstrOr ( GRBVar    resvar,
                              GRBVar[]  vars,
                              String     name )
```

**Arguments:**

- resvar:** The resultant variable of the new constraint.
- vars:** Array of variables that are the operands of the new constraint.
- name:** Name for the new general constraint.

**Return value:**

New general constraint.

**GRBModel.addGenConstrIndicator()**

Add a new general constraint of type `GRB.GENCONSTR_INDICATOR` to a model.

An INDICATOR constraint  $z = f \rightarrow a^T x \leq b$  states that if the binary indicator variable  $z$  is equal to  $f \in \{0, 1\}$ , then the linear constraint  $a^T x \leq b$  should hold. On the other hand, if  $z = 1 - f$ , the linear constraint may be violated. The sense of the linear constraint can also be specified to be  $=$  or  $\geq$ .

Note that the indicator variable  $z$  of a constraint will be forced to be binary; independently of how it was created.

```
GRBGenConstr addGenConstrIndicator ( GRBVar    binvar,
                                     int        binval,
                                     GRBLinExpr expr,
                                     char       sense,
                                     double     rhs,
                                     String     name )
```

**Arguments:**

- binvar:** The binary indicator variable.
- binval:** The value for the binary indicator variable that would force the linear constraint to be satisfied (0 or 1).

**expr:** Left-hand side expression for the linear constraint triggered by the indicator.  
**sense:** Sense for the linear constraint. Options are `GRB.LESS_EQUAL`, `GRB.EQUAL`, or `GRB.GREATER_EQUAL`.  
**rhs:** Right-hand-side value for the linear constraint.  
**name:** Name for the new general constraint.

**Return value:**

New general constraint.

## GRBModel.addQConstr()

Add a quadratic constraint to a model. Multiple signatures are available.

Important note: the algorithms that Gurobi uses to solve quadratically constrained problems can only handle certain types of quadratic constraints. Constraints of the following forms are always accepted:

- $x^T Q x + q^T x \leq b$ , where  $Q$  is Positive Semi-Definite (PSD)
- $x^T x \leq y^2$ , where  $x$  is a vector of variables, and  $y$  is a non-negative variable (a Second-Order Cone)
- $x^T x \leq yz$ , where  $x$  is a vector of variables, and  $y$  and  $z$  are non-negative variables (a rotated Second-Order Cone)

If you add a constraint that isn't in one of these forms (and Gurobi presolve is unable to transform the constraint into one of these forms), you'll get an error when you try to solve the model. Constraints where the quadratic terms only involve binary variables will always be transformed into one of these forms.

```
GRBQConstr addQConstr ( GRBQuadExpr lhsExpr,
                        char         sense,
                        GRBQuadExpr rhsExpr,
                        String        name )
```

Add a quadratic constraint to a model.

**Arguments:**

**lhsExpr:** Left-hand side quadratic expression for new quadratic constraint.  
**sense:** Sense for new quadratic constraint (`GRB.LESS_EQUAL` or `GRB.GREATER_EQUAL`).  
**rhsExpr:** Right-hand side quadratic expression for new quadratic constraint.  
**name:** Name for new constraint.

**Return value:**

New quadratic constraint object.

```
GRBQConstr addQConstr ( GRBQuadExpr lhsExpr,
                        char         sense,
                        GRBVar       rhsVar,
                        String        name )
```

Add a quadratic constraint to a model.

**Arguments:**

**lhsExpr:** Left-hand side quadratic expression for new quadratic constraint.  
**sense:** Sense for new quadratic constraint (GRB.LESS\_EQUAL or GRB.GREATER\_EQUAL).  
**rhsVar:** Right-hand side variable for new quadratic constraint.  
**name:** Name for new constraint.

**Return value:**

New quadratic constraint object.

```
GRBQConstr addQConstr ( GRBQuadExpr lhsExpr,
                       char          sense,
                       GRBLinExpr   rhsExpr,
                       String        name )
```

Add a quadratic constraint to a model.

**Arguments:**

**lhsExpr:** Left-hand side quadratic expression for new quadratic constraint.  
**sense:** Sense for new quadratic constraint (GRB.LESS\_EQUAL or GRB.GREATER\_EQUAL).  
**rhsExpr:** Right-hand side linear expression for new quadratic constraint.  
**name:** Name for new constraint.

**Return value:**

New quadratic constraint object.

```
GRBQConstr addQConstr ( GRBQuadExpr lhsExpr,
                       char          sense,
                       double         rhsVal,
                       String        name )
```

Add a quadratic constraint to a model.

**Arguments:**

**lhsExpr:** Left-hand side quadratic expression for new quadratic constraint.  
**sense:** Sense for new quadratic constraint (GRB.LESS\_EQUAL or GRB.GREATER\_EQUAL).  
**rhsVal:** Right-hand side value for new quadratic constraint.  
**name:** Name for new constraint.

**Return value:**

New quadratic constraint object.

```
GRBQConstr addQConstr ( GRBLinExpr  lhsExpr,
                       char          sense,
                       GRBQuadExpr   rhsExpr,
                       String        name )
```

Add a quadratic constraint to a model.

**Arguments:**

**lhsExpr:** Left-hand side linear expression for new quadratic constraint.  
**sense:** Sense for new quadratic constraint (GRB.LESS\_EQUAL or GRB.GREATER\_EQUAL).  
**rhsExpr:** Right-hand side quadratic expression for new quadratic constraint.  
**name:** Name for new constraint.

**Return value:**

New quadratic constraint object.

```
GRBQConstr addQConstr ( GRBVar      lhsVar,
                        char        sense,
                        GRBQuadExpr rhsExpr,
                        String       name )
```

Add a quadratic constraint to a model.

**Arguments:**

**lhsVar**: Left-hand side variable for new quadratic constraint.

**sense**: Sense for new quadratic constraint (`GRB.LESS_EQUAL` or `GRB.GREATER_EQUAL`).

**rhsExpr**: Right-hand side quadratic expression for new quadratic constraint.

**name**: Name for new constraint.

**Return value:**

New quadratic constraint object.

```
GRBQConstr addQConstr ( double     lhsVal,
                        char        sense,
                        GRBQuadExpr rhsExpr,
                        String       name )
```

Add a quadratic constraint to a model.

**Arguments:**

**lhsVal**: Left-hand side value for new quadratic constraint.

**sense**: Sense for new quadratic constraint (`GRB.LESS_EQUAL` or `GRB.GREATER_EQUAL`).

**rhsExpr**: Right-hand side quadratic expression for new quadratic constraint.

**name**: Name for new constraint.

**Return value:**

New quadratic constraint object.

**GRBModel.addRange()**

Add a single range constraint to a model. A range constraint states that the value of the input expression must be between the specified **lower** and **upper** bounds in any solution.

Note that range constraints are stored internally as equality constraints. We add an extra variable to the model to capture the range information. Thus, the [Sense](#) attribute on a range constraint will always be `GRB.EQUAL`.

```
GRBConstr addRange ( GRBLinExpr  expr,
                     double      lower,
                     double      upper,
                     String       name )
```

**Arguments:**

**expr**: Linear expression for new range constraint.

**lower**: Lower bound for linear expression.

**upper:** Upper bound for linear expression.  
**name:** Name for new constraint.

**Return value:**

New constraint object.

### GRBModel.addRanges()

Add new range constraints to a model. A range constraint states that the value of the input expression must be between the specified **lower** and **upper** bounds in any solution.

```
GRBConstr[] addRanges ( GRBLinExpr[] exprs,  
                        double[] lower,  
                        double[] upper,  
                        String[] names )
```

**Arguments:**

**exprs:** Linear expressions for the new range constraints.  
**lower:** Lower bounds for linear expressions.  
**upper:** Upper bounds for linear expressions.  
**name:** Names for new range constraints.  
**count:** Number of range constraints to add.

**Return value:**

Array of new constraint objects.

### GRBModel.addSOS()

Add an SOS constraint to the model. Please refer to [this section](#) for details on SOS constraints.

```
GRBSOS addSOS ( GRBVar[] vars,  
                double[] weights,  
                int type )
```

**Arguments:**

**vars:** Array of variables that participate in the SOS constraint.  
**weights:** Weights for the variables in the SOS constraint.  
**type:** SOS type (can be `GRB.SOS_TYPE1` or `GRB.SOS_TYPE2`).

**Return value:**

New SOS constraint.

### GRBModel.addVar()

Add a single decision variable to a model.

```
GRBVar addVar ( double lb,  
                double ub,  
                double obj,  
                char type,  
                String name )
```

Add a variable to a model; non-zero entries will be added later.

**Arguments:**

- lb:** Lower bound for new variable.
- ub:** Upper bound for new variable.
- obj:** Objective coefficient for new variable.
- type:** Variable type for new variable (GRB.CONTINUOUS, GRB.BINARY, GRB.INTEGER, GRB.SEMICONT, or GRB.SEMIINT).
- name:** Name for new variable.

**Return value:**

New variable object.

```
GRBVar addVar ( double lb,
                double ub,
                double obj,
                char type,
                GRBConstr[] constrs,
                double[] coeffs,
                String name )
```

Add a variable to a model, and the associated non-zero coefficients.

**Arguments:**

- lb:** Lower bound for new variable.
- ub:** Upper bound for new variable.
- obj:** Objective coefficient for new variable.
- type:** Variable type for new variable (GRB.CONTINUOUS, GRB.BINARY, GRB.INTEGER, GRB.SEMICONT, or GRB.SEMIINT).
- constrs:** Array of constraints in which the variable participates.
- coeffs:** Array of coefficients for each constraint in which the variable participates. The lengths of the **constrs** and **coeffs** arrays must be identical.
- name:** Name for new variable.

**Return value:**

New variable object.

```
GRBVar addVar ( double lb,
                double ub,
                double obj,
                char type,
                GRBColumn col,
                String name )
```

Add a variable to a model. This signature allows you to specify the set of constraints to which the new variable belongs using a [GRBColumn](#) object.

**Arguments:**

- lb:** Lower bound for new variable.
- ub:** Upper bound for new variable.
- obj:** Objective coefficient for new variable.

**type:** Variable type for new variable (GRB.CONTINUOUS, GRB.BINARY, GRB.INTEGER, GRB.SEMICONT, or GRB.SEMIINT).  
**col:** GRBColumn object for specifying a set of constraints to which new variable belongs.  
**name:** Name for new variable.

**Return value:**

New variable object.

## GRBModel.addVars()

Add new decision variables to a model.

```
GRBVar[] addVars ( int count,  
                  char type )
```

Add `count` new decision variables to a model. All associated attributes take their default values, except the variable `type`, which is specified as an argument.

**Arguments:**

**count:** Number of variables to add.

**type:** Variable type for new variables (GRB.CONTINUOUS, GRB.BINARY, GRB.INTEGER, GRB.SEMICONT, or GRB.SEMIINT).

**Return value:**

Array of new variable objects.

```
GRBVar[] addVars ( double[] lb,  
                  double[] ub,  
                  double[] obj,  
                  char[] type,  
                  String[] names )
```

Add new decision variables to a model. The number of added variables is determined by the length of the input arrays (which must be consistent across all arguments).

**Arguments:**

**lb:** Lower bounds for new variables. Can be `null`, in which case the variables get lower bounds of 0.0.

**ub:** Upper bounds for new variables. Can be `null`, in which case the variables get infinite upper bounds.

**obj:** Objective coefficients for new variables. Can be `null`, in which case the variables get objective coefficients of 0.0.

**type:** Variable types for new variables (GRB.CONTINUOUS, GRB.BINARY, GRB.INTEGER, GRB.SEMICONT, or GRB.SEMIINT). Can be `null`, in which case the variables are assumed to be continuous.

**names:** Names for new variables. Can be `null`, in which case all variables are given default names.

**Return value:**

Array of new variable objects.

```
GRBVar[] addVars ( double[] lb,
                  double[] ub,
                  double[] obj,
                  char[] type,
                  String[] names,
                  int start,
                  int len )
```

Add new decision variables to a model. This signature allows you to use arrays to hold the various variable attributes (lower bound, upper bound, etc.), without forcing you to add a variable for each entry in the array. The `start` and `len` arguments allow you to specify which variables to add.

**Arguments:**

- lb:** Lower bounds for new variables. Can be `null`, in which case the variables get lower bounds of 0.0.
- ub:** Upper bounds for new variables. Can be `null`, in which case the variables get infinite upper bounds.
- obj:** Objective coefficients for new variables. Can be `null`, in which case the variables get objective coefficients of 0.0.
- type:** Variable types for new variables (`GRB.CONTINUOUS`, `GRB.BINARY`, `GRB.INTEGER`, `GRB.SEMICONT`, or `GRB.SEMIINT`). Can be `null`, in which case the variables are assumed to be continuous.
- names:** Names for new variables. Can be `null`, in which case all variables are given default names.
- start:** The first variable in the list to add.
- len:** The number of variables to add.

**Return value:**

Array of new variable objects.

```
GRBVar[] addVars ( double[] lb,
                  double[] ub,
                  double[] obj,
                  char[] type,
                  String[] names,
                  GRBColumn[] col )
```

Add new decision variables to a model. This signature allows you to specify the list of constraints to which each new variable belongs using an array of [GRBColumn](#) objects.

**Arguments:**

- lb:** Lower bounds for new variables. Can be `null`, in which case the variables get lower bounds of 0.0.
- ub:** Upper bounds for new variables. Can be `null`, in which case the variables get infinite upper bounds.
- obj:** Objective coefficients for new variables. Can be `null`, in which case the variables get objective coefficients of 0.0.
- type:** Variable types for new variables (`GRB.CONTINUOUS`, `GRB.BINARY`, `GRB.INTEGER`, `GRB.SEMICONT`, or `GRB.SEMIINT`). Can be `null`, in which case the variables are assumed

to be continuous.

**names:** Names for new variables. Can be `null`, in which case all variables are given default names.

**cols:** `GRBColumn` objects for specifying a set of constraints to which each new column belongs.

**Return value:**

Array of new variable objects.

## **GRBModel.chgCoeff()**

Change one coefficient in the model. The desired change is captured using a `GRBVar` object, a `GRBConstr` object, and a desired coefficient for the specified variable in the specified constraint. If you make multiple changes to the same coefficient, the last one will be applied.

Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using `GRBModel.update`), optimize the model (using `GRBModel.optimize`), or write the model to disk (using `GRBModel.write`).

```
void chgCoeff ( GRBConstr  constr,  
                GRBVar    var,  
                double    newvalue )
```

**Arguments:**

**constr:** Constraint for coefficient to be changed.

**var:** Variable for coefficient to be changed.

**newvalue:** Desired new value for coefficient.

## **GRBModel.chgCoeffs()**

Change a list of coefficients in the model. Each desired change is captured using a `GRBVar` object, a `GRBConstr` object, and a desired coefficient for the specified variable in the specified constraint. The entries in the input arrays each correspond to a single desired coefficient change. The lengths of the input arrays must all be the same. If you make multiple changes to the same coefficient, the last one will be applied.

Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using `GRBModel.update`), optimize the model (using `GRBModel.optimize`), or write the model to disk (using `GRBModel.write`).

```
void chgCoeffs ( GRBConstr[]  constrs,  
                 GRBVar[]    vars,  
                 double[]    vals )
```

**Arguments:**

**constrs:** Constraints for coefficients to be changed.

**vars:** Variables for coefficients to be changed.

**vals:** Desired new values for coefficients.

## GRBModel.computeIIS()

Compute an Irreducible Inconsistent Subsystem (IIS). An IIS is a subset of the constraints and variable bounds of the original model. If all constraints in the model except those in the IIS are removed, the model is still infeasible. However, further removing any one member of the IIS produces a feasible result.

This method populates the `IISCONSTR`, `IISQCONSTR`, and `IISGENCONSTR` constraint attributes, the `IISOS` SOS attribute, and the `IISLB`, and `IISUB` variable attributes. You can also obtain information about the results of the IIS computation by writing a `.ilp` format file (see [GRBModel.write](#)). This file contains only the IIS from the original model.

Note that this method can be used to compute IISs for both continuous and MIP models.

```
| void computeIIS ( )
```

## GRBModel.discardConcurrentEnvs()

Discard concurrent environments for a model.

The concurrent environments created by [getConcurrentEnv](#) will be used by every subsequent call to the concurrent optimizer until the concurrent environments are discarded.

```
| void discardConcurrentEnvs ( )
```

## GRBModel.dispose()

Release the resources associated with a `GRBModel` object. While the Java garbage collector will eventually reclaim these resources, we recommend that you call the `dispose` method when you are done using a model.

You should not attempt to use a `GRBModel` object after calling `dispose` on it.

```
| void dispose ( )
```

## GRBModel.feasRelax()

Modifies the `GRBModel` object to create a feasibility relaxation. Note that you need to call [optimize](#) on the result to compute the actual relaxed solution.

The feasibility relaxation is a model that, when solved, minimizes the amount by which the solution violates the bounds and linear constraints of the original model. This method provides a number of options for specifying the relaxation.

If you specify `relaxobjtype=0`, the objective of the feasibility relaxation is to minimize the sum of the weighted magnitudes of the bound and constraint violations. The `lbpn`, `ubpn`, and `rhspn` arguments specify the cost per unit violation in the lower bounds, upper bounds, and linear constraints, respectively.

If you specify `relaxobjtype=1`, the objective of the feasibility relaxation is to minimize the weighted sum of the squares of the bound and constraint violations. The `lbpn`, `ubpn`, and

`rhspen` arguments specify the coefficients on the squares of the lower bound, upper bound, and linear constraint violations, respectively.

If you specify `relaxobjtype=2`, the objective of the feasibility relaxation is to minimize the weighted count of bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the cost of violating a lower bound, upper bound, and linear constraint, respectively.

To give an example, if a constraint with `rhspen` value `p` is violated by 2.0, it would contribute  $2 * p$  to the feasibility relaxation objective for `relaxobjtype=0`, it would contribute  $2 * 2 * p$  for `relaxobjtype=1`, and it would contribute `p` for `relaxobjtype=2`.

The `minrelax` argument is a boolean that controls the type of feasibility relaxation that is created. If `minrelax=false`, optimizing the returned model gives a solution that minimizes the cost of the violation. If `minrelax=true`, optimizing the returned model finds a solution that minimizes the original objective, but only from among those solutions that minimize the cost of the violation. Note that `feasRelax` must solve an optimization problem to find the minimum possible relaxation when `minrelax=true`, which can be quite expensive.

There are two signatures for this method. The more complex one takes a list of variables and constraints, as well as penalties associated with relaxing the corresponding lower bounds, upper bounds, and constraints. If a variable or constraint is not included in one of these lists, the associated bounds or constraints may not be violated. The simpler signature takes a pair of boolean arguments, `vrelax` and `crelax`, that indicate whether variable bounds and/or constraints can be violated. If `vrelax/crelax` is `true`, then every bound/constraint is allowed to be violated, respectively, and the associated cost is 1.0.

Note that this is a destructive method: it modifies the model on which it is invoked. If you don't want to modify your original model, use the [GRBModel constructor](#) to create a copy before invoking this method.

```
double feasRelax ( int      relaxobjtype,
                  boolean   minrelax,
                  GRBVar[]  vars,
                  double[]   lbpen,
                  double[]   ubpen,
                  GRBConstr[] constr,
                  double[]   rhspen )
```

Create a feasibility relaxation model.

**Arguments:**

**relaxobjtype:** The cost function used when finding the minimum cost relaxation.

**minrelax:** The type of feasibility relaxation to perform.

**vars:** Variables whose bounds are allowed to be violated.

**lbpen:** Penalty for violating a variable lower bound. One entry for each variable in argument `vars`.

**ubpen:** Penalty for violating a variable upper bound. One entry for each variable in argument `vars`.

**constr:** Linear constraints that are allowed to be violated.

**rhspen:** Penalty for violating a linear constraint. One entry for each variable in argument `constr`.

**Arguments:**

**Return value:**

Zero if `minrelax` is false. If `minrelax` is true, the return value is the objective value for the relaxation performed. If the value is less than 0, it indicates that the method failed to create the feasibility relaxation.

```
double feasRelax ( int      relaxobjtype,
                  boolean  minrelax,
                  boolean  vrelax,
                  boolean  crelax )
```

Simplified method for creating a feasibility relaxation model.

**Arguments:**

**relaxobjtype:** The cost function used when finding the minimum cost relaxation.

**minrelax:** The type of feasibility relaxation to perform.

**vrelax:** Indicates whether variable bounds can be relaxed (with a cost of 1.0 for any violations).

**crelax:** Indicates whether linear constraints can be relaxed (with a cost of 1.0 for any violations).

**Return value:**

Zero if `minrelax` is false. If `minrelax` is true, the return value is the objective value for the relaxation performed. If the value is less than 0, it indicates that the method failed to create the feasibility relaxation.

**GRBModel.fixedModel()**

Create the fixed model associated with a MIP model. The MIP model must have a solution loaded (e.g., after a call to the [optimize](#) method). In the fixed model, each integer variable is fixed to the value that variable takes in the MIP solution.

```
GRBModel fixedModel ( )
```

**Return value:**

Fixed model associated with calling object.

**GRBModel.get()**

Query the value(s) of a parameter or attribute. Use this method for parameters, for scalar model attributes, and for arrays of constraint or variable attributes.

```
double get ( GRB.DoubleParam param )
```

Query the value of a double-valued parameter.

**Arguments:**

**param:** The parameter being queried.

**Return value:**

The current value of the requested parameter.

```
int get ( GRB.IntParam param )
```

Query the value of an int-valued parameter.

**Arguments:**

**param:** The parameter being queried.

**Return value:**

The current value of the requested parameter.

```
String get ( GRB.StringParam param )
```

Query the value of a string-valued parameter.

**Arguments:**

**param:** The parameter being queried.

**Return value:**

The current value of the requested parameter.

```
char [] get ( GRB.CharAttr attr,  
             GRBVar [] vars )
```

Query a char-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** The variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
char [] get ( GRB.CharAttr attr,  
             GRBVar [] vars,  
             int start,  
             int len )
```

Query a char-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A one-dimensional array of variables whose attribute values are being queried.

**start:** The index of the first variable of interest in the list.

**len:** The number of variables.

**Return value:**

The current values of the requested attribute for each input variable.

```
char [] [] get ( GRB.CharAttr attr,  
               GRBVar [] [] vars )
```

Query a char-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A two-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
char [] [] [] get ( GRB.CharAttr attr,  
                  GRBVar [] [] [] vars )
```

Query a char-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A three-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
char [] get ( GRB.CharAttr attr,  
             GRBConstr [] constrs )
```

Query a char-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** The constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
char [] get ( GRB.CharAttr attr,  
             GRBConstr [] constrs,  
             int start,  
             int len )
```

Query a char-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A one-dimensional array of constraints whose attribute values are being queried.

**start:** The index of the first constraint of interest in the list.

**len:** The number of constraints.

**Return value:**

The current values of the requested attribute for each input constraint.

```
char [] [] get ( GRB.CharAttr attr,  
               GRBConstr [] [] constrs )
```

Query a char-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A two-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
char [] [] [] get ( GRB.CharAttr attr,  
                  GRBConstr [] [] [] constrs )
```

Query a char-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A three-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
char [] get ( GRB.CharAttr attr,  
             GRBQConstr [] qconstrs )
```

Query a char-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** The quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
char [] get ( GRB.CharAttr attr,  
             GRBQConstr [] qconstrs,  
             int start,  
             int len )
```

Query a char-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being queried.

**start:** The index of the first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
char [] [] get ( GRB.CharAttr attr,  
               GRBQConstr [] [] qconstrs )
```

Query a char-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
char [] [] [] get ( GRB.CharAttr attr,  
                  GRBQConstr [] [] [] qconstrs )
```

Query a char-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
double get ( GRB.DoubleAttr attr )
```

Query the value of a double-valued model attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
double[] get ( GRB.DoubleAttr attr,  
              GRBVar [] vars )
```

Query a double-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** The variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
double[] get ( GRB.DoubleAttr attr,  
              GRBVar [] vars,  
              int start,  
              int len )
```

Query a double-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A one-dimensional array of variables whose attribute values are being queried.

**start:** The index of the first variable of interest in the list.

**len:** The number of variables.

**Return value:**

The current values of the requested attribute for each input variable.

```
double [] [] get ( GRB.DoubleAttr attr,  
                  GRBVar [] [] vars )
```

Query a double-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A two-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
double[] [] [] get ( GRB.DoubleAttr attr,  
                    GRBVar[] [] [] vars )
```

Query a double-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A three-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
double[] get ( GRB.DoubleAttr attr,  
              GRBConstr[] constrs )
```

Query a double-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** The constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
double[] get ( GRB.DoubleAttr attr,  
              GRBConstr[] constrs,  
              int start,  
              int len )
```

Query a double-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A one-dimensional array of constraints whose attribute values are being queried.

**start:** The first constraint of interest in the list.

**len:** The number of constraints.

**Return value:**

The current values of the requested attribute for each input constraint.

```
double[] [] get ( GRB.DoubleAttr attr,  
                 GRBConstr[] [] constrs )
```

Query a double-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A two-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
double[] [] [] get ( GRB.DoubleAttr attr,  
                    GRBConstr[] [] constrs )
```

Query a double-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A three-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
double[] get ( GRB.DoubleAttr attr,  
              GRBQConstr[] qconstrs )
```

Query a double-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** The quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
double[] get ( GRB.DoubleAttr attr,  
              GRBQConstr[] qconstrs,  
              int start,  
              int len )
```

Query a double-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being queried.

**start:** The first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
double[] [] get ( GRB.DoubleAttr attr,  
                 GRBQConstr[] [] qconstrs )
```

Query a double-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
double[] [] [] get ( GRB.DoubleAttr attr,
                    GRBQConstr[] [] [] qconstrs )
```

Query a double-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
int get ( GRB.IntAttr attr )
```

Query the value of an int-valued model attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
int[] get ( GRB.IntAttr attr,
            GRBVar[] vars )
```

Query an int-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** The variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
int[] get ( GRB.IntAttr attr,
            GRBVar[] vars,
            int start,
            int len )
```

Query an int-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A one-dimensional array of variables whose attribute values are being queried.

**start:** The index of the first variable of interest in the list.

**len:** The number of variables.

**Return value:**

The current values of the requested attribute for each input variable.

```
int[] [] get ( GRB.IntAttr attr,
               GRBVar[] [] vars )
```

Query an int-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A two-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
int[] [] [] get ( GRB.IntAttr attr,
                  GRBVar[] [] [] vars )
```

Query an int-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A three-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
int[] get ( GRB.IntAttr attr,
            GRBConstr[] constrs )
```

Query an int-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** The constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
int[] get ( GRB.IntAttr attr,
            GRBConstr[] constrs,
            int start,
            int len )
```

Query an int-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A one-dimensional array of constraints whose attribute values are being queried.

**start:** The index of the first constraint of interest in the list.

**len:** The number of constraints.

**Return value:**

The current values of the requested attribute for each input constraint.

```
int[] [] get ( GRB.IntAttr attr,
               GRBConstr[] [] constrs )
```

Query an int-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A two-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
int[] [] [] get ( GRB.IntAttr attr,
                 GRBConstr[] [] [] constrs )
```

Query an int-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A three-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
int[] get ( GRB.IntAttr attr,
            GRBQConstr[] qconstrs )
```

Query an int-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** The quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
int[] get ( GRB.IntAttr attr,
            GRBQConstr[] qconstrs,
            int start,
            int len )
```

Query an int-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being queried.

**start:** The index of the first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
int[] [] get ( GRB.IntAttr attr,
              GRBQConstr[] [] qconstrs )
```

Query an int-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
int[] [] [] get ( GRB.IntAttr attr,  
                 GRBQConstr[] [] qconstrs )
```

Query an int-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
int[] get ( GRB.IntAttr attr,  
            GRBGenConstr[] genconstrs )
```

Query an int-valued general constraint attribute for an array of general constraints.

**Arguments:**

**attr:** The attribute being queried.

**genconstrs:** The general constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input general constraint.

```
int[] get ( GRB.IntAttr attr,  
            GRBGenConstr[] genconstrs,  
            int start,  
            int len )
```

Query an int-valued general constraint attribute for a sub-array of general constraints.

**Arguments:**

**attr:** The attribute being queried.

**genconstrs:** A one-dimensional array of general constraints whose attribute values are being queried.

**start:** The index of the first general constraint of interest in the list.

**len:** The number of general constraints.

**Return value:**

The current values of the requested attribute for each input general constraint.

```
int[] [] get ( GRB.IntAttr attr,  
              GRBGenConstr[] [] genconstrs )
```

Query an int-valued general constraint attribute for a two-dimensional array of general constraints.

**Arguments:**

**attr:** The attribute being queried.

**genconstrs:** A two-dimensional array of general constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input general constraint.

```
int[] [] [] get ( GRB.IntAttr      attr,
                  GRBGenConstr[] [] genconstrs )
```

Query an int-valued general constraint attribute for a three-dimensional array of general constraints.

**Arguments:**

**attr:** The attribute being queried.

**genconstrs:** A three-dimensional array of general constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input general constraint.

```
String get ( GRB.StringAttr attr )
```

Query the value of a string-valued model attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
String[] get ( GRB.StringAttr attr,
               GRBVar[]      vars )
```

Query a String-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** The variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
String[] get ( GRB.StringAttr attr,
               GRBVar[]      vars,
               int           start,
               int           len )
```

Query a String-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A one-dimensional array of variables whose attribute values are being queried.

**start:** The index of the first variable of interest in the list.

**len:** The number of variables.

**Return value:**

The current values of the requested attribute for each input variable.

```
String[] [] get ( GRB.StringAttr attr,  
                 GRBVar [] [] vars )
```

Query a String-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A two-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
String[] [] [] get ( GRB.StringAttr attr,  
                   GRBVar [] [] [] vars )
```

Query a String-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A three-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
String[] get ( GRB.StringAttr attr,  
              GRBConstr [] constrs )
```

Query a String-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** The constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
String[] get ( GRB.StringAttr attr,  
              GRBConstr [] constrs,  
              int start,  
              int len )
```

Query a String-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A one-dimensional array of constraints whose attribute values are being queried.

**start:** The index of the first constraint of interest in the list.

**len:** The number of constraints.

**Return value:**

The current values of the requested attribute for each input constraint.

```
String[] [] get ( GRB.StringAttr attr,  
                 GRBConstr[] []  constrs )
```

Query a String-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A two-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
String[] [] [] get ( GRB.StringAttr attr,  
                   GRBConstr[] [] [] constrs )
```

Query a String-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A three-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
String[] get ( GRB.StringAttr attr,  
              GRBQConstr[]   qconstrs )
```

Query a String-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** The quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
String[] get ( GRB.StringAttr attr,  
              GRBQConstr[]   qconstrs,  
              int             start,  
              int             len )
```

Query a String-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being queried.

**start:** The index of the first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
String[] [] get ( GRB.StringAttr attr,  
                 GRBQConstr[] [] qconstrs )
```

Query a String-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
String[] [] [] get ( GRB.StringAttr attr,  
                   GRBQConstr[] [] [] qconstrs )
```

Query a String-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
String[] get ( GRB.StringAttr attr,  
              GRBGenConstr[] genconstrs )
```

Query a String-valued general constraint attribute for an array of general constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** The general constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input general constraint.

```
String[] get ( GRB.StringAttr attr,  
              GRBGenConstr[] genconstrs,  
              int start,  
              int len )
```

Query a String-valued general constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A one-dimensional array of general constraints whose attribute values are being queried.

**start:** The index of the first general constraint of interest in the list.

**len:** The number of general constraints.

**Return value:**

The current values of the requested attribute for each input general constraint.

```
String[] [] get ( GRB.StringAttr attr,  
                 GRBGenConstr[] [] genconstrs )
```

Query a String-valued constraint attribute for a two-dimensional array of general constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A two-dimensional array of general constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input general constraint.

```
String[] [] [] get ( GRB.StringAttr attr,  
                   GRBConstr[] [] [] constrs )
```

Query a String-valued constraint attribute for a three-dimensional array of general constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A three-dimensional array of general constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input general constraint.

## GRBModel.getCoeff()

Query the coefficient of variable `var` in linear constraint `constr` (note that the result can be zero).

```
double getCoeff ( GRBConstr constr,  
                 GRBVar var )
```

**Arguments:**

**constr:** The requested constraint.

**var:** The requested variable.

**Return value:**

The current value of the requested coefficient.

## GRBModel.getCol()

Retrieve the list of constraints in which a variable participates, and the associated coefficients. The result is returned as a [GRBColumn](#) object.

```
GRBColumn getCol ( GRBVar var )
```

**Arguments:**

**var:** The variable of interest.

**Return value:**

A [GRBColumn](#) object that captures the set of constraints in which the variable participates.

## GRBModel.getConcurrentEnv()

Create/retrieve a concurrent environment for a model.

This method provides fine-grained control over the concurrent optimizer. By creating your own concurrent environments and setting appropriate parameters on these environments (e.g., the [Method](#) parameter), you can control exactly which strategies the concurrent optimizer employs. For example, if you create two concurrent environments, and set `Method` to primal simplex for one and dual simplex for the other, subsequent concurrent optimizer runs will use the two simplex algorithms rather than the default choices.

Note that you must create contiguously numbered concurrent environments, starting with `num=0`. For example, if you want three concurrent environments, they must be numbered 0, 1, and 2.

Once you create concurrent environments, they will be used for every subsequent concurrent optimization on that model. Use [discardConcurrentEnvs](#) to revert back to default concurrent optimizer behavior.

```
| GRBEnv getConcurrentEnv ( int num )
```

### Arguments:

`num`: The concurrent environment number.

### Return value:

The concurrent environment for the model.

## GRBModel.getConstrByName()

Retrieve a linear constraint from its name. If multiple linear constraints have the same name, this method chooses one arbitrarily. Returns null if no constraint has that name.

```
| GRBConstr getConstrByName ( String name )
```

### Arguments:

`name`: The name of the desired linear constraint.

### Return value:

The requested linear constraint.

## GRBModel.getConstrs()

Retrieve an array of all linear constraints in the model.

```
| GRBConstr[] getConstrs ( )
```

### Return value:

All linear constraints in the model.

## GRBModel.getEnv()

Query the environment associated with the model. Note that each model makes its own copy of the environment when it is created. To change parameters for a model, for example, you should use this method to obtain the appropriate environment object.

```
GRBEnv getEnv ( )
```

**Return value:**

The environment for the model.

## GRBModel.getGenConstrMax()

Retrieve the data of a general constraint of type MAX. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with a `null` value for the `vars` argument. The routine returns the total number of operand variables in the specified general constraint in `len`. That allows you to make certain that the `vars` array is of sufficient size to hold the result of the second call.

See also [addGenConstrMax](#) for a description of the semantics of this general constraint type.

```
void getGenConstrMax ( GRBGenConstr genc,  
                      GRBVar[] resvar,  
                      GRBVar[] vars,  
                      int[] len,  
                      double[] constant )
```

**Arguments:**

**genc:** The index of the general constraint.

Any combination of the following four arguments can be `null`.

**resvar:** Store the resultant variable of the constraint at `resvar[0]`.

**vars:** Array to store the operand variables of the constraint.

**len:** Store the number of operand variables of the constraint at `len[0]`.

**constant:** Store the additional constant operand of the constraint at `constant[0]`.

## GRBModel.getGenConstrMin()

Retrieve the data of a general constraint of type MIN. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with a `null` value for the `vars` argument. The routine returns the total number of operand variables in the specified general constraint in `len`. That allows you to make certain that the `vars` array is of sufficient size to hold the result of the second call.

See also [addGenConstrMin](#) for a description of the semantics of this general constraint type.

```
void getGenConstrMin ( GRBGenConstr genc,
                      GRBVar []    resvar,
                      GRBVar []    vars,
                      int []       len,
                      double []    constant )
```

**Arguments:**

- genc:** The index of the general constraint.
- Any combination of the following four arguments can be null.
- resvar:** Store the resultant variable of the constraint at `resvar[0]`.
- vars:** Array to store the operand variables of the constraint.
- len:** Store the number of operand variables of the constraint at `len[0]`.
- constant:** Store the additional constant operand of the constraint at `constant[0]`.

### GRBModel.getGenConstrAbs()

Retrieve the data of a general constraint of type ABS. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [addGenConstrAbs](#) for a description of the semantics of this general constraint type.

```
void getGenConstrAbs ( GRBGenConstr genc,
                      GRBVar []    resvar,
                      GRBVar []    argvar )
```

**Arguments:**

- genc:** The index of the general constraint.
- Any combination of the following two arguments can be null.
- resvar:** Store the resultant variable of the constraint at `resvar[0]`.
- argvar:** Store the argument variable of the constraint at `resvar[0]`.

### GRBModel.getGenConstrAnd()

Retrieve the data of a general constraint of type AND. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with a null value for the `vars` argument. The routine returns the total number of operand variables in the specified general constraint in `len`. That allows you to make certain that the `vars` array is of sufficient size to hold the result of the second call.

See also [addGenConstrAnd](#) for a description of the semantics of this general constraint type.

```
void getGenConstrAnd ( GRBGenConstr genc,
                      GRBVar []    resvar,
                      GRBVar []    vars,
                      int []       len )
```

**Arguments:**

**genc**: The index of the general constraint.

Any combination of the following four arguments can be `null`.

**resvar**: Store the resultant variable of the constraint at `resvar[0]`.

**vars**: Array to store the operand variables of the constraint.

**len**: Store the number of operand variables of the constraint at `len[0]`.

## GRBModel.getGenConstrOr()

Retrieve the data of a general constraint of type OR. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

Typical usage is to call this routine twice. In the first call, you specify the requested general constraint, with a `null` value for the `vars` argument. The routine returns the total number of operand variables in the specified general constraint in `len`. That allows you to make certain that the `vars` array is of sufficient size to hold the result of the second call.

See also [addGenConstrOr](#) for a description of the semantics of this general constraint type.

```
void getGenConstrOr ( GRBGenConstr genc,  
                    GRBVar []    resvar,  
                    GRBVar []    vars,  
                    int []       len )
```

### Arguments:

**genc**: The index of the general constraint.

Any combination of the following four arguments can be `null`.

**resvar**: Store the resultant variable of the constraint at `resvar[0]`.

**vars**: Array to store the operand variables of the constraint.

**len**: Store the number of operand variables of the constraint at `len[0]`.

## GRBModel.getGenConstrIndicator()

Retrieve the data of a general constraint of type INDICATOR. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [addGenConstrIndicator](#) for a description of the semantics of this general constraint type.

```
void getGenConstrIndicator ( GRBGenConstr genc,  
                             GRBVar []    binvar,  
                             int []       binval,  
                             GRBLinExpr [] expr,  
                             char []     sense,  
                             double []   rhs )
```

### Arguments:

**genc**: The index of the general constraint.

Any combination of the following five arguments can be `null`.

**binvar**: Store the binary indicator variable of the constraint at `binvar[0]`.  
**binval**: Store the value that the indicator variable has to take in order to trigger the linear constraint at `binval[0]`.  
**expr**: Create a [GRBLinExpr](#) object to store the left-hand-side expression of the linear constraint that is triggered by the indicator at `expr[0]`.  
**sense**: Store the sense for the linear constraint at `sense[0]`. Options are `GRB.LESS_EQUAL`, `GRB.EQUAL`, or `GRB.GREATER_EQUAL`.  
**rhs**: Store the right-hand-side value for the linear constraint at `rhs[0]`.

### **GRBModel.getGenConstrs()**

Retrieve an array of all general constraints in the model.

```
| GRBGenConstr[] getGenConstrs ( )  
  Return value:  
    All general constraints in the model.
```

### **GRBModel.getObjective()**

Retrieve the model objective.

Note that the constant and linear portions of the objective can also be retrieved using the `ObjCon` and `Obj` attributes.

```
| GRBExpr getObjective ( )  
  Return value:  
    The model objective.
```

### **GRBModel.getPWLObj()**

Retrieve the piecewise-linear objective function for a variable. The return value gives the number of points that define the function, and the  $x$  and  $y$  arguments give the coordinates of the points, respectively. The  $x$  and  $y$  arguments must be large enough to hold the result. Call this method with `null` values for  $x$  and  $y$  if you just want the number of points.

Refer to the description of [setPWLObj](#) for additional information on what the values in  $x$  and  $y$  mean.

```
| int getPWLObj ( GRBVar var,  
                 double[] x,  
                 double[] y )
```

**Arguments:**

**var**: The variable whose objective function is being retrieved.

**x**: The  $x$  values for the points that define the piecewise-linear function. These will always be in non-decreasing order.

**y**: The  $y$  values for the points that define the piecewise-linear function.

**Return value:**

The number of points that define the piecewise-linear objective function.

## GRBModel.getQConstr()

Retrieve the left-hand side expression from a quadratic constraint. The result is returned as a [GRBQuadExpr](#) object.

```
| GRBQuadExpr getQConstr ( GRBQConstr qconstr )
```

### Arguments:

**qconstr:** The quadratic constraint of interest.

### Return value:

A [GRBQuadExpr](#) object that captures the left-hand side of the quadratic constraint.

## GRBModel.getQConstrs()

Retrieve an array of all quadratic constraints in the model.

```
| GRBQConstr[] getQConstrs ( )
```

### Return value:

All quadratic constraints in the model.

## GRBModel.getRow()

Retrieve a list of variables that participate in a constraint, and the associated coefficients. The result is returned as a [GRBLinExpr](#) object.

```
| GRBLinExpr getRow ( GRBConstr constr )
```

### Arguments:

**constr:** The constraint of interest.

### Return value:

A [GRBLinExpr](#) object that captures the set of variables that participate in the constraint.

## GRBModel.getSOS()

Retrieve the list of variables that participate in an SOS constraint, and the associated coefficients. The return value is the length of this list. Note that the argument arrays must be long enough to accommodate the result. Call the method with `null` array arguments to determine the appropriate array lengths.

```
| int getSOS ( GRBSOS   sos,  
              GRBVar[] vars,  
              double[] weights,  
              int[]    type )
```

### Arguments:

**sos:** The SOS set of interest.

**vars:** A list of variables that participate in **sos**. Can be null.

**weights:** The SOS weights for each participating variable. Can be null.

**type:** The type of the SOS set (either `GRB.SOS_TYPE1` or `GRB.SOS_TYPE2`) is returned in `type[0]`.

**Return value:**

The number of entries placed in the output arrays. Note that you should consult the return value to determine the length of the result; the arrays sizes won't necessarily match the result size.

## GRBModel.getSOSs()

Retrieve an array of all SOS constraints in the model.

```
| GRBSOS[] getSOSs ( )
```

**Return value:**

All SOS constraints in the model.

## GRBModel.getTuneResult()

Use this method to retrieve the results of a previous [tune](#) call. Calling this method with argument `n` causes tuned parameter set `n` to be copied into the model. Parameter sets are stored in order of decreasing quality, with parameter set 0 being the best. The number of available sets is stored in attribute [TuneResultCount](#).

Once you have retrieved a tuning result, you can call [optimize](#) to use these parameter settings to optimize the model, or [write](#) to write the changed parameters to a `.prm` file.

Please refer to the [parameter tuning](#) section for details on the tuning tool.

```
| void getTuneResult ( int n )
```

**n:** The index of the tuning result to retrieve. The best result is available as index 0. The number of stored results is available in attribute [TuneResultCount](#).

## GRBModel.getVarByName()

Retrieve a variable from its name. If multiple variables have the same name, this method chooses one arbitrarily. Returns null if no variable has that name.

```
| GRBVar getVarByName ( String name )
```

**Arguments:**

**name:** The name of the desired variable.

**Return value:**

The requested variable.

## GRBModel.getVars()

Retrieve an array of all variables in the model.

```
| GRBVar[] getVars ( )
```

**Return value:**

All variables in the model.

## GRBModel.optimize()

Optimize the model. The algorithm used for the optimization depends on the model type (simplex or barrier for a continuous model; branch-and-cut for a MIP model). Upon successful completion, this method will populate the solution related attributes of the model. See the [Attributes](#) section for more information on attributes.

Please consult [this section](#) for a discussion of some of the practical issues associated with solving a precisely defined mathematical model using finite-precision floating-point arithmetic.

Note that this method will process all pending model modifications.

```
| void optimize ( )
```

## GRBModel.optimizeasync()

Optimize a model asynchronously. This routine returns immediately. Your program can perform other computations while optimization proceeds in the background. To check the state of the asynchronous optimization, query the [Status](#) attribute for the model. A value of `IN_PROGRESS` indicates that the optimization has not yet completed. When you are done with your foreground tasks, you must call [sync](#) to sync your foreground program with the asynchronous optimization task.

Note that the set of Gurobi calls that you are allowed to make while optimization is running in the background is severely limited. Specifically, you can only perform attribute queries, and only for a few attributes (listed below). Any other calls on the running model, *or on any other models that were built within the same Gurobi environment*, will fail with error code `OPTIMIZATION_IN_PROGRESS`.

Note that there are no such restrictions on models built in other environments. Thus, for example, you could create multiple environments, and then have a single foreground program launch multiple simultaneous asynchronous optimizations, each in its own environment.

As already noted, you are allowed to query the value of the `Status` attribute while an asynchronous optimization is in progress. The other attributes that can be queried are: [ObjVal](#), [ObjBound](#), [IterCount](#), [NodeCount](#), and [BarIterCount](#). In each case, the returned value reflects progress in the optimization to that point. Any attempt to query the value of an attribute not on this list will return an `OPTIMIZATION_IN_PROGRESS` error.

```
| void optimizeasync ( )
```

## GRBModel.presolve()

Perform presolve on a model.

```
| GRBModel presolve ( )
```

**Return value:**

Presolved version of original model.

## GRBModel.read()

This method is the general entry point for importing data from a file into a model. It can be used to read basis files for continuous models, start vectors for MIP models, or parameter settings. The type of data read is determined by the file suffix. File formats are described in the [File Format](#) section.

Note that this is **not** the method to use if you want to read a new model from a file. For that, use the [GRBModel constructor](#). One variant of the constructor takes the name of the file that contains the new model as its argument.

```
| void read ( String filename )
```

**Arguments:**

**filename:** Name of the file to read. The suffix on the file must be either `.bas` (for an LP basis), `.mst` or `.sol` (for a MIP start), `.hnt` (for MIP hints), `.ord` (for a priority order), or `.prm` (for a parameter file). The suffix may optionally be followed by `.zip`, `.gz`, `.bz2`, or `.7z`.

## GRBModel.remove()

Remove a variable, constraint, or SOS from a model.

```
| void remove ( GRBConstr constr )
```

Remove a linear constraint from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel.update](#)), optimize the model (using [GRBModel.optimize](#)), or write the model to disk (using [GRBModel.write](#)).

**Arguments:**

**constr:** The linear constraint to remove.

```
| void remove ( GRBGenConstr genconstr )
```

Remove a general constraint from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel.update](#)), optimize the model (using [GRBModel.optimize](#)), or write the model to disk (using [GRBModel.write](#)).

**Arguments:**

**genconstr**: The general constraint to remove.

```
| void remove ( GRBQConstr qconstr )
```

Remove a quadratic constraint from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel.update](#)), optimize the model (using [GRBModel.optimize](#)), or write the model to disk (using [GRBModel.write](#)).

**Arguments:**

**qconstr**: The quadratic constraint to remove.

```
| void remove ( GRBSOS sos )
```

Remove an SOS constraint from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel.update](#)), optimize the model (using [GRBModel.optimize](#)), or write the model to disk (using [GRBModel.write](#)).

**Arguments:**

**sos**: The SOS constraint to remove.

```
| void remove ( GRBVar var )
```

Remove a variable from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel.update](#)), optimize the model (using [GRBModel.optimize](#)), or write the model to disk (using [GRBModel.write](#)).

**Arguments:**

**var**: The variable to remove.

## **GRBModel.reset()**

Reset the model to an unsolved state, discarding any previously computed solution information.

```
| void reset ( )
```

## **GRBModel.setCallback()**

Set the callback object for a model. The `callback()` method on this object will be called periodically from the Gurobi solver. You will have the opportunity to obtain more detailed information about the state of the optimization from this callback. See the documentation for [GRBCallback](#) for additional information.

Note that a model can only have a single callback method, so this call will replace an existing callback. To disable a previously set callback, call this method with a `null` argument.

```
| void setCallback ( GRBCallback cb )
```

## GRBModel.set()

Set the value(s) of a parameter or attribute. Use this method for parameters, for scalar model attributes, or for arrays of constraint or variable attributes.

```
void set ( GRB.DoubleParam param,  
           double          newvalue )
```

Set the value of a double-valued parameter.

The difference between setting a parameter on a model and setting it on an environment (i.e., through [GRBEnv.set](#)) is that the former modifies the parameter for a single model, while the latter modifies the parameter for every model that is subsequently built using that environment (and leaves the parameter unchanged for models that were previously built using that environment).

### Arguments:

**param:** The parameter being modified.

**newvalue:** The desired new value for the parameter.

```
void set ( GRB.IntParam  param,  
           int           newvalue )
```

Set the value of an int-valued parameter.

The difference between setting a parameter on a model and setting it on an environment (i.e., through [GRBEnv.set](#)) is that the former modifies the parameter for a single model, while the latter modifies the parameter for every model that is subsequently built using that environment (and leaves the parameter unchanged for models that were previously built using that environment).

### Arguments:

**param:** The parameter being modified.

**newvalue:** The desired new value for the parameter.

```
void set ( GRB.StringParam param,  
           String          newvalue )
```

Set the value of a string-valued parameter.

The difference between setting a parameter on a model and setting it on an environment (i.e., through [GRBEnv.set](#)) is that the former modifies the parameter for a single model, while the latter modifies the parameter for every model that is subsequently built using that environment (and leaves the parameter unchanged for models that were previously built using that environment).

### Arguments:

**param:** The parameter being modified.

**newvalue:** The desired new value for the parameter.

```
void set ( String param,  
           String newvalue )
```

Set the value of any parameter using strings alone.

The difference between setting a parameter on a model and setting it on an environment (i.e., through [GRBEnv.set](#)) is that the former modifies the parameter for a single model, while the latter

modifies the parameter for every model that is subsequently built using that environment (and leaves the parameter unchanged for models that were previously built using that environment).

**Arguments:**

**param:** The name of the parameter being modified.  
**newvalue:** The desired new value for the parameter.

```
void set ( GRB.CharAttr attr,  
          GRBVar[] vars,  
          char[] newvalues )
```

Set a char-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being modified.  
**vars:** The variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void set ( GRB.CharAttr attr,  
          GRBVar[] vars,  
          char[] newvalues,  
          int start,  
          int len )
```

Set a char-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being modified.  
**vars:** A one-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.  
**start:** The index of the first variable of interest in the list.  
**len:** The number of variables.

```
void set ( GRB.CharAttr attr,  
          GRBVar[] [] vars,  
          char[] [] newvalues )
```

Set a char-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being modified.  
**vars:** A two-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void set ( GRB.CharAttr attr,  
          GRBVar[] [] [] vars,  
          char[] [] [] newvalues )
```

Set a char-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** A three-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void set ( GRB.CharAttr attr,  
          GRBConstr[]  constrs,  
          char[]       newvalues )
```

Set a char-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** The constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void set ( GRB.CharAttr attr,  
          GRBConstr[]  constrs,  
          char[]       newvalues,  
          int          start,  
          int          len )
```

Set a char-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A one-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.  
**start:** The index of the first constraint of interest in the list.  
**len:** The number of constraints.

```
void set ( GRB.CharAttr attr,  
          GRBConstr[] [] constrs,  
          char[] []     newvalues )
```

Set a char-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A two-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void set ( GRB.CharAttr attr,  
          GRBConstr[] [] [] constrs,  
          char[] [] []     newvalues )
```

Set a char-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A three-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void set ( GRB.CharAttr attr,
           GRBQConstr[] qconstrs,
           char[]       newvalues )
```

Set a char-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** The quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void set ( GRB.CharAttr attr,
           GRBQConstr[] qconstrs,
           char[]       newvalues,
           int          start,
           int          len )
```

Set a char-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

**start:** The index of the first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

```
void set ( GRB.CharAttr attr,
           GRBQConstr[] [] qconstrs,
           char[] []       newvalues )
```

Set a char-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void set ( GRB.CharAttr attr,
           GRBQConstr[] [] [] qconstrs,
           char[] [] []       newvalues )
```

Set a char-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void set ( GRB.DoubleAttr attr,
           double          newvalue )
Set the value of a double-valued model attribute.
```

**Arguments:**

**attr:** The attribute being modified.  
**newvalue:** The desired new value for the attribute.

```
void set ( GRB.DoubleAttr attr,
           GRBVar[]       vars,
           double[]       newvalues )
Set a double-valued variable attribute for an array of variables.
```

**Arguments:**

**attr:** The attribute being modified.  
**vars:** The variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void set ( GRB.DoubleAttr attr,
           GRBVar[]       vars,
           double[]       newvalues,
           int            start,
           int            len )
Set a double-valued variable attribute for a sub-array of variables.
```

**Arguments:**

**attr:** The attribute being modified.  
**vars:** A one-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.  
**start:** The index of the first variable of interest in the list.  
**len:** The number of variables.

```
void set ( GRB.DoubleAttr attr,
           GRBVar[] []    vars,
           double[] []    newvalues )
Set a double-valued variable attribute for a two-dimensional array of variables.
```

**Arguments:**

**attr:** The attribute being modified.  
**vars:** A two-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void set ( GRB.DoubleAttr attr,
           GRBVar[] [] [] vars,
           double[] [] [] newvalues )
Set a double-valued variable attribute for a three-dimensional array of variables.
```

**Arguments:**

**attr:** The attribute being modified.

**vars:** A three-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void set ( GRB.DoubleAttr attr,  
          GRBConstr[]   constrs,  
          double[]      newvalues )
```

Set a double-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** The constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void set ( GRB.DoubleAttr attr,  
          GRBConstr[]   constrs,  
          double[]      newvalues,  
          int           start,  
          int           len )
```

Set a double-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A one-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.  
**start:** The first constraint of interest in the list.  
**len:** The number of constraints.

```
void set ( GRB.DoubleAttr attr,  
          GRBConstr[][]  constrs,  
          double[][]     newvalues )
```

Set a double-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A two-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void set ( GRB.DoubleAttr attr,  
          GRBConstr[][][] constrs,  
          double[][][]    newvalues )
```

Set a double-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A three-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void set ( GRB.DoubleAttr attr,
           GRBQConstr[]   qconstrs,
           double[]       newvalues )
```

Set a double-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** The quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void set ( GRB.DoubleAttr attr,
           GRBQConstr[]   qconstrs,
           double[]       newvalues,
           int             start,
           int             len )
```

Set a double-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

**start:** The first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

```
void set ( GRB.DoubleAttr attr,
           GRBQConstr[] [] qconstrs,
           double[] []     newvalues )
```

Set a double-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void set ( GRB.DoubleAttr attr,
           GRBQConstr[] [] [] qconstrs,
           double[] [] []     newvalues )
```

Set a double-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void set ( GRB.IntAttr attr,
           int          newvalue )
```

Set the value of an int-valued model attribute.

**Arguments:**

**attr:** The attribute being modified.  
**newvalue:** The desired new value for the attribute.

```
void set ( GRB.IntAttr attr,
           GRBVar[]    vars,
           int[]       newvalues )
```

Set an int-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being modified.  
**vars:** The variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void set ( GRB.IntAttr attr,
           GRBVar[]    vars,
           int[]       newvalues,
           int         start,
           int         len )
```

Set an int-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being modified.  
**vars:** A one-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.  
**start:** The index of the first variable of interest in the list.  
**len:** The number of variables.

```
void set ( GRB.IntAttr attr,
           GRBVar[] []  vars,
           int[] []     newvalues )
```

Set an int-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being modified.  
**vars:** A two-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void set ( GRB.IntAttr attr,
           GRBVar[] [] [] vars,
           int[] [] []   newvalues )
```

Set an int-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** A three-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void set ( GRB.IntAttr attr,  
          GRBConstr[] constrs,  
          int[] newvalues )
```

Set an int-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** The constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void set ( GRB.IntAttr attr,  
          GRBConstr[] constrs,  
          int[] newvalues,  
          int start,  
          int len )
```

Set an int-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A one-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.  
**start:** The index of the first constraint of interest in the list.  
**len:** The number of constraints.

```
void set ( GRB.IntAttr attr,  
          GRBConstr[][] constrs,  
          int[][] newvalues )
```

Set an int-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A two-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void set ( GRB.IntAttr attr,  
          GRBConstr[][][] constrs,  
          int[][][] newvalues )
```

Set an int-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A three-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void set ( GRB.StringAttr attr,
           String          newvalue )
Set the value of a String-valued model attribute.
```

**Arguments:**

**attr:** The attribute being modified.  
**newvalue:** The desired new value for the attribute.

```
void set ( GRB.StringAttr attr,
           GRBVar[]       vars,
           String[]       newvalues )
Set a String-valued variable attribute for an array of variables.
```

**Arguments:**

**attr:** The attribute being modified.  
**vars:** The variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void set ( GRB.StringAttr attr,
           GRBVar[]       vars,
           String[]       newvalues,
           int            start,
           int            len )
Set a String-valued variable attribute for a sub-array of variables.
```

**Arguments:**

**attr:** The attribute being modified.  
**vars:** A one-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.  
**start:** The index of the first variable of interest in the list.  
**len:** The number of variables.

```
void set ( GRB.StringAttr attr,
           GRBVar[] []    vars,
           String[] []    newvalues )
Set a String-valued variable attribute for a two-dimensional array of variables.
```

**Arguments:**

**attr:** The attribute being modified.  
**vars:** A two-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void set ( GRB.StringAttr attr,
           GRBVar[] [] [] vars,
           String[] [] [] newvalues )
Set a String-valued variable attribute for a three-dimensional array of variables.
```

**Arguments:**

**attr:** The attribute being modified.

**vars:** A three-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void set ( GRB.StringAttr attr,  
          GRBConstr[]   constrs,  
          String[]      newvalues )
```

Set a String-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** The constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void set ( GRB.StringAttr attr,  
          GRBConstr[]   constrs,  
          String[]      newvalues,  
          int           start,  
          int           len )
```

Set a String-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A one-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.  
**start:** The index of the first constraint of interest in the list.  
**len:** The number of constraints.

```
void set ( GRB.StringAttr attr,  
          GRBConstr[] []  constrs,  
          String[] []     newvalues )
```

Set a String-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A two-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void set ( GRB.StringAttr attr,  
          GRBConstr[] [] [] constrs,  
          String[] [] []   newvalues )
```

Set a String-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A three-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void set ( GRB.StringAttr attr,
           GRBQConstr[] qconstrs,
           String[] newvalues )
```

Set a String-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** The quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void set ( GRB.StringAttr attr,
           GRBQConstr[] qconstrs,
           String[] newvalues,
           int start,
           int len )
```

Set a String-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

**start:** The index of the first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

```
void set ( GRB.StringAttr attr,
           GRBQConstr[] [] qconstrs,
           String[] [] newvalues )
```

Set a String-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void set ( GRB.StringAttr attr,
           GRBQConstr[] [] [] qconstrs,
           String[] [] [] newvalues )
```

Set a String-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void set ( GRB.StringAttr attr,
           GRBGenConstr[] genconstrs,
           String[]       newvalues )
```

Set a String-valued general constraint attribute for an array of general constraints.

**Arguments:**

**attr:** The attribute being modified.

**genconstrs:** The general constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input general constraint.

```
void set ( GRB.StringAttr attr,
           GRBGenConstr[] genconstrs,
           String[]       newvalues,
           int             start,
           int             len )
```

Set a String-valued general constraint attribute for a sub-array of general constraints.

**Arguments:**

**attr:** The attribute being modified.

**genconstrs:** A one-dimensional array of general constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input general constraint.

**start:** The index of the first general constraint of interest in the list.

**len:** The number of general constraints.

```
void set ( GRB.StringAttr attr,
           GRBGenConstr[][] genconstrs,
           String[][]       newvalues )
```

Set a String-valued general constraint attribute for a two-dimensional array of general constraints.

**Arguments:**

**attr:** The attribute being modified.

**genconstrs:** A two-dimensional array of general constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input general constraint.

```
void set ( GRB.StringAttr attr,
           GRBGenConstr[][][] genconstrs,
           String[][][]       newvalues )
```

Set a String-valued general constraint attribute for a three-dimensional array of general constraints.

**Arguments:**

**attr:** The attribute being modified.

**genconstrs:** A three-dimensional array of general constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input general constraint.

## GRBModel.setObjective()

Set the model objective equal to a linear or quadratic expression.

Note that you can also modify the linear portion of a model objective using the `Obj` variable attribute. If you wish to mix and match these two approaches, please note that this method replaces the entire existing objective, while the `Obj` attribute can be used to modify individual linear terms.

```
void setObjective ( GRBExpr expr,  
                   int      sense )
```

Set the model objective, and the objective sense (`GRB.MINIMIZE` for minimization, `GRB.MAXIMIZE` for maximization).

### Arguments:

**expr:** New model objective.

**sense:** New optimization sense (`GRB.MINIMIZE` for minimization, `GRB.MAXIMIZE` for maximization).

```
void setObjective ( GRBExpr expr )
```

Set the model objective. The sense of the objective is determined by the value of the [ModelSense](#) attribute.

### Arguments:

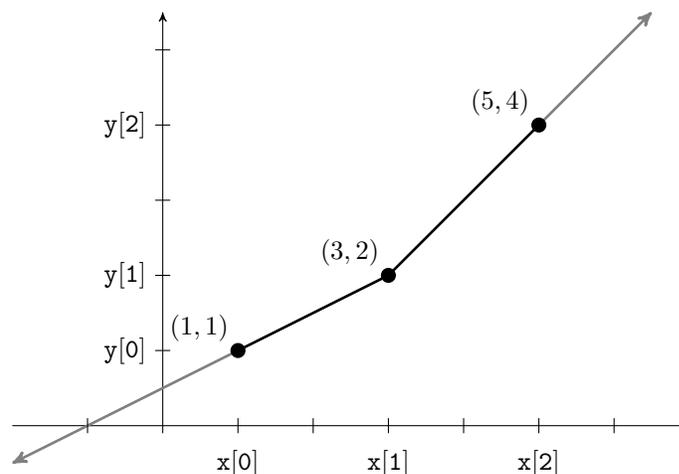
**expr:** New model objective.

## GRBModel.setPWLObj()

Set a piecewise-linear objective function for a variable.

The arguments to this method specify a list of points that define a piecewise-linear objective function for a single variable. Specifically, the  $x$  and  $y$  arguments give coordinates for the vertices of the function.

For example, suppose we want to define the function  $f(x)$  shown below:



The vertices of the function occur at the points (1, 1), (3, 2) and (5, 4), so  $x$  is {1, 3, 5} and  $y$  is {1, 2, 4}. With these arguments we define  $f(1) = 1$ ,  $f(3) = 2$  and  $f(5) = 4$ . Other objective values are linearly interpolated between neighboring points. The first pair and last pair of points each define a ray, so values outside the specified  $x$  values are extrapolated from these points. Thus, in our example,  $f(-1) = 0$  and  $f(6) = 5$ .

More formally, a set of  $n$  points

$$\mathbf{x} = \{x_1, \dots, x_n\}, \quad \mathbf{y} = \{y_1, \dots, y_n\}$$

define the following piecewise-linear function:

$$f(v) = \begin{cases} y_1 + \frac{y_2 - y_1}{x_2 - x_1}(v - x_1), & \text{if } v \leq x_1, \\ y_i + \frac{y_{i+1} - y_i}{x_{i+1} - x_i}(v - x_i), & \text{if } v \geq x_i \text{ and } v \leq x_{i+1}, \\ y_n + \frac{y_n - y_{n-1}}{x_n - x_{n-1}}(v - x_n), & \text{if } v \geq x_n. \end{cases}$$

The  $x$  entries must appear in non-decreasing order. Two points can have the same  $x$  coordinate — this can be useful for specifying a discrete jump in the objective function.

Note that a piecewise-linear objective can change the type of a model. Specifically, including a non-convex piecewise linear objective function in a continuous model will transform that model into a MIP. This can significantly increase the cost of solving the model.

Setting a piecewise-linear objective for a variable will set the [Obj attribute](#) on that variable to 0. Similarly, setting the `Obj` attribute will delete the piecewise-linear objective on that variable.

Each variable can have its own piecewise-linear objective function. They must be specified individually, even if multiple variables share the same function.

```
void setPWLObj ( GRBvar   var,
                 double[] x,
                 double[] y )
```

Set the piecewise-linear objective function for a variable.

**Arguments:**

**var:** The variable whose objective function is being set.

**x:** The  $x$  values for the points that define the piecewise-linear function. Must be in non-decreasing order.

**y:** The  $y$  values for the points that define the piecewise-linear function.

### **GRBModel.terminate()**

Generate a request to terminate the current optimization. This method can be called at any time during an optimization.

```
void terminate ( )
```

## GRBModel.tune()

Perform an automated search for parameter settings that improve performance. Upon completion, this method stores the best parameter sets it found. The number of stored parameter sets can be determined by querying the value of the [TuneResultCount](#) attribute. The actual settings can be retrieved using [getTuneResult](#)

Please refer to the [parameter tuning](#) section for details on the tuning tool.

```
| void tune ( )
```

## GRBModel.update()

Process any pending model modifications.

```
| void update ( )
```

## GRBModel.write()

This method is the general entry point for writing model data to a file. It can be used to write optimization models, IIS submodels, solutions, basis vectors, MIP start vectors, or parameter settings. The type of file is determined by the file suffix. File formats are described in the [File Format](#) section.

Note that writing a model to a file will process all pending model modifications. However, writing other model information (solutions, bases, etc.) will not.

```
| void write ( String filename )
```

### Arguments:

**filename:** Name of the file to write. The file type is encoded in the file name suffix. Valid suffixes for writing the model itself are `.mps`, `.rew`, `.lp`, or `.rlp`. An IIS can be written by using an `.ilp` suffix. Use `.sol` for a solution file, `.mst` for a MIP start, `.hnt` for MIP hints, `.bas` for a basis file, or `.prm` for a parameter file. The suffix may optionally be followed by `.gz`, `.bz2`, or `.7z`, which produces a compressed result.

## 4.3 GRBVar

Gurobi variable object. Variables are always associated with a particular model. You create a variable object by adding a variable to a model (using `GRBModel.addVar`), rather than by using a `GRBVar` constructor.

The methods on variable objects are used to get and set variable attributes. For example, solution information can be queried by calling `get(GRB.DoubleAttr.X)`. Note, however, that it is generally more efficient to query attributes for a set of variables at once. This is done using the attribute query method on the `GRBModel` object (`GRBModel.get`).

### `GRBVar.get()`

Query the value of a variable attribute.

```
| char get ( GRB.CharAttr attr )
```

Query the value of a char-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| double get ( GRB.DoubleAttr attr )
```

Query the value of a double-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| int get ( GRB.IntAttr attr )
```

Query the value of an int-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| String get ( GRB.StringAttr attr )
```

Query the value of a string-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

## GRBVar.sameAs()

```
boolean sameAs ( GRBVar var2 )
```

Check whether two variable objects refer to the same variable.

**Arguments:**

**var2:** The other variable.

**Return value:**

Boolean result indicates whether the two variable objects refer to the same model variable.

## GRBVar.set()

Set the value of a variable attribute.

```
void set ( GRB.CharAttr attr,  
           char          newvalue )
```

Set the value of a char-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB.DoubleAttr attr,  
           double         newvalue )
```

Set the value of a double-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB.IntAttr  attr,  
           int          newvalue )
```

Set the value of an int-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB.StringAttr attr,  
           String         newvalue )
```

Set the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

## 4.4 GRBConstr

Gurobi constraint object. Constraints are always associated with a particular model. You create a constraint object by adding a constraint to a model (using `GRBModel.addConstr`), rather than by using a `GRBConstr` constructor.

The methods on constraint objects are used to get and set constraint attributes. For example, constraint right-hand sides can be queried by calling `get(GRB.DoubleAttr.RHS)`. Note, however, that it is generally more efficient to query attributes for a set of constraints at once. This is done using the attribute query method on the `GRBModel` object (`GRBModel.get`).

### GRBConstr.get()

Query the value of a constraint attribute.

```
| char get ( GRB.CharAttr attr )
```

Query the value of a char-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| double get ( GRB.DoubleAttr attr )
```

Query the value of a double-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| int get ( GRB.IntAttr attr )
```

Query the value of an int-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| String get ( GRB.StringAttr attr )
```

Query the value of a string-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

## GRBConstr.sameAs()

```
boolean sameAs ( GRBConstr constr2 )
```

Check whether two constraint objects refer to the same constraint.

**Arguments:**

**constr2:** The other constraint.

**Return value:**

Boolean result indicates whether the two constraint objects refer to the same model constraint.

## GRBConstr.set()

Set the value of a constraint attribute.

```
void set ( GRB.CharAttr attr,  
          char          newvalue )
```

Set the value of a char-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB.DoubleAttr attr,  
          double          newvalue )
```

Set the value of a double-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB.IntAttr attr,  
          int          newvalue )
```

Set the value of an int-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB.StringAttr attr,  
          String          newvalue )
```

Set the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

## 4.5 GRBQConstr

Gurobi quadratic constraint object. Quadratic constraints are always associated with a particular model. You create a quadratic constraint object by adding a quadratic constraint to a model (using [GRBModel.addQConstr](#)), rather than by using a `GRBQConstr` constructor.

The methods on quadratic constraint objects are used to get and set constraint attributes. For example, quadratic constraint right-hand sides can be queried by calling `get(GRB.DoubleAttr.QCRHS)`. Note, however, that it is generally more efficient to query attributes for a set of constraints at once. This is done using the attribute query method on the `GRBModel` object ([GRBModel.get](#)).

### GRBQConstr.get()

Query the value of a quadratic constraint attribute.

```
| char get ( GRB.CharAttr attr )
```

Query the value of a char-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| double get ( GRB.DoubleAttr attr )
```

Query the value of a double-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| int get ( GRB.IntAttr attr )
```

Query the value of an int-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| String get ( GRB.StringAttr attr )
```

Query the value of a string-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

## GRBQConstr.set()

Set the value of a quadratic constraint attribute.

```
void set ( GRB.CharAttr attr,  
           char          newvalue )
```

Set the value of a char-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB.DoubleAttr attr,  
           double         newvalue )
```

Set the value of a double-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void set ( GRB.StringAttr attr,  
           String         newvalue )
```

Set the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

## 4.6 GRBSOS

Gurobi SOS constraint object. SOS constraints are always associated with a particular model. You create an SOS object by adding an SOS constraint to a model (using [GRBModel.addSOS](#)), rather than by using a `GRBSOS` constructor. Similarly, SOS constraints are removed using the [GRBModel.remove](#) method.

An SOS constraint can be of type 1 or 2 (`GRB.SOS_TYPE1` or `GRB.SOS_TYPE2`). A type 1 SOS constraint is a set of variables for which at most one variable in the set may take a value other than zero. A type 2 SOS constraint is an ordered set of variables where at most two variables in the set may take non-zero values. If two take non-zero values, they must be contiguous in the ordered set.

SOS constraint objects have one attribute, `IISOS`, which can be queried with the [GRBSOS.get](#) method.

### **GRBSOS.get()**

Query the value of an SOS attribute.

```
| int get ( GRB.IntAttr attr )
```

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

## 4.7 GRBGenConstr

Gurobi general constraint object. General constraints are always associated with a particular model. You create a general constraint object by adding a general constraint to a model (using [GRBModel.addGenConstr](#)), rather than by using a `GRBGenConstr` constructor.

The methods on general constraint objects are used to get and set constraint attributes. For example, general constraint types can be queried by calling `get(GRB.IntAttr.GenConstrType)`. Note, however, that it is generally more efficient to query attributes for a set of constraints at once. This is done using the attribute query method on the `GRBModel` object ([GRBModel.get](#)).

### GRBGenConstr.get()

Query the value of a general constraint attribute.

```
| int  get ( GRB.IntAttr attr )
```

Query the value of a int-valued attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| String get ( GRB.StringAttr attr )
```

Query the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

### GRBGenConstr.set()

Set the value of a general constraint attribute.

```
| void set ( GRB.StringAttr attr,  
            String          newvalue )
```

Set the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

## 4.8 GRBExpr

Abstract base class for the [GRBLinExpr](#) and [GRBQuadExpr](#) classes. Expressions are used to build objectives and constraints. They are temporary objects that typically have short lifespans.

### **GRBExpr.getValue()**

Compute the value of an expression for the current solution.

```
| double getValue ( )
```

**Return value:**

Value of the expression for the current solution.

## 4.9 GRBLinExpr

Gurobi linear expression object. A linear expression consists of a constant term, plus a list of coefficient-variable pairs that capture the linear terms. Linear expressions are used to build constraints. They are temporary objects that typically have short lifespans.

The `GRBLinExpr` class is a sub-class of the abstract base class `GRBExpr`.

You generally build linear expressions by starting with an empty expression (using the `GRBLinExpr` constructor), and then adding terms. Terms can be added individually, using `addTerm`, or in groups, using `addTerms`, or `multAdd`. Terms can also be removed from an expression, using `remove`.

Individual terms in a linear expression can be queried using the `getVar`, `getCoeff`, and `getConstant` methods. You can query the number of terms in the expression using the `size` method.

Note that a linear expression may contain multiple terms that involve the same variable. These duplicate terms are merged when creating a constraint from an expression, but they may be visible when inspecting individual terms in the expression (e.g., when using `getVar`).

### GRBLinExpr()

Linear expression constructor. Create an empty linear expression, or copy an existing expression.

```
| GRBLinExpr GRBLinExpr ( )  
| Create an empty linear expression.  
| Return value:  
| An empty expression object.
```

```
| GRBLinExpr GRBLinExpr ( GRBLinExpr orig )
```

Copy an existing linear expression.

**Arguments:**

`orig`: Existing expression to copy.

**Return value:**

A copy of the input expression object.

### GRBLinExpr.add()

Add one linear expression into another. Upon completion, the invoking linear expression will be equal to the sum of itself and the argument expression.

```
| void add ( GRBLinExpr le )
```

**Arguments:**  
`le`: Linear expression to add.

## GRBLinExpr.addConstant()

Add a constant into a linear expression.

```
void addConstant ( double c )
```

### Arguments:

**c:** Constant to add to expression.

## GRBLinExpr.addTerm()

Add a single term into a linear expression.

```
void addTerm ( double coeff,  
              GRBVar var )
```

### Arguments:

**coeff:** Coefficient for new term.

**var:** Variable for new term.

## GRBLinExpr.addTerms()

Add new terms into a linear expression.

```
void addTerms ( double[] coeffs,  
               GRBVar[] vars )
```

Add a list of terms into a linear expression. Note that the lengths of the two argument arrays must be equal.

### Arguments:

**coeffs:** Coefficients for new terms.

**vars:** Variables for new terms.

```
void addTerms ( double[] coeffs,  
               GRBVar[] vars,  
               int start,  
               int len )
```

Add new terms into a linear expression. This signature allows you to use arrays to hold the coefficients and variables that describe the terms in an array without being forced to add a term for each entry in the array. The **start** and **len** arguments allow you to specify which terms to add.

### Arguments:

**coeffs:** Coefficients for new terms.

**vars:** Variables for new terms.

**start:** The first term in the list to add.

**len:** The number of terms to add.

## GRBLinExpr.clear()

Set a linear expression to 0.

```
| void clear ( )
```

## GRBLinExpr.getConstant()

Retrieve the constant term from a linear expression.

```
| double getConstant ( )
```

**Return value:**

Constant from expression.

## GRBLinExpr.getCoeff()

Retrieve the coefficient from a single term of the expression.

```
| double getCoeff ( int i )
```

**Return value:**

Coefficient for the term at index *i* in the expression.

## GRBLinExpr.getValue()

Compute the value of a linear expression for the current solution.

```
| double getValue ( )
```

**Return value:**

Value of the expression for the current solution.

## GRBLinExpr.getVar()

Retrieve the variable object from a single term of the expression.

```
| GRBVar getVar ( int i )
```

**Return value:**

Variable for the term at index *i* in the expression.

## GRBLinExpr.multAdd()

Add a constant multiple of one linear expression into another. Upon completion, the invoking linear expression is equal the sum of itself and the constant times the argument expression.

```
void multAdd ( double      m,  
              GRBLinExpr le )
```

### Arguments:

**m:** Constant multiplier for added expression.

**le:** Linear expression to add.

## GRBLinExpr.remove()

Remove a term from a linear expression.

```
void remove ( int i )
```

Remove the term stored at index *i* of the expression.

### Arguments:

**i:** The index of the term to be removed.

```
boolean remove ( GRBVar var )
```

Remove all terms associated with variable *var* from the expression.

### Arguments:

**var:** The variable whose term should be removed.

### Return value:

Returns `true` if the variable appeared in the linear expression (and was removed).

## GRBLinExpr.size()

Retrieve the number of terms in the linear expression (not including the constant).

```
int size ( )
```

### Return value:

Number of terms in the expression.

## 4.10 GRBQuadExpr

Gurobi quadratic expression object. A quadratic expression consists of a linear expression, plus a list of coefficient-variable-variable triples that capture the quadratic terms. Quadratic expressions are used to build quadratic objective functions and quadratic constraints. They are temporary objects that typically have short lifespans.

The `GRBQuadExpr` class is a sub-class of the abstract base class `GRBExpr`.

You generally build quadratic expressions by starting with an empty expression (using the `GRBQuadExpr` constructor), and then adding terms. Terms can be added individually, using `addTerm`, or in groups, using `addTerms`, or `multAdd`. Quadratic terms can be removed from a quadratic expression using `remove`.

Individual quadratic terms in a quadratic expression can be queried using the `getVar1`, `getVar2`, and `getCoeff` methods. You can query the number of quadratic terms in the expression using the `size` method. To query the constant and linear terms associated with a quadratic expression, first obtain the linear portion of the quadratic expression using `getLinExpr`, and then use the `getConstant`, `getCoeff`, and `getVar` methods on the resulting `GRBLinExpr` object.

Note that a quadratic expression may contain multiple terms that involve the same variable pair. These duplicate terms are merged when creating the model objective from an expression, but they may be visible when inspecting individual quadratic terms in the expression (e.g., when using `getVar1` and `getVar2`).

### GRBQuadExpr()

Quadratic expression constructor. Create an empty quadratic expression, or copy an existing expression.

```
| GRBQuadExpr GRBQuadExpr ( )  
  Create an empty quadratic expression.  
  Return value:  
    An empty expression object.
```

```
| GRBQuadExpr GRBQuadExpr ( GRBLinExpr orig )  
  
  Initialize a quadratic expression from an existing linear expression.  
  Arguments:  
    orig: Existing linear expression to copy.  
  Return value:  
    Quadratic expression object whose initial value is taken from the input linear expression.
```

```
| GRBQuadExpr GRBQuadExpr ( GRBQuadExpr orig )  
  
  Copy an existing quadratic expression.  
  Arguments:  
    orig: Existing expression to copy.  
  Return value:  
    A copy of the input expression object.
```

## GRBQuadExpr.add()

Add an expression into a quadratic expression. Upon completion, the invoking quadratic expression will be equal to the sum of itself and the argument expression.

```
| void add ( GRBLinExpr le )
```

Add a linear expression.

**Arguments:**

**le:** Linear expression to add.

```
| void add ( GRBQuadExpr qe )
```

Add a quadratic expression.

**Arguments:**

**qe:** Quadratic expression to add.

## GRBQuadExpr.addConstant()

Add a constant into a quadratic expression.

```
| void addConstant ( double c )
```

**Arguments:**

**c:** Constant to add to expression.

## GRBQuadExpr.addTerm()

Add a single term into a quadratic expression.

```
| void addTerm ( double coeff,  
                GRBVar var )
```

Add a single linear term (**coeff\*var**) into a quadratic expression.

**Arguments:**

**coeff:** Coefficient for new term.

**var:** Variable for new term.

```
| void addTerm ( double coeff,  
                GRBVar var1,  
                GRBVar var2 )
```

Add a single quadratic term (**coeff\*var1\*var2**) into a quadratic expression.

**Arguments:**

**coeff:** Coefficient for new quadratic term.

**var1:** First variable for new quadratic term.

**var2:** Second variable for new quadratic term.

## GRBQuadExpr.addTerms()

Add new terms into a quadratic expression.

```
void addTerms ( double[] coeffs,  
                GRBVar[] vars )
```

Add a list of linear terms into a quadratic expression. Note that the lengths of the two argument arrays must be equal.

### Arguments:

**coeffs:** Coefficients for new terms.  
**vars:** Variables for new terms.

```
void addTerms ( double[] coeffs,  
                GRBVar[] vars,  
                int      start,  
                int      len )
```

Add new linear terms into a quadratic expression. This signature allows you to use arrays to hold the coefficients and variables that describe the linear terms in an array without being forced to add a term for each entry in the array. The **start** and **len** arguments allow you to specify which terms to add.

### Arguments:

**coeffs:** Coefficients for new terms.  
**vars:** Variables for new terms.  
**start:** The first term in the list to add.  
**len:** The number of terms to add.

```
void addTerms ( double[] coeffs,  
                GRBVar[] vars1,  
                GRBVar[] vars2 )
```

Add a list of quadratic terms into a quadratic expression. Note that the lengths of the three argument arrays must be equal.

### Arguments:

**coeffs:** Coefficients for new quadratic terms.  
**vars1:** First variables for new quadratic terms.  
**vars2:** Second variables for new quadratic terms.

```
void addTerms ( double[] coeffs,  
                GRBVar[] vars1,  
                GRBVar[] vars2,  
                int      start,  
                int      len )
```

Add new quadratic terms into a quadratic expression. This signature allows you to use arrays to hold the coefficients and variables that describe the terms in an array without being forced to

add a term for each entry in the array. The **start** and **len** arguments allow you to specify which terms to add.

**Arguments:**

- coeffs:** Coefficients for new quadratic terms.
- vars1:** First variables for new quadratic terms.
- vars2:** Second variables for new quadratic terms.
- start:** The first term in the list to add.
- len:** The number of terms to add.

### **GRBQuadExpr.clear()**

Set a quadratic expression to 0.

```
| void clear ( )
```

### **GRBQuadExpr.getCoeff()**

Retrieve the coefficient from a single quadratic term of the quadratic expression.

```
| double getCoeff ( int i )
```

**Return value:**

Coefficient for the quadratic term at index **i** in the expression.

### **GRBQuadExpr.getLinExpr()**

A quadratic expression is represented as a linear expression, plus a list of quadratic terms. This method retrieves the linear expression associated with the quadratic expression.

```
| GRBLinExpr getLinExpr ( )
```

**Return value:**

Linear expression associated with the quadratic expression.

### **GRBQuadExpr.getValue()**

Compute the value of a quadratic expression for the current solution.

```
| double getValue ( )
```

**Return value:**

Value of the expression for the current solution.

## GRBQuadExpr.getVar1()

Retrieve the first variable object associated with a single quadratic term from the expression.

```
| GRBVar getVar1 ( int i )
```

### Return value:

First variable for the quadratic term at index *i* in the quadratic expression.

## GRBQuadExpr.getVar2()

Retrieve the second variable object associated with a single quadratic term from the expression.

```
| GRBVar getVar2 ( int i )
```

### Return value:

Second variable for the quadratic term at index *i* in the quadratic expression.

## GRBQuadExpr.multAdd()

Add a constant multiple of one quadratic expression into another. Upon completion, the invoking quadratic expression is equal the sum of itself and the constant times the argument expression.

```
| void multAdd ( double m,  
               GRBLinExpr le )
```

Add a linear expression into a quadratic expression.

### Arguments:

**m**: Constant multiplier for added expression.

**le**: Linear expression to add.

```
| void multAdd ( double m,  
               GRBQuadExpr qe )
```

Add a quadratic expression into a quadratic expression.

### Arguments:

**m**: Constant multiplier for added expression.

**qe**: Quadratic expression to add.

## GRBQuadExpr.remove()

Remove a term from a quadratic expression.

```
| void remove ( int i )
```

Remove the quadratic term stored at index *i* of the expression.

**Arguments:**

`i`: The index of the quadratic term to be removed.

```
| boolean remove ( GRBVar var )
```

Remove all quadratic terms associated with variable `var` from the expression.

**Arguments:**

`var`: The variable whose quadratic term should be removed.

**Return value:**

Returns `true` if the variable appeared in the quadratic expression (and was removed).

**GRBQuadExpr.size()**

Retrieve the number of quadratic terms in the quadratic expression. Use [GRBQuadExpr.getLinExpr](#) to retrieve constant or linear terms from the quadratic expression.

```
| int size ( )
```

**Return value:**

Number of quadratic terms in the expression.

## 4.11 GRBColumn

Gurobi column object. A column consists of a list of coefficient, constraint pairs. Columns are used to represent the set of constraints in which a variable participates, and the associated coefficients. They are temporary objects that typically have short lifespans.

You generally build columns by starting with an empty column (using the [GRBColumn](#) constructor), and then adding terms. Terms can be added individually, using [addTerm](#), or in groups, using [addTerms](#). Terms can also be removed from a column, using [remove](#).

Individual terms in a column can be queried using the [getConstr](#), and [getCoeff](#) methods. You can query the number of terms in the column using the [size](#) method.

### GRBColumn()

Column constructor. Create an empty column, or copy an existing column.

```
| GRBColumn GRBColumn ( )
```

Create an empty column.

**Return value:**

An empty column object.

```
| GRBColumn GRBColumn ( GRBColumn orig )
```

Copy an existing column.

**Return value:**

A copy of the input column object.

### GRBColumn.addTerm()

Add a single term into a column.

```
| void addTerm ( double coeff,  
               GRBConstr constr )
```

**Arguments:**

**coeff:** Coefficient for new term.

**constr:** Constraint for new term.

### GRBColumn.addTerms()

Add new terms into a column.

```
| void addTerms ( double[] coeffs,  
                GRBConstr[] constrs )
```

Add a list of terms into a column. Note that the lengths of the two argument arrays must be equal.

**Arguments:**

**coeffs:** Coefficients for added constraints.

**constrs:** Constraints to add to column.

```
void addTerms ( double[]    coeffs,  
                GRBConstr[] constrs,  
                int        start,  
                int        len )
```

Add new terms into a column. This signature allows you to use arrays to hold the coefficients and constraints that describe the terms in an array without being forced to add an term for each member in the array. The **start** and **len** arguments allow you to specify which terms to add.

**Arguments:**

**coeffs:** Coefficients for added constraints.

**constrs:** Constraints to add to column.

**start:** The first term in the list to add.

**len:** The number of terms to add.

**GRBColumn.clear()**

Remove all terms from a column.

```
void clear ( )
```

**GRBColumn.getCoeff()**

Retrieve the coefficient from a single term in the column.

```
double getCoeff ( int i )
```

**Return value:**

Coefficient for the term at index **i** in the column.

**GRBColumn.getConstr()**

Retrieve the constraint object from a single term in the column.

```
GRBConstr getConstr ( int i )
```

**Return value:**

Constraint for the term at index **i** in the column.

## GRBColumn.remove()

Remove a single term from a column.

```
| GRBConstr remove ( int i )
```

Remove the term stored at index `i` of the column.

**Arguments:**

`i`: The index of the term to be removed.

**Return value:**

The constraint whose term was removed from the column. Returns `null` if the specified index is out of range.

```
| boolean remove ( GRBConstr constr )
```

Remove the term associated with constraint `constr` from the column.

**Arguments:**

`constr`: The constraint whose term should be removed.

**Return value:**

Returns `true` if the constraint appeared in the column (and was removed).

## GRBColumn.size()

Retrieve the number of terms in the column.

```
| int size ( )
```

**Return value:**

Number of terms in the column.

## 4.12 GRBCallback

Gurobi callback class. This is an abstract class. To implement a callback, you should create a subclass of this class and implement a `callback()` method. If you pass an object of this subclass to method `GRBModel.setCallback` before calling `GRBModel.optimize`, the `callback()` method of the class will be called periodically. Depending on where the callback is called from, you will be able to obtain various information about the progress of the optimization.

Note that this class contains one protected `int` member variable: `where`. You can query this variable from your `callback()` method to determine where the callback was called from.

Gurobi callbacks can be used both to monitor the progress of the optimization and to modify the behavior of the Gurobi optimizer. A simple user callback function might call the `GRBCallback.getIntInfo` or `GRBCallback.getDoubleInfo` methods to produce a custom display, or perhaps to terminate optimization early (using `GRBCallback.abort`). More sophisticated MIP callbacks might use `GRBCallback.getNodeRel` or `GRBCallback.getSolution` to retrieve values from the solution to the current node, and then use `GRBCallback.addCut` or `GRBCallback.addLazy` to add a constraint to cut off that solution, or `GRBCallback.setSolution` to import a heuristic solution built from that solution.

When solving a model using multiple threads, note that the user callback is only ever called from a single thread, so you don't need to worry about the thread-safety of your callback.

You can look at the `Callback.java` example for details of how to use Gurobi callbacks.

### GRBCallback()

Callback constructor.

```
| GRBCallback GRBCallback ( )  
|   Return value:  
|   A callback object.
```

### GRBCallback.abort()

Abort optimization. When the optimization stops, the `Status` attribute will be equal to `GRB.Status.INTERRUPTED`.

```
| void abort ( )
```

### GRBCallback.addCut()

Add a cutting plane to the MIP model from within a callback function. Note that this method can only be invoked when the `where` member variable is equal to `GRB.CB_MIPNODE` (see the [Callback Codes](#) section for more information).

Cutting planes can be added at any node of the branch-and-cut tree. However, they should be added sparingly, since they increase the size of the relaxation model that is solved at each node and can significantly degrade node processing speed.

Cutting planes are typically used to cut off the current relaxation solution. To retrieve the relaxation solution at the current node, you should first call `getNodeRel`.

When adding your own cuts, you must set parameter [PreCrush](#) to value 1. This setting shuts off a few presolve reductions that sometimes prevent cuts on the original model from being applied to the presolved model.

Note that cutting planes added through this method must truly be cutting planes — they can cut off continuous solutions, but they may not cut off integer solutions that respect the original constraints of the model. Ignoring this restriction will lead to incorrect solutions.

```
void addCut ( GRBLinExpr lhsExpr,
              char       sense,
              double     rhsVal )
```

**Arguments:**

**lhsExpr:** Left-hand side expression for new cutting plane.

**sense:** Sense for new cutting plane (`GRB.LESS_EQUAL`, `GRB.EQUAL`, or `GRB.GREATER_EQUAL`).

**rhsVal:** Right-hand side value for new cutting plane.

## GRBCallback.addLazy()

Add a lazy constraint to the MIP model from within a callback function. Note that this method can only be invoked when the `where` member variable is equal to `GRB.CB_MIPNODE` or `GRB.CB_MIPSOL` (see the [Callback Codes](#) section for more information).

Lazy constraints are typically used when the full set of constraints for a MIP model is too large to represent explicitly. By only including the constraints that are actually violated by solutions found during the branch-and-cut search, it is sometimes possible to find a proven optimal solution while only adding a fraction of the full set of constraints.

You would typically add a lazy constraint by first querying the current node solution (by calling [getSolution](#) from a `GRB.CB_MIPSOL` callback, or [getNodeRel](#) from a `GRB.CB_MIPNODE` callback), and then calling `addLazy()` to add a constraint that cuts off the solution. Gurobi guarantees that you will have the opportunity to cut off any solutions that would otherwise be considered feasible.

Your callback should be prepared to cut off solutions that violate any of your lazy constraints, including those that have already been added. Node solutions will usually respect previously added lazy constraints, but not always.

Note that you must set the [LazyConstraints](#) parameter if you want to use lazy constraints.

```
void addLazy ( GRBLinExpr lhsExpr,
               char       sense,
               double     rhsVal )
```

**Arguments:**

**lhsExpr:** Left-hand side expression for new lazy constraint.

**sense:** Sense for new lazy constraint (`GRB.LESS_EQUAL`, `GRB.EQUAL`, or `GRB.GREATER_EQUAL`).

**rhsVal:** Right-hand side value for new lazy constraint.

## GRBCallback.getDoubleInfo()

Request double-valued callback information. The available information depends on the value of the **where** member. For information on possible values of **where**, and the double-valued information that can be queried for different values of **where**, please refer to the [Callback](#) section.

```
| double getDoubleInfo ( int what )
```

### Arguments:

**what**: Information requested (refer the list of Gurobi [Callback Codes](#) for possible values).

### Return value:

Value of requested callback information.

## GRBCallback.getIntInfo()

Request int-valued callback information. The available information depends on the value of the **where** member. For information on possible values of **where**, and the int-valued information that can be queried for different values of **where**, please refer to the [Callback](#) section.

```
| int getIntInfo ( int what )
```

### Arguments:

**what**: Information requested (refer the list of Gurobi [Callback Codes](#) for possible values).

### Return value:

Value of requested callback information.

## GRBCallback.getNodeRel()

Retrieve node relaxation solution values at the current node. Only available when the **where** member variable is equal to `GRB.CB_MIPNODE`, and `GRB.CB_MIPNODE_STATUS` is equal to `GRB.Status.OPTIMAL`.

```
| double getNodeRel ( GRBVar v )
```

### Arguments:

**v**: The variable whose value is desired.

### Return value:

The value of the specified variable in the node relaxation for the current node.

```
| double[] getNodeRel ( GRBVar[] xvars )
```

### Arguments:

**xvars**: The list of variables whose values are desired.

### Return value:

The values of the specified variables in the node relaxation for the current node.

```
| double[] [] getNodeRel ( GRBVar[] [] xvars )
```

**Arguments:**

**xvars:** The array of variables whose values are desired.

**Return value:**

The values of the specified variables in the node relaxation for the current node.

### GRBCallback.getSolution()

Retrieve values from the current solution vector. Only available when the **where** member variable is equal to GRB.CB\_MIPSOL.

```
| double getSolution ( GRBVar v )
```

**Arguments:**

**v:** The variable whose value is desired.

**Return value:**

The value of the specified variable in the current solution vector.

```
| double[] getSolution ( GRBVar[] xvars )
```

**Arguments:**

**xvars:** The list of variables whose values are desired.

**Return value:**

The values of the specified variables in the current solution.

```
| double[] [] getSolution ( GRBVar[] [] xvars )
```

**Arguments:**

**xvars:** The array of variables whose values are desired.

**Return value:**

The values of the specified variables in the current solution.

### GRBCallback.getStringInfo()

Request string-valued callback information. The available information depends on the value of the **where** member. For information on possible values of **where**, and the string-valued information that can be queried for different values of **where**, please refer to the [Callback](#) section.

```
| String getStringInfo ( int what )
```

**Arguments:**

**what:** Information requested (refer the list of Gurobi [Callback Codes](#) for possible values).

**Return value:**

Value of requested callback information.

## GRBCallback.setSolution()

Import solution values for a heuristic solution. Only available when the `where` member variable is equal to `GRB.CB_MIPNODE`.

When you specify a heuristic solution from a callback, variables initially take undefined values. You should use this method to specify variable values. You can make multiple calls to `setSolution` from one callback invocation to specify values for multiple sets of variables. At the end of the callback, if values have been specified for any variables, the Gurobi optimizer will try to compute a feasible solution from the specified values, possibly filling in values for variables whose values were left undefined.

```
void setSolution ( GRBVar v,  
                  double val )
```

**Arguments:**

- v**: The variable whose values is being set.
- val**: The value of the variable in the new solution.

```
void setSolution ( GRBVar[] xvars,  
                  double[] sol )
```

**Arguments:**

- xvars**: The variables whose values are being set.
- sol**: The desired values of the specified variables in the new solution.

## 4.13 GRBException

Gurobi exception object. This is a sub-class of the Java `Exception` class. A number of useful methods, including `getMessage()` and `printStackTrace()`, are inherited from the parent class. For a list of parent class methods in Java 1.5, visit [this site](#).

### GRBException()

Exception constructor.

```
| GRBException GRBException ( int errcode )
```

Create a Gurobi exception.

**Arguments:**

`errcode`: Error code for exception.

**Return value:**

An exception object.

```
| GRBException GRBException ( String errmsg )
```

Create a Gurobi exception.

**Arguments:**

`errmsg`: Error message for exception.

**Return value:**

An exception object.

```
| GRBException GRBException ( String errmsg,
                             int errcode )
```

Create a Gurobi exception.

**Arguments:**

`errmsg`: Error message for exception.

`errcode`: Error code for exception.

**Return value:**

An exception object.

### GRBException.getErrorCode()

Retrieve the error code associated with a Gurobi exception.

```
| int getErrorCode ( )
```

**Return value:**

The error code associated with the exception.

## 4.14 GRB

Class for Java enums and constants. The enums are used to get or set Gurobi attributes or parameters.

### Constants

The following list contains the set of constants needed by the Gurobi Java interface. You would refer to them using a GRB. prefix (e.g., GRB.Status.OPTIMAL).

```
// Model status codes (after call to optimize())

public class Status {
    public static final int LOADED           = 1;
    public static final int OPTIMAL         = 2;
    public static final int INFEASIBLE      = 3;
    public static final int INF_OR_UNBD    = 4;
    public static final int UNBOUNDED      = 5;
    public static final int CUTOFF         = 6;
    public static final int ITERATION_LIMIT = 7;
    public static final int NODE_LIMIT     = 8;
    public static final int TIME_LIMIT     = 9;
    public static final int SOLUTION_LIMIT = 10;
    public static final int INTERRUPTED    = 11;
    public static final int NUMERIC        = 12;
    public static final int SUBOPTIMAL     = 13;
    public static final int INPROGRESS     = 14;
    public static final int USER_OBJ_LIMIT = 15;
}

// Basis status info

public static final int BASIC           = 0;
public static final int NONBASIC_LOWER = -1;
public static final int NONBASIC_UPPER = -2;
public static final int SUPERBASIC     = -3;

// Constraint senses

public static final char LESS_EQUAL    = '<';
public static final char GREATER_EQUAL = '>';
public static final char EQUAL         = '=';

// Variable types
```

```

public static final char CONTINUOUS    = 'C';
public static final char BINARY       = 'B';
public static final char INTEGER      = 'I';
public static final char SEMICONT     = 'S';
public static final char SEMIINT      = 'N';

// Objective sense

public static final int MINIMIZE = 1;
public static final int MAXIMIZE = -1;

// SOS types

public static final int SOS_TYPE1     = 1;
public static final int SOS_TYPE2     = 2;

// General constraint types

public static final int GENCONSTR_MAX    = 0;
public static final int GENCONSTR_MIN    = 1;
public static final int GENCONSTR_ABS    = 2;
public static final int GENCONSTR_AND    = 3;
public static final int GENCONSTR_OR     = 4;
public static final int GENCONSTR_INDICATOR = 5;

// Numeric constants

public static final double INFINITY     = 1e100;
public static final double UNDEFINED    = 1e101;

// Callback constants

public class Callback {
    public static final int POLLING      = 0;
    public static final int PRESOLVE    = 1;
    public static final int SIMPLEX     = 2;
    public static final int MIP         = 3;
    public static final int MIPSOL      = 4;
    public static final int MIPNODE     = 5;
    public static final int MESSAGE     = 6;
    public static final int BARRIER    = 7;
    public static final int PRE_COLDEL  = 1000;
    public static final int PRE_ROWDEL  = 1001;
    public static final int PRE_SENCHG  = 1002;
    public static final int PRE_BNDCHG  = 1003;
}

```

```

public static final int PRE_COECHG      = 1004;
public static final int SPX_ITRCNT      = 2000;
public static final int SPX_OBJVAL      = 2001;
public static final int SPX_PRIMINF     = 2002;
public static final int SPX_DUALINF     = 2003;
public static final int SPX_ISPERT      = 2004;
public static final int MIP_OBJBST      = 3000;
public static final int MIP_OBJBND      = 3001;
public static final int MIP_NODCNT      = 3002;
public static final int MIP_SOLCNT      = 3003;
public static final int MIP_CUTCNT      = 3004;
public static final int MIP_NODLFT      = 3005;
public static final int MIP_ITRCNT      = 3006;
public static final int MIPSOL_SOL      = 4001;
public static final int MIPSOL_OBJ      = 4002;
public static final int MIPSOL_OBJBST   = 4003;
public static final int MIPSOL_OBJBND   = 4004;
public static final int MIPSOL_NODCNT   = 4005;
public static final int MIPSOL_SOLCNT   = 4006;
public static final int MIPNODE_STATUS= 5001;
public static final int MIPNODE_REL     = 5002;
public static final int MIPNODE_OBJBST= 5003;
public static final int MIPNODE_OBJBND= 5004;
public static final int MIPNODE_NODCNT= 5005;
public static final int MIPNODE_SOLCNT= 5006;
public static final int MSG_STRING      = 6001;
public static final int RUNTIME         = 6002;
public static final int BARRIER_ITRCNT = 7001;
public static final int BARRIER_PRIMOBJ = 7002;
public static final int BARRIER_DUALOBJ = 7003;
public static final int BARRIER_PRIMINF = 7004;
public static final int BARRIER_DUALINF = 7005;
public static final int BARRIER_COMPL   = 7006;
}

```

```
// Errors
```

```

public class Error {
    public static final int OUT_OF_MEMORY      = 10001;
    public static final int NULL_ARGUMENT      = 10002;
    public static final int INVALID_ARGUMENT   = 10003;
    public static final int UNKNOWN_ATTRIBUTE  = 10004;
    public static final int DATA_NOT_AVAILABLE = 10005;
    public static final int INDEX_OUT_OF_RANGE = 10006;
    public static final int UNKNOWN_PARAMETER  = 10007;
}

```

```

public static final int VALUE_OUT_OF_RANGE           = 10008;
public static final int NO_LICENSE                   = 10009;
public static final int SIZE_LIMIT_EXCEEDED         = 10010;
public static final int CALLBACK                    = 10011;
public static final int FILE_READ                   = 10012;
public static final int FILE_WRITE                  = 10013;
public static final int NUMERIC                     = 10014;
public static final int IIS_NOT_INFEASIBLE         = 10015;
public static final int NOT_FOR_MIP                 = 10016;
public static final int OPTIMIZATION_IN_PROGRESS    = 10017;
public static final int DUPLICATES                  = 10018;
public static final int NODEFILE                    = 10019;
public static final int Q_NOT_PSD                   = 10020;
public static final int QCP_EQUALITY_CONSTRAINT     = 10021;
public static final int NETWORK                     = 10022;
public static final int JOB_REJECTED                = 10023;
public static final int NOT_SUPPORTED               = 10024;
public static final int EXCEED_2B_NONZEROS         = 10025;
public static final int INVALID_PIECEWISE_OBJ      = 10026;
public static final int UPDATEMODE_CHANGE          = 10027;
public static final int CLOUD                       = 10028;
public static final int MODEL_MODIFICATION         = 10029;
public static final int NOT_IN_MODEL                = 20001;
public static final int FAILED_TO_CREATE_MODEL     = 20002;
public static final int INTERNAL                    = 20003;
}

```

```

public static final int CUTS_AUTO                   = -1;
public static final int CUTS_OFF                     = 0;
public static final int CUTS_CONSERVATIVE           = 1;
public static final int CUTS_AGGRESSIVE             = 2;
public static final int CUTS_VERYAGGRESSIVE         = 3;

```

```

public static final int METHOD_AUTO                  = -1;
public static final int METHOD_PRIMAL                = 0;
public static final int METHOD_DUAL                  = 1;
public static final int METHOD_BARRIER              = 2;
public static final int METHOD_CONCURRENT            = 3;
public static final int METHOD_DETERMINISTIC_CONCURRENT = 4;

```

```

public static final int BARORDER_AUTOMATIC          = 0;
public static final int BARORDER_AMD                = 1;
public static final int BARORDER_NESTEDDISSECTION  = 2;

```

```

public static final int FEASRELAX_LINEAR            = 0;

```

```
public static final int FEASRELAX_QUADRATIC    = 1;
public static final int FEASRELAX_CARDINALITY = 2;
```

### **GRB.CharAttr**

This enum is used to get or set char-valued attributes (through [GRBModel.get](#) or [GRBModel.set](#)). Please refer to the [Attributes](#) section to see a list of all char attributes and their functions.

### **GRB.DoubleAttr**

This enum is used to get or set double-valued attributes (through [GRBModel.get](#) or [GRBModel.set](#)). Please refer to the [Attributes](#) section to see a list of all double attributes and their functions.

### **GRB.DoubleParam**

This enum is used to get or set double-valued parameters (through [GRBModel.get](#), [GRBModel.set](#), [GRBEnv.get](#), or [GRBEnv.set](#)). Please refer to the [Parameters](#) section to see a list of all double parameters and their functions.

### **GRB.IntAttr**

This enum is used to get or set int-valued attributes (through [GRBModel.get](#) or [GRBModel.set](#)). Please refer to the [Attributes](#) section to see a list of all int attributes and their functions.

### **GRB.IntParam**

This enum is used to get or set int-valued parameters (through [GRBModel.get](#), [GRBModel.set](#), [GRBEnv.get](#), or [GRBEnv.set](#)). Please refer to the [Parameters](#) section to see a list of all int parameters and their functions.

### **GRB.StringAttr**

This enum is used to get or set string-valued attributes (through [GRBModel.get](#) or [GRBModel.set](#)). Please refer to the [Attributes](#) section to see a list of all string attributes and their functions.

### **GRB.StringParam**

This enum is used to get or set string-valued parameters (through [GRBModel.get](#), [GRBModel.set](#), [GRBEnv.get](#), or [GRBEnv.set](#)). Please refer to the [Parameters](#) section to see a list of all string parameters and their functions.

This section documents the Gurobi .NET interface. This manual begins with a quick overview of the classes exposed in the interface and the most important methods on those classes. It then continues with a [comprehensive presentation of all of the available classes and methods](#).

If you are new to the Gurobi Optimizer, we suggest that you start with the [Quick Start Guide](#) or the [Example Tour](#). These documents provide concrete examples of how to use the classes and methods described here.

## Environments

The first step in using the Gurobi .NET interface is to create an environment object. Environments are represented using the [GRBEnv](#) class. An environment acts as the container for all data associated with a set of optimization runs. You will generally only need one environment object in your program.

## Models

You can create one or more optimization models within an environment. Each model is represented as an object of class [GRBModel](#). A model consists of a set of decision variables (objects of class [GRBVar](#)), a linear or quadratic objective function on those variables (specified using [GRBModel.SetObjective](#)), and a set of constraints on these variables (objects of class [GRBConstr](#), [GRBQConstr](#), [GRBSOS](#), or [GRBGenConstr](#)). Each variable has an associated lower bound, upper bound, and type (continuous, binary, etc.). Each linear or quadratic constraint has an associated sense (less-than-or-equal, greater-than-or-equal, or equal), and right-hand side value. Refer to [this section](#) for more information on variables and constraints.

Linear constraints are specified by building linear expressions (objects of class [GRBLinExpr](#)), and then specifying relationships between these expressions (for example, requiring that one expression be equal to another). Quadratic constraints are built in a similar fashion, but using quadratic expressions (objects of class [GRBQuadExpr](#)) instead.

An optimization model may be specified all at once, by loading the model from a file (using the appropriate [GRBModel](#) constructor), or built incrementally, by first constructing an empty object of class [GRBModel](#) and then subsequently calling [GRBModel.AddVar](#) or [GRBModel.AddVars](#) to add additional variables, and [GRBModel.AddConstr](#), [GRBModel.AddQConstr](#), [GRBModel.AddSOS](#), or any of the [GRBModel.AddGenConstrXxx](#) methods to add additional constraints. Models are dynamic entities; you can always add or remove variables or constraints.

We often refer to the *class* of an optimization model. A model with a linear objective function, linear constraints, and continuous variables is a *Linear Program (LP)*. If the objective is quadratic, the model is a *Quadratic Program (QP)*. If any of the constraints are quadratic, the model is a *Quadratically-Constrained Program (QCP)*. We'll sometimes also discuss a special case of QCP, the *Second-Order Cone Program (SOCP)*. If the model contains any integer variables, semi-continuous variables, semi-integer variables, Special Ordered Set (SOS) constraints, or general constraints, the model is a *Mixed Integer Program (MIP)*. We'll also sometimes discuss special cases of MIP, including *Mixed Integer Linear Programs (MILP)*, *Mixed Integer Quadratic Programs (MIQP)*, *Mixed*

*Integer Quadratically-Constrained Programs (MIQCP)*, and *Mixed Integer Second-Order Cone Programs (MISOCP)*. The Gurobi Optimizer handles all of these model classes.

### Solving a Model

Once you have built a model, you can call `GRBModel.Optimize` to compute a solution. By default, `Optimize` will use the `concurrent optimizer` to solve LP models, the barrier algorithm to solve QP and QCP models, and the branch-and-cut algorithm to solve mixed integer models. The solution is stored in a set of *attributes* of the model. These attributes can be queried using a set of attribute query methods on the `GRBModel`, `GRBVar`, `GRBConstr`, `GRBQConstr`, `GRBSOS`, and `GRBGenConstr` classes.

The Gurobi algorithms keep careful track of the state of the model, so calls to `GRBModel.Optimize` will only perform further optimization if relevant data has changed since the model was last optimized. If you would like to discard previously computed solution information and restart the optimization from scratch without changing the model, you can call `GRBModel.Reset`.

After a MIP model has been solved, you can call `GRBModel.FixedModel` to compute the associated *fixed* model. This model is identical to the input model, except that all integer variables are fixed to their values in the MIP solution. In some applications, it is useful to compute information on this continuous version of the MIP model (e.g., dual variables, sensitivity information, etc.).

### Multiple Solutions and Multiple Objectives

By default, the Gurobi Optimizer assumes that your goal is to find one proven optimal solution to a model with a single objective function. Gurobi provides features that allow you to relax either of these assumptions. You should refer to the section on `Solution Pools` for information on how to request more than one solution, or the section on `Multiple Objectives` for information on how to specify multiple objective functions and control the tradeoff between them.

### Infeasible Models

You have a few options if a model is found to be infeasible. You can try to diagnose the cause of the infeasibility, attempt to repair the infeasibility, or both. To obtain information that can be useful for diagnosing the cause of an infeasibility, call `GRBModel.ComputeIIS` to compute an Irreducible Inconsistent Subsystem (IIS). This method can be used for both continuous and MIP models, but you should be aware that the MIP version can be quite expensive. This method populates a set of IIS attributes.

To attempt to repair an infeasibility, call `GRBModel.FeasRelax` to compute a feasibility relaxation for the model. This relaxation allows you to find a solution that minimizes the magnitude of the constraint violation.

### Querying and Modifying Attributes

Most of the information associated with a Gurobi model is stored in a set of attributes. Some attributes are associated with the variables of the model, some with the constraints of the model, and some with the model itself. To give a simple example, solving an optimization model causes the `X` variable attribute to be populated. Attributes such as `X` that are computed by the Gurobi optimizer cannot be modified directly by the user, while others, such as the variable lower bound (the `LB` attribute) can.

Attributes can be accessed in two ways in the .NET interface. The easiest is through .NET properties. To query or modify the `LB` attribute on variable `v`, you would use `v.LB` or `v.LB = 0`, respectively. Attributes can also be queried using `GRBVar.Get`, `GRBConstr.Get`, `GRBQConstr.Get`,

`GRBSOS.Get`, `GRBGenConstr.Get`, or `GRBModel.Get`, and modified using `GRBVar.Set`, `GRBConstr.Set`, `GRBQConstr.Set`, `GRBGenConstr.Set`, or `GRBModel.Set`. Attributes are grouped into a set of enums by type (`GRB.CharAttr`, `GRB.DoubleAttr`, `GRB.IntAttr`, `GRB.StringAttr`). The `Get()` and `Set()` methods are overloaded, so the type of the attribute determines the type of the returned value. Thus, `constr.Get(GRB.DoubleAttr.RHS)` returns a double, while `constr.Get(GRB.CharAttr.Sense)` returns a char.

If you wish to retrieve attribute values for a set of variables or constraints, it is usually more efficient to use the array methods on the associated `GRBModel` object. Method `GRBModel.Get` includes signatures that allow you to query or modify attribute values for one-, two-, and three-dimensional arrays of variables or constraints.

The full list of attributes can be found in the [Attributes](#) section.

### Additional Model Modification Information

Most modifications to an existing model are done through the attribute interface (e.g., changes to variable bounds, constraint right-hand sides, etc.). The main exceptions are modifications to the constraint matrix and to the objective function.

The constraint matrix can be modified in a few ways. The first is to call the `ChgCoeff` method on a `GRBModel` object to change individual matrix coefficients. This method can be used to modify the value of an existing non-zero, to set an existing non-zero to zero, or to create a new non-zero. The constraint matrix is also modified when you remove a variable or constraint from the model (through the `GRBModel.Remove` method). The non-zero values associated with the deleted constraint or variable are removed along with the constraint or variable itself.

The model objective function can also be modified in a few ways. The easiest is to build an expression that captures the objective function (a `GRBLinExpr` or `GRBQuadExpr` object), and then pass that expression to method `GRBModel.SetObjective`. If you wish to modify the objective, you can simply call `setObjective` again with a new `GRBLinExpr` or `GRBQuadExpr` object.

For linear objective functions, an alternative to `SetObjective` is to use the `Obj` variable attribute to modify individual linear objective coefficients.

If your variables have piecewise-linear objectives, you can specify them using the `GRBModel.SetPWLObj` method. Call this method once for each relevant variable. The Gurobi simplex solver includes algorithmic support for convex piecewise-linear objective functions, so for continuous models you should see a substantial performance benefit from using this feature. To clear a previously specified piecewise-linear objective function, simply set the `Obj` attribute on the corresponding variable to 0.

### Lazy Updates

One important item to note about model modification in the Gurobi optimizer is that it is performed in a *lazy* fashion, meaning that modifications don't affect the model immediately. Rather, they are queued and applied later. If your program simply creates a model and solves it, you will probably never notice this behavior. However, if you ask for information about the model before your modifications have been applied, the details of the lazy update approach may be relevant to you.

As we just noted, model modifications (bound changes, right-hand side changes, objective changes, etc.) are placed in a queue. These queued modifications can be applied to the model in three different ways. The first is by an explicit call to `GRBModel.Update`. The second is by a call to `GRBModel.Optimize`. The third is by a call to `GRBModel.Write` to write out the model. The

first case gives you fine-grained control over when modifications are applied. The second and third make the assumption that you want all pending modifications to be applied before you optimize your model or write it to disk.

Why does the Gurobi interface behave in this manner? There are a few reasons. The first is that this approach makes it much easier to perform multiple modifications to a model, since the model remains unchanged between modifications. The second is that processing model modifications can be expensive, particularly in a Compute Server environment, where modifications require communication between machines. Thus, it is useful to have visibility into exactly when these modifications are applied. In general, if your program needs to make multiple modifications to the model, you should aim to make them in phases, where you make a set of modifications, then update, then make more modifications, then update again, etc. Updating after each individual modification can be extremely expensive.

If you forget to call `update`, your program won't crash. Your query will simply return the value of the requested data from the point of the last update. If the object you tried to query didn't exist then, you'll get a `NOT_IN_MODEL` exception instead.

The semantics of lazy updates have changed in this release. While the vast majority of programs will continue to work unmodified, you can use the `UpdateMode` parameter to revert to the previous behavior if you run into an issue.

## Managing Parameters

The Gurobi optimizer provides a set of parameters that allow you to control many of the details of the optimization process. Factors like feasibility and optimality tolerances, choices of algorithms, strategies for exploring the MIP search tree, etc., can be controlled by modifying Gurobi parameters before beginning the optimization. Parameters can be of type *int*, *double*, or *string*.

The simplest way to set parameters is through the `Model.Parameters` class and its associated `.NET` properties. To set the `MIPGap` parameter to 0.0 for model `m`, for example, you would do `m.Parameters.MIPGap = 0`.

Parameters can also be set on the Gurobi environment object, using `GRBEnv.Set`. Note that each model gets its own copy of the environment when it is created, so parameter changes to the original environment have no effect on existing models.

You can read a set of parameter settings from a file using `GRBEnv.ReadParams`, or write the set of changed parameters using `GRBEnv.WriteParams`.

We also include an automated parameter tuning tool that explores many different sets of parameter changes in order to find a set that improves performance. You can call `GRBModel.Tune` to invoke the tuning tool on a model. Refer to the [parameter tuning tool](#) section for more information.

The full list of Gurobi parameters can be found in the [Parameters](#) section.

## Memory Management

Users typically do not need to concern themselves with memory management in `.NET`, since it is handled automatically by the garbage collector. The Gurobi `.NET` interface utilizes the same garbage collection mechanism as other `.NET` programs, but there are a few specifics of our memory management that users should be aware of.

In general, Gurobi objects live in the same `.NET` heap as other `.NET` objects. When they are no longer referenced, they become candidates for garbage collection, and are returned to the pool of free space at the next invocation of the garbage collector. Two important exceptions are the `GRBEnv` and `GRBModel` objects. A `GRBModel` object has a small amount of memory associated

with it in the .NET heap, but the majority of the space associated with a model lives in the heap of the Gurobi native code DLL. The .NET heap manager is unaware of the memory associated with the model in the native code library, so it does not consider this memory usage when deciding whether to invoke the garbage collector. When the garbage collector eventually collects the .NET `GRBModel` object, the memory associated with the model in the Gurobi native code library will be freed, but this collection may come later than you might want. Similar considerations apply to the `GRBEnv` object.

If you are writing a .NET program that makes use of multiple Gurobi models or environments, we recommend that you call `GRBModel.Dispose` when you are done using the associated `GRBModel` object, and `GRBEnv.Dispose` when you are done using the associated `GRBEnv` object and after you have called `GRBModel.Dispose` on all of the models created using that `GRBEnv` object.

## Native Code

As noted earlier, the Gurobi .NET interface is a thin layer that sits on top of our native code DLL. Thus, an application that uses the Gurobi .NET library will load the Gurobi DLL at runtime. In order for this happen, you need to make sure that two things are true. First, you need to make sure that the native code library is available in the Windows `PATH`. This environment variable is set up as part of the installation of the Gurobi Optimizer, but it may not be configured appropriately on a machine where the full Gurobi Optimizer has not been installed. Second, you need to be sure that the selected .NET Platform Target (as selected in Visual Studio) is compatible with the Gurobi DLL that is available through your `PATH`. In particular, you need to use the 32-bit Gurobi native library when you've selected the `x86` Platform Target, and similarly you need to use the 64-bit Gurobi native library when you've selected the `x64` Platform Target. If you use the default `Any` CPU target, then your .NET application will look for the 64-bit Gurobi DLL on a 64-bit Windows machine, and the 32-bit DLL on a 32-bit Windows machine.

## Monitoring Progress - Logging and Callbacks

Progress of the optimization can be monitored through Gurobi logging. By default, Gurobi will send output to the screen. A few simple controls are available for modifying the default logging behavior. If you would like to direct output to a file as well as to the screen, specify the log file name in the `GRBEnv` constructor. You can modify the `LogFile` parameter if you wish to redirect the log to a different file after creating the environment object. The frequency of logging output can be controlled with the `DisplayInterval` parameter, and logging can be turned off entirely with the `OutputFlag` parameter. A detailed description of the Gurobi log file can be found in the [Logging](#) section.

More detailed progress monitoring can be done through the `GRBCallback` class. The `GRBModel.SetCallback` method allows you to receive a periodic callback from the Gurobi optimizer. You do this by sub-classing the `GRBCallback` abstract class, and writing your own `Callback()` method on this class. You can call `GRBCallback.GetDoubleInfo`, `GRBCallback.GetIntInfo`, `GRBCallback.GetStringInfo`, or `GRBCallback.GetSolution` from within the callback to obtain additional information about the state of the optimization.

## Modifying Solver Behavior - Callbacks

Callbacks can also be used to modify the behavior of the Gurobi optimizer. The simplest control callback is `GRBCallback.Abort`, which asks the optimizer to terminate at the earliest convenient point. Method `GRBCallback.SetSolution` allows you to inject a feasible solution (or partial solution)

during the solution of a MIP model. Methods [GRBCallback.AddCut](#) and [GRBCallback.AddLazy](#) allow you to add *cutting planes* and *lazy constraints* during a MIP optimization, respectively.

### **Error Handling**

All of the methods in the Gurobi .NET library can throw an exception of type [GRBException](#). When an exception occurs, additional information on the error can be obtained by retrieving the error code (using property [GRBException.ErrorCode](#)), or by retrieving the exception message (using property [GRBException.Message](#) from the parent class). The list of possible error return codes can be found in the [Error Codes](#) section.

## 5.1 GRBEnv

Gurobi environment object. Gurobi models are always associated with an environment. You must create an environment before you can create and populate a model. You will generally only need a single environment object in your program.

Objects of this class have unmanaged resources associated with them. The class implements the `IDisposable` interface.

The methods on environment objects are mainly used to manage Gurobi parameters (e.g., [Get](#), [GetParamInfo](#), [Set](#)).

While the .NET garbage collector will eventually collect an unused `GRBEnv` object, an environment will hold onto resources (Gurobi licenses, file descriptors, etc.) until that collection occurs. If your program creates multiple `GRBEnv` objects, we recommend that you call [GRBEnv.Dispose](#) when you are done using one (or use the .NET `using` statement).

### GRBEnv()

Environment constructor.

Constructor for `GRBEnv` object. If the constructor is called with no arguments, no log file will be written for the environment.

You have the option of constructing either a local environment, which solves Gurobi models on the local machine, a client environment for a Gurobi compute server, which will solve Gurobi models on a server machine, or an Instant Cloud environment, which will launch a Gurobi Cloud server and solve models on that server. Choose the appropriate signature for the type of environment you wish to launch.

Note that the `GRBEnv` constructor will check the current working directory for a file named `gurobi.env`, and it will attempt to read parameter settings from this file if it exists. The file should be in [PRM](#) format (briefly, each line should contain a parameter name, followed by the desired value for that parameter).

In general, you should aim to create a single Gurobi environment object in your program, even if you plan to work with multiple models. Reusing one environment is much more efficient than creating and destroying multiple environments.

```
| GRBEnv GRBEnv ( )
```

Create a Gurobi environment (with logging disabled).

**Return value:**

An environment object (with no associated log file).

```
| GRBEnv GRBEnv ( string logFileName )
```

Create a Gurobi environment (with logging enabled).

**Arguments:**

**logFileName:** The desired log file name.

**Return value:**

An environment object.

```
GRBEnv GRBEnv ( string logFileName,
                string computeserver,
                int    port,
                string password,
                int    priority,
                double timeout )
```

Create a client Gurobi environment on a compute server.

**Arguments:**

**logFileName:** The name of the log file for this environment. Pass an empty string for no log file.

**computeserver:** A comma-separated list of Gurobi compute servers. You can refer to compute server machines using their names or their IP addresses.

**port:** The port number used to connect to the compute server. You should pass a -1 value, which indicates that the default port should be used, unless your server administrator has changed our recommended port settings.

**password:** The password for gaining access to the specified compute servers. Pass an empty string if no password is required.

**priority:** The priority of the job. Priorities must be between -100 and 100, with a default value of 0 (by convention). Higher priority jobs are chosen from the server job queue before lower priority jobs. A job with priority 100 runs immediately, bypassing the job queue and ignoring the job limit on the server. You should exercise caution with priority 100 jobs, since they can severely overload a server, which can cause jobs to fail, and in extreme cases can cause the server to crash.

**timeout:** Job timeout (in seconds). If the job doesn't reach the front of the queue before the specified timeout, the constructor will throw a `JOB_REJECTED` exception. Use a negative value to indicate that the call should never timeout.

**Return value:**

An environment object.

```
GRBEnv GRBEnv ( string logFileName,
                string accessID,
                string secretKey,
                string pool )
```

Create a Gurobi environment on Gurobi Instant Cloud

**Arguments:**

**logfile**name: The name of the log file for this environment. May be `NULL` (or an empty string), in which case no log file is created.

**accessID:** The access ID for your Gurobi Instant Cloud license. This can be retrieved from the Gurobi Instant Cloud website. When used in combination with your `secretKey`, this allows you to launch Instant Cloud instances and submit jobs to them.

**secretKey:** The secret key for your Gurobi Instant Cloud license. This can be retrieved from the Gurobi Instant Cloud website. When used in combination with your `accessID`, this allows you to launch Instant Cloud instances and submit jobs to them. Note that you should keep your secret key private.

**pool:** The machine pool. Machine pools allow you to create fixed configurations on the Instant Cloud website (capturing things like type of machine, geographic region, etc.), and then launch and share machines from client programs without having to restate the configuration information each time you launch a machine. May be an empty string, in which case your job will be launched in the default pool associated with your cloud license.

**Return value:**

An environment object.

## GRBEnv.Dispose()

Release the resources associated with a `GRBEnv` object. While the .NET garbage collector will eventually reclaim these resources, we recommend that you call the `Dispose` method when you are done using an environment if your program creates more than one.

The `Dispose` method on a `GRBEnv` should be called only after you have called `Dispose` on all of the models that were created within that environment. You should not attempt to use a `GRBEnv` object after calling `Dispose`.

```
| void Dispose ( )
```

## GRBEnv.ErrorMessage

(Property) The error message for the most recent exception associated with this environment.

## GRBEnv.Get()

Query the value of a parameter.

```
| double Get ( GRB.DoubleParam param )
```

Query the value of a double-valued parameter.

**Arguments:**

**param:** The parameter being queried. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**Return value:**

The current value of the requested parameter.

```
| int Get ( GRB.IntParam param )
```

Query the value of an int-valued parameter.

**Arguments:**

**param:** The parameter being queried. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**Return value:**

The current value of the requested parameter.

```
| string Get ( GRB.StringParam param )
```

Query the value of a string-valued parameter.

**Arguments:**

**param:** The parameter being queried. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**Return value:**

The current value of the requested parameter.

## GRBEnv.GetParamInfo()

Obtain information about a parameter.

```
void GetParamInfo ( GRB.DoubleParam param,  
                   double[] info )
```

Obtain detailed information about a double parameter.

**Arguments:**

**param:** The parameter of interest. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**info:** The returned information. The result will contain four entries: the current value of the parameter, the minimum allowed value, the maximum allowed value, and the default value.

```
void GetParamInfo ( GRB.IntParam param,  
                   int[] info )
```

Obtain detailed information about an integer parameter.

**Arguments:**

**param:** The parameter of interest. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**info:** The returned information. The result will contain four entries: the current value of the parameter, the minimum allowed value, the maximum allowed value, and the default value.

```
void GetParamInfo ( GRB.StringParam param,  
                   string[] info )
```

Obtain detailed information about a string parameter.

**Arguments:**

**param:** The parameter of interest. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**info:** The returned information. The result will contain two entries: the current value of the parameter and the default value.

## GRBEnv.Message()

Write a message to the console and the log file.

```
| void Message ( string message )
```

### Arguments:

**message:** Print a message to the console and to the log file. Note that this call has no effect unless the `OutputFlag` parameter is set.

## GRBEnv.ReadParams()

Read new parameter settings from a file.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

```
| void ReadParams ( string paramfile )
```

### Arguments:

**paramfile:** Name of the file containing parameter settings. Parameters should be listed one per line, with the parameter name first and the desired value second. For example:

```
# Gurobi parameter file
Threads 1
MIPGap 0
```

Blank lines and lines that begin with the hash symbol are ignored.

## GRBEnv.Release()

Release the license associated with this environment. You will no longer be able to call [Optimize](#) on models created with this environment after the license has been released.

```
| void Release ( )
```

## GRBEnv.ResetParams()

Reset all parameters to their default values.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

```
| void ResetParams ( )
```

## GRBEnv.Set()

Set the value of a parameter.

### Important notes:

Note that a model gets its own copy of the environment when it is created. Changes to the original environment have no effect on the copy. Use [GRBModel.Set](#) to change a parameter on an existing model.

```
void Set ( GRB.DoubleParam param,  
           double          newvalue )
```

Set the value of a double-valued parameter.

**Arguments:**

**param:** The parameter being modified. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

```
void Set ( GRB.IntParam  param,  
           int           newvalue )
```

Set the value of an int-valued parameter.

**Arguments:**

**param:** The parameter being modified. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

```
void Set ( GRB.StringParam param,  
           string          newvalue )
```

Set the value of a string-valued parameter.

**Arguments:**

**param:** The parameter being modified. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

```
void Set ( string param,  
           string newvalue )
```

Set the value of any parameter using strings alone.

**Arguments:**

**param:** The name of the parameter being modified. Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**newvalue:** The desired new value of the parameter.

## GRBEnv.WriteParams()

Write all non-default parameter settings to a file.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

```
void WriteParams ( string paramfile )
```

**Arguments:**

**paramfile:** Name of the file to which non-default parameter settings should be written. The previous contents are overwritten.

## 5.2 GRBModel

Gurobi model object. Commonly used methods include [AddVar](#) (adds a new decision variable to the model), [AddConstr](#) (adds a new constraint to the model), [Optimize](#) (optimizes the current model), and [Get](#) (retrieves the value of an attribute).

Objects of this class have unmanaged resources associated with them. The class implements the `IDisposable` interface.

While the .NET garbage collector will eventually collect an unused `GRBModel` object, the vast majority of the memory associated with a model is stored outside of the .NET heap. As a result, the garbage collector can't see this memory usage, and thus it can't take this quantity into account when deciding whether collection is necessary. We recommend that you call [GRBModel.Dispose](#) when you are done using a model (or use the .NET `using` statement).

### GRBModel()

Constructor for `GRBModel`. The simplest version creates an empty model. You can then call [AddVar](#) and [AddConstr](#) to populate the model with variables and constraints. The more complex constructors can read a model from a file, or make a copy of an existing model.

```
| GRBModel GRBModel ( GRBEnv env )
```

Model constructor.

**Arguments:**

**env:** Environment for new model.

**Return value:**

New model object. Model initially contains no variables or constraints.

```
| GRBModel GRBModel ( GRBEnv env,  
                      string filename )
```

Read a model from a file. Note that the type of the file is encoded in the file name suffix. Valid suffixes are `.mps`, `.rew`, `.lp`, `.rlp`, `.ilp`, or `.opb`. The files can be compressed, so additional suffixes of `.zip`, `.gz`, `.bz2`, or `.7z` are accepted.

**Arguments:**

**env:** Environment for new model.

**modelName:** Name of the file containing the model.

**Return value:**

New model object.

```
| GRBModel GRBModel ( GRBModel model )
```

Create a copy of an existing model.

**Arguments:**

**model:** Model to copy.

**Return value:**

New model object. Model is a clone of the input model.

## GRBModel.AddConstr()

Add a single linear constraint to a model. Multiple signatures are available.

```
GRBConstr AddConstr ( GRBLinExpr lhsExpr,  
                        char         sense,  
                        GRBLinExpr rhsExpr,  
                        string        name )
```

Add a single linear constraint to a model.

### Arguments:

**lhsExpr**: Left-hand side expression for new linear constraint.

**sense**: Sense for new linear constraint (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhsExpr**: Right-hand side expression for new linear constraint.

**name**: Name for new constraint.

### Return value:

New constraint object.

```
GRBConstr AddConstr ( GRBTempConstr tempConstr,  
                        string         name )
```

Add a single linear constraint to a model.

### Arguments:

**tempConstr**: Temporary constraint object, created by an overloaded comparison operator. See [GRBTempConstr](#) for more information.

**name**: Name for new constraint.

### Return value:

New constraint object.

## GRBModel.AddConstrs()

Add new linear constraints to a model.

We recommend that you build your model one constraint at a time (using [AddConstr](#)), since it introduces no significant overhead and we find that it produces simpler code. Feel free to use these methods if you disagree, though.

```
GRBConstr[] AddConstrs ( int count )
```

Add count new linear constraints to a model. The new constraints are all of the form  $0 \leq 0$ .

### Arguments:

**count**: Number of constraints to add.

### Return value:

Array of new constraint objects.

```
GRBConstr[] AddConstrs ( GRBLinExpr[] lhsExprs,  
                            char[]       senses,  
                            double[]     rhsVals,  
                            string[]     names )
```

Add new linear constraints to a model. The number of added constraints is determined by the length of the input arrays (which must be consistent across all arguments).

**Arguments:**

**lhsExprs:** Left-hand side expressions for the new linear constraints.

**senses:** Senses for new linear constraints (`GRB.LESS_EQUAL`, `GRB.EQUAL`, or `GRB.GREATER_EQUAL`).

**rhsVals:** Right-hand side values for the new linear constraints.

**names:** Names for new constraints.

**Return value:**

Array of new constraint objects.

```
GRBConstr[] AddConstrs ( GRBLinExpr[] lhsExprs,
                        char[] senses,
                        GRBLinExpr[] rhsExprs,
                        int start,
                        int len,
                        string[] names )
```

Add new linear constraints to a model. This signature allows you to use arrays to hold the various constraint attributes (left-hand side, sense, etc.), without forcing you to add one constraint for each entry in the array. The `start` and `len` arguments allow you to specify which constraints to add.

**Arguments:**

**lhsExprs:** Left-hand side expressions for the new linear constraints.

**senses:** Senses for new linear constraints (`GRB.LESS_EQUAL`, `GRB.EQUAL`, or `GRB.GREATER_EQUAL`).

**rhs:** Right-hand side expressions for the new linear constraints.

**start:** The first constraint in the list to add.

**len:** The number of variables to add.

**names:** Names for new constraints.

**Return value:**

Array of new constraint objects.

## GRBModel.AddGenConstrXxx()

Each of the functions described below adds a new *general constraint* to a model.

Mathematical programming has traditionally defined a set of fundamental constraint types: variable bound constraints, linear constraints, quadratic constraints, integrality constraints, and SOS constraints. These are typically treated directly by the underlying solver (although not always), and are fundamental to the overall algorithm.

Gurobi accepts a number of additional constraint types, which we collectively refer to as *general constraints*. These are typically *not* treated directly by the solver. Rather, they are transformed by presolve into mathematically equivalent sets of constraints (and variables), chosen from among the fundamental types listed above. These general constraints are provided as a convenience to users. If such constraints appear in your model, but if you prefer to reformulate them yourself using fundamental constraint types instead, you can certainly do so. However, note that Gurobi

can sometimes exploit information contained in the other constraints in the model to build a more efficient formulation than what you might create.

The additional constraint types that fall under this *general constraint* umbrella are:

- MAX ([AddGenConstrMax](#)): set a decision variable equal to the maximum value from among a set of decision variables
- MIN ([AddGenConstrMin](#)): set a decision variable equal to the minimum value from among a set of decision variables
- ABS ([AddGenConstrAbs](#)): set a decision variable equal to the absolute value of some other decision variable
- AND ([AddGenConstrAnd](#)): set a binary variable equal to one if and only if all of a set of binary decision variables are equal to one
- OR ([AddGenConstrOr](#)): set a binary variable equal to one if and only if at least one variable out of a set of binary decision variables is equal to one
- INDICATOR ([AddGenConstrIndicator](#)): a given binary variable may only take a certain value if a given linear constraint is satisfied

Please refer to [this section](#) for additional details on general constraints.

### **GRBModel.AddGenConstrMax()**

Add a new general constraint of type `GRB.GENCONSTR_MAX` to a model.

A MAX constraint  $r = \max\{x_1, \dots, x_n, c\}$  states that the resultant variable  $r$  should be equal to the maximum of the operand variables  $x_1, \dots, x_n$  and the constant  $c$ .

```
GRBGenConstr AddGenConstrMax ( GRBVar   resvar,  
                               GRBVar[] vars,  
                               double    constant,  
                               string     name )
```

#### **Arguments:**

**resvar:** The resultant variable of the new constraint.

**vars:** Array of variables that are the operands of the new constraint.

**constant:** The additional constant operand of the new constraint.

**name:** Name for the new general constraint.

#### **Return value:**

New general constraint.

### GRBModel.AddGenConstrMin()

Add a new general constraint of type `GRB.GENCONSTR_MIN` to a model.

A MIN constraint  $r = \min\{x_1, \dots, x_n, c\}$  states that the resultant variable  $r$  should be equal to the minimum of the operand variables  $x_1, \dots, x_n$  and the constant  $c$ .

```
GRBGenConstr AddGenConstrMin ( GRBVar  resvar,  
                               GRBVar[] vars,  
                               double   constant,  
                               string   name )
```

#### Arguments:

**resvar:** The resultant variable of the new constraint.

**vars:** Array of variables that are the operands of the new constraint.

**constant:** The additional constant operand of the new constraint.

**name:** Name for the new general constraint.

#### Return value:

New general constraint.

### GRBModel.AddGenConstrAbs()

Add a new general constraint of type `GRB.GENCONSTR_ABS` to a model.

An ABS constraint  $r = \text{abs}\{x\}$  states that the resultant variable  $r$  should be equal to the absolute value of the argument variable  $x$ .

```
GRBGenConstr AddGenConstrAbs ( GRBVar  resvar,  
                               GRBVar  argvar,  
                               string   name )
```

#### Arguments:

**resvar:** The resultant variable of the new constraint.

**argvar:** The argument variable of the new constraint.

**name:** Name for the new general constraint.

#### Return value:

New general constraint.

### GRBModel.AddGenConstrAnd()

Add a new general constraint of type `GRB.GENCONSTR_AND` to a model.

An AND constraint  $r = \text{and}\{x_1, \dots, x_n\}$  states that the binary resultant variable  $r$  should be 1 if and only if all of the operand variables  $x_1, \dots, x_n$  are equal to 1. If any of the operand variables is 0, then the resultant should be 0 as well.

Note that all variables participating in such a constraint will be forced to be binary; independently of how they were created.

```
GRBGenConstr AddGenConstrAnd ( GRBVar  resvar,  
                               GRBVar[] vars,  
                               string   name )
```

**Arguments:**

- resvar:** The resultant variable of the new constraint.
- vars:** Array of variables that are the operands of the new constraint.
- name:** Name for the new general constraint.

**Return value:**

New general constraint.

**GRBModel.AddGenConstrOr()**

Add a new general constraint of type `GRB.GENCONSTR_OR` to a model.

An OR constraint  $r = \text{or}\{x_1, \dots, x_n\}$  states that the binary resultant variable  $r$  should be 1 if and only if any of the operand variables  $x_1, \dots, x_n$  is equal to 1. If all operand variables are 0, then the resultant should be 0 as well.

Note that all variables participating in such a constraint will be forced to be binary; independently of how they were created.

```
GRBGenConstr AddGenConstrOr ( GRBVar    resvar,
                              GRBVar[]  vars,
                              string     name )
```

**Arguments:**

- resvar:** The resultant variable of the new constraint.
- vars:** Array of variables that are the operands of the new constraint.
- name:** Name for the new general constraint.

**Return value:**

New general constraint.

**GRBModel.AddGenConstrIndicator()**

Add a new general constraint of type `GRB.GENCONSTR_INDICATOR` to a model.

An INDICATOR constraint  $z = f \rightarrow a^T x \leq b$  states that if the binary indicator variable  $z$  is equal to  $f \in \{0, 1\}$ , then the linear constraint  $a^T x \leq b$  should hold. On the other hand, if  $z = 1 - f$ , the linear constraint may be violated. The sense of the linear constraint can also be specified to be  $=$  or  $\geq$ .

Note that the indicator variable  $z$  of a constraint will be forced to be binary; independently of how it was created.

Multiple signatures are available.

```
GRBGenConstr AddGenConstrIndicator ( GRBVar    binvar,
                                     int        binval,
                                     GRBLinExpr expr,
                                     char       sense,
                                     double     rhs,
                                     string     name )
```

**Arguments:**

- binvar:** The binary indicator variable.

**binval:** The value for the binary indicator variable that would force the linear constraint to be satisfied (0 or 1).

**expr:** Left-hand side expression for the linear constraint triggered by the indicator.

**sense:** Sense for the linear constraint. Options are `GRB.LESS_EQUAL`, `GRB.EQUAL`, or `GRB.GREATER_EQUAL`.

**rhs:** Right-hand-side value for the linear constraint.

**name:** Name for the new general constraint.

**Return value:**

New general constraint.

```
GRBGenConstr AddGenConstrIndicator ( GRBVar      binvar,
                                     int          binval,
                                     GRBTempConstr constr,
                                     string       name )
```

**Arguments:**

**binvar:** The binary indicator variable.

**binval:** The value for the binary indicator variable that would force the linear constraint to be satisfied (0 or 1).

**constr:** Temporary constraint object defining the linear constraint that is triggered by the indicator. The temporary constraint object is created using an overloaded comparison operator. See [GRBTempConstr](#) for more information.

**name:** Name for the new general constraint.

**Return value:**

New general constraint.

## GRBModel.AddQConstr()

Add a quadratic constraint to a model. Multiple signatures are available.

Important note: the algorithms that Gurobi uses to solve quadratically constrained problems can only handle certain types of quadratic constraints. Constraints of the following forms are always accepted:

- $x^T Q x + q^T x \leq b$ , where  $Q$  is Positive Semi-Definite (PSD)
- $x^T x \leq y^2$ , where  $x$  is a vector of variables, and  $y$  is a non-negative variable (a Second-Order Cone)
- $x^T x \leq yz$ , where  $x$  is a vector of variables, and  $y$  and  $z$  are non-negative variables (a rotated Second-Order Cone)

If you add a constraint that isn't in one of these forms (and Gurobi presolve is unable to transform the constraint into one of these forms), you'll get an error when you try to solve the model. Constraints where the quadratic terms only involve binary variables will always be transformed into one of these forms.

```
GRBQConstr AddQConstr ( GRBQuadExpr lhsExpr,  
                          char         sense,  
                          GRBQuadExpr rhsExpr,  
                          string       name )
```

Add a quadratic constraint to a model.

**Arguments:**

**lhsExpr:** Left-hand side expression for new quadratic constraint.

**sense:** Sense for new quadratic constraint (`GRB.LESS_EQUAL` or `GRB.GREATER_EQUAL`).

**rhsExpr:** Right-hand side expression for new quadratic constraint.

**name:** Name for new constraint.

**Return value:**

New quadratic constraint object.

```
GRBQConstr AddQConstr ( GRBTempConstr tempConstr,  
                          string       name )
```

Add a quadratic constraint to a model.

**Arguments:**

**tempConstr:** Temporary constraint object, created by an overloaded comparison operator.  
See [GRBTempConstr](#) for more information.

**name:** Name for new constraint.

**Return value:**

New quadratic constraint object.

## GRBModel.AddRange()

Add a single range constraint to a model. A range constraint states that the value of the input expression must be between the specified **lower** and **upper** bounds in any solution.

Note that range constraints are stored internally as equality constraints. We add an extra variable to the model to capture the range information. Thus, the **Sense** attribute on a range constraint will always be `GRB.EQUAL`.

```
GRBConstr AddRange ( GRBLinExpr expr,  
                      double     lower,  
                      double     upper,  
                      string     name )
```

**Arguments:**

**expr:** Linear expression for new range constraint.

**lower:** Lower bound for linear expression.

**upper:** Upper bound for linear expression.

**name:** Name for new constraint.

**Return value:**

New constraint object.

## GRBModel.AddRanges()

Add new range constraints to a model. A range constraint states that the value of the input expression must be between the specified **lower** and **upper** bounds in any solution.

```
GRBConstr[] AddRanges ( GRBLinExpr[] exprs,  
                        double[]     lower,  
                        double[]     upper,  
                        string[]     names )
```

### Arguments:

**exprs**: Linear expressions for the new range constraints.

**lower**: Lower bounds for linear expressions.

**upper**: Upper bounds for linear expressions.

**name**: Names for new range constraints.

**count**: Number of range constraints to add.

### Return value:

Array of new constraint objects.

## GRBModel.AddSOS()

Add an SOS constraint to the model. Please refer to [this section](#) for details on SOS constraints.

```
GRBSOS AddSOS ( GRBVar[] vars,  
                double[] weights,  
                int     type )
```

### Arguments:

**vars**: Array of variables that participate in the SOS constraint.

**weights**: Weights for the variables in the SOS constraint.

**type**: SOS type (can be GRB.SOS\_TYPE1 or GRB.SOS\_TYPE2).

### Return value:

New SOS constraint.

## GRBModel.AddVar()

Add a single decision variable to a model.

```
GRBVar AddVar ( double lb,  
                double ub,  
                double obj,  
                char  type,  
                string name )
```

Add a variable to a model; non-zero entries will be added later.

### Arguments:

**lb**: Lower bound for new variable.

**ub**: Upper bound for new variable.

**obj:** Objective coefficient for new variable.  
**type:** Variable type for new variable (GRB.CONTINUOUS, GRB.BINARY, GRB.INTEGER, GRB.SEMICONT, or GRB.SEMIINT).  
**name:** Name for new variable.

**Return value:**

New variable object.

```
GRBVar AddVar ( double lb,  
               double ub,  
               double obj,  
               char type,  
               GRBConstr[] constrs,  
               double[] coeffs,  
               string name )
```

Add a variable to a model, and the associated non-zero coefficients.

**Arguments:**

**lb:** Lower bound for new variable.  
**ub:** Upper bound for new variable.  
**obj:** Objective coefficient for new variable.  
**type:** Variable type for new variable (GRB.CONTINUOUS, GRB.BINARY, GRB.INTEGER, GRB.SEMICONT, or GRB.SEMIINT).  
**constrs:** Array of constraints in which the variable participates.  
**coeffs:** Array of coefficients for each constraint in which the variable participates. The lengths of the **constrs** and **coeffs** arrays must be identical.  
**name:** Name for new variable.

**Return value:**

New variable object.

```
GRBVar AddVar ( double lb,  
               double ub,  
               double obj,  
               char type,  
               GRBColumn col,  
               string name )
```

Add a variable to a model. This signature allows you to specify the set of constraints to which the new variable belongs using a [GRBColumn](#) object.

**Arguments:**

**lb:** Lower bound for new variable.  
**ub:** Upper bound for new variable.  
**obj:** Objective coefficient for new variable.  
**type:** Variable type for new variable (GRB.CONTINUOUS, GRB.BINARY, GRB.INTEGER, GRB.SEMICONT, or GRB.SEMIINT).  
**col:** GRBColumn object for specifying a set of constraints to which new variable belongs.  
**name:** Name for new variable.

**Return value:**

New variable object.

**GRBModel.AddVars()**

Add new decision variables to a model.

```
GRBVar[] AddVars ( int count,
                  char type )
```

Add `count` new decision variables to a model. All associated attributes take their default values, except the variable `type`, which is specified as an argument.

**Arguments:**

**count:** Number of variables to add.

**type:** Variable type for new variables (GRB.CONTINUOUS, GRB.BINARY, GRB.INTEGER, GRB.SEMICONT, or GRB.SEMIINT).

**Return value:**

Array of new variable objects.

```
GRBVar[] AddVars ( double[] lb,
                  double[] ub,
                  double[] obj,
                  char[] type,
                  string[] names )
```

Add new decision variables to a model. The number of added variables is determined by the length of the input arrays (which must be consistent across all arguments).

**Arguments:**

**lb:** Lower bounds for new variables. Can be `null`, in which case the variables get lower bounds of 0.0.

**ub:** Upper bounds for new variables. Can be `null`, in which case the variables get infinite upper bounds.

**obj:** Objective coefficients for new variables. Can be `null`, in which case the variables get objective coefficients of 0.0.

**type:** Variable types for new variables (GRB.CONTINUOUS, GRB.BINARY, GRB.INTEGER, GRB.SEMICONT, or GRB.SEMIINT). Can be `null`, in which case the variables are assumed to be continuous.

**names:** Names for new variables. Can be `null`, in which case all variables are given default names.

**Return value:**

Array of new variable objects.

```
GRBVar[] AddVars ( double[] lb,
                    double[] ub,
                    double[] obj,
                    char[] type,
                    string[] names,
                    int start,
                    int len )
```

Add new decision variables to a model. This signature allows you to use arrays to hold the various variable attributes (lower bound, upper bound, etc.), without forcing you to add a variable for each entry in the array. The `start` and `len` arguments allow you to specify which variables to add.

**Arguments:**

- lb:** Lower bounds for new variables. Can be `null`, in which case the variables get lower bounds of 0.0.
- ub:** Upper bounds for new variables. Can be `null`, in which case the variables get infinite upper bounds.
- obj:** Objective coefficients for new variables. Can be `null`, in which case the variables get objective coefficients of 0.0.
- type:** Variable types for new variables (`GRB.CONTINUOUS`, `GRB.BINARY`, `GRB.INTEGER`, `GRB.SEMICONT`, or `GRB.SEMIINT`). Can be `null`, in which case the variables are assumed to be continuous.
- names:** Names for new variables. Can be `null`, in which case all variables are given default names.
- start:** The first variable in the list to add.
- len:** The number of variables to add.

**Return value:**

Array of new variable objects.

```
GRBVar[] AddVars ( double[] lb,
                    double[] ub,
                    double[] obj,
                    char[] type,
                    string[] names,
                    GRBColumn[] col )
```

Add new decision variables to a model. This signature allows you to specify the list of constraints to which each new variable belongs using an array of [GRBColumn](#) objects.

**Arguments:**

- lb:** Lower bounds for new variables. Can be `null`, in which case the variables get lower bounds of 0.0.
- ub:** Upper bounds for new variables. Can be `null`, in which case the variables get infinite upper bounds.
- obj:** Objective coefficients for new variables. Can be `null`, in which case the variables get objective coefficients of 0.0.
- type:** Variable types for new variables (`GRB.CONTINUOUS`, `GRB.BINARY`, `GRB.INTEGER`, `GRB.SEMICONT`, or `GRB.SEMIINT`). Can be `null`, in which case the variables are assumed

to be continuous.

**names:** Names for new variables. Can be `null`, in which case all variables are given default names.

**cols:** `GRBColumn` objects for specifying a set of constraints to which each new column belongs.

**Return value:**

Array of new variable objects.

## GRBModel.ChgCoeff()

Change one coefficient in the model. The desired change is captured using a `GRBVar` object, a `GRBConstr` object, and a desired coefficient for the specified variable in the specified constraint. If you make multiple changes to the same coefficient, the last one will be applied.

Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using `GRBModel.Update`), optimize the model (using `GRBModel.Optimize`), or write the model to disk (using `GRBModel.Write`).

```
void ChgCoeff ( GRBConstr  constr,  
               GRBVar     var,  
               double     newvalue )
```

**Arguments:**

**constr:** Constraint for coefficient to be changed.

**var:** Variable for coefficient to be changed.

**newvalue:** Desired new value for coefficient.

## GRBModel.ChgCoeffs()

Change a list of coefficients in the model. Each desired change is captured using a `GRBVar` object, a `GRBConstr` object, and a desired coefficient for the specified variable in the specified constraint. The entries in the input arrays each correspond to a single desired coefficient change. The lengths of the input arrays must all be the same. If you make multiple changes to the same coefficient, the last one will be applied.

Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using `GRBModel.Update`), optimize the model (using `GRBModel.Optimize`), or write the model to disk (using `GRBModel.Write`).

```
void ChgCoeffs ( GRBConstr[] constrs,  
                GRBVar[]   vars,  
                double[]   vals )
```

**Arguments:**

**constrs:** Constraints for coefficients to be changed.

**vars:** Variables for coefficients to be changed.

**vals:** Desired new values for coefficients.

## GRBModel.ComputeIIS()

Compute an Irreducible Inconsistent Subsystem (IIS). An IIS is a subset of the constraints and variable bounds of the original model. If all constraints in the model except those in the IIS are removed, the model is still infeasible. However, further removing any one member of the IIS produces a feasible result.

This method populates the `IISCONSTR`, `IISQCONSTR`, and `IISGENCONSTR` constraint attributes, the `IISOS` SOS attribute, and the `IISLB`, and `IISUB` variable attributes. You can also obtain information about the results of the IIS computation by writing a `.ilp` format file (see [GRBModel.Write](#)). This file contains only the IIS from the original model.

Note that this method can be used to compute IISs for both continuous and MIP models.

```
| void ComputeIIS ( )
```

## GRBModel.DiscardConcurrentEnvs()

Discard concurrent environments for a model.

The concurrent environments created by [GetConcurrentEnv](#) will be used by every subsequent call to the concurrent optimizer until the concurrent environments are discarded.

```
| void DiscardConcurrentEnvs ( )
```

## GRBModel.Dispose()

Release the resources associated with a `GRBModel` object. While the .NET garbage collector will eventually reclaim these resources, we recommend that you call the `Dispose` method when you are done using a model.

You should not attempt to use a `GRBModel` object after calling `Dispose` on it.

```
| void Dispose ( )
```

## GRBModel.FeasRelax()

Modifies the `GRBModel` object to create a feasibility relaxation. Note that you need to call [Optimize](#) on the result to compute the actual relaxed solution.

The feasibility relaxation is a model that, when solved, minimizes the amount by which the solution violates the bounds and linear constraints of the original model. This method provides a number of options for specifying the relaxation.

If you specify `relaxobjtype=0`, the objective of the feasibility relaxation is to minimize the sum of the weighted magnitudes of the bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the cost per unit violation in the lower bounds, upper bounds, and linear constraints, respectively.

If you specify `relaxobjtype=1`, the objective of the feasibility relaxation is to minimize the weighted sum of the squares of the bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the coefficients on the squares of the lower bound, upper bound, and linear constraint violations, respectively.

If you specify `relaxobjtype=2`, the objective of the feasibility relaxation is to minimize the weighted count of bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the cost of violating a lower bound, upper bound, and linear constraint, respectively.

To give an example, if a constraint with `rhspen` value `p` is violated by 2.0, it would contribute `2*p` to the feasibility relaxation objective for `relaxobjtype=0`, it would contribute `2*2*p` for `relaxobjtype=1`, it would contribute `p` for `relaxobjtype=2`.

The `minrelax` argument is a boolean that controls the type of feasibility relaxation that is created. If `minrelax=false`, optimizing the returned model gives a solution that minimizes the cost of the violation. If `minrelax=true`, optimizing the returned model finds a solution that minimizes the original objective, but only from among those solutions that minimize the cost of the violation. Note that `FeasRelax` must solve an optimization problem to find the minimum possible relaxation when `minrelax=true`, which can be quite expensive.

There are two signatures for this method. The more complex one takes a list of variables and constraints, as well as penalties associated with relaxing the corresponding lower bounds, upper bounds, and constraints. If a variable or constraint is not included in one of these lists, the associated bounds or constraints may not be violated. The simpler signature takes a pair of boolean arguments, `vrelax` and `crelax`, that indicate whether variable bounds and/or constraints can be violated. If `vrelax/crelax` is `true`, then every bound/constraint is allowed to be violated, respectively, and the associated cost is 1.0.

Note that this is a destructive method: it modifies the model on which it is invoked. If you don't want to modify your original model, use the [GRBModel constructor](#) to create a copy before invoking this method.

```
double FeasRelax ( int          relaxobjtype,
                  boolean      minrelax,
                  GRBVar[]     vars,
                  double[]     lbpen,
                  double[]     ubpen,
                  GRBConstr[]  constr,
                  double[]     rhspen )
```

Create a feasibility relaxation model.

**Arguments:**

**relaxobjtype:** The cost function used when finding the minimum cost relaxation.

**minrelax:** The type of feasibility relaxation to perform.

**vars:** Variables whose bounds are allowed to be violated.

**lbpen:** Penalty for violating a variable lower bound. One entry for each variable in argument `vars`.

**ubpen:** Penalty for violating a variable upper bound. One entry for each variable in argument `vars`.

**constr:** Linear constraints that are allowed to be violated.

**rhspen:** Penalty for violating a linear constraint. One entry for each variable in argument `constr`.

**Arguments:**

**Return value:**

Zero if `minrelax` is false. If `minrelax` is true, the return value is the objective value for the relaxation performed. If the value is less than 0, it indicates that the method failed to create the feasibility relaxation.

```
double FeasRelax ( int      relaxobjtype,
                  boolean  minrelax,
                  boolean  vrelax,
                  boolean  crelax )
```

Simplified method for creating a feasibility relaxation model.

**Arguments:**

**relaxobjtype:** The cost function used when finding the minimum cost relaxation.

**minrelax:** The type of feasibility relaxation to perform.

**vrelax:** Indicates whether variable bounds can be relaxed (with a cost of 1.0 for any violations).

**crelax:** Indicates whether linear constraints can be relaxed (with a cost of 1.0 for any violations).

**Return value:**

Zero if **minrelax** is false. If **minrelax** is true, the return value is the objective value for the relaxation performed. If the value is less than 0, it indicates that the method failed to create the feasibility relaxation.

## GRBModel.FixedModel()

Create the fixed model associated with a MIP model. The MIP model must have a solution loaded (e.g., after a call to the [Optimize](#) method). In the fixed model, each integer variable is fixed to the value that variable takes in the MIP solution.

```
GRBModel FixedModel ( )
```

**Return value:**

Fixed model associated with calling object.

## GRBModel.Get()

Query the value(s) of a parameter or attribute. Use this method for parameters, for scalar model attributes, and for arrays of constraint or variable attributes.

```
double Get ( GRB.DoubleParam param )
```

Query the value of a double-valued parameter.

**Arguments:**

**param:** The parameter being queried.

**Return value:**

The current value of the requested parameter.

```
int Get ( GRB.IntParam param )
```

Query the value of an int-valued parameter.

**Arguments:**

**param:** The parameter being queried.

**Return value:**

The current value of the requested parameter.

```
string Get ( GRB.StringParam param )
```

Query the value of a string-valued parameter.

**Arguments:**

**param:** The parameter being queried.

**Return value:**

The current value of the requested parameter.

```
char [] Get ( GRB.CharAttr attr,  
             GRBVar [] vars )
```

Query a char-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** The variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
char [] Get ( GRB.CharAttr attr,  
             GRBVar [] vars,  
             int start,  
             int len )
```

Query a char-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A one-dimensional array of variables whose attribute values are being queried.

**start:** The index of the first variable of interest in the list.

**len:** The number of variables.

**Return value:**

The current values of the requested attribute for each input variable.

```
char [,] Get ( GRB.CharAttr attr,  
             GRBVar [,] vars )
```

Query a char-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A two-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
char [,,] Get ( GRB.CharAttr attr,  
             GRBVar [,,] vars )
```

Query a char-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A three-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
char[] Get ( GRB.CharAttr attr,
             GRBConstr[]  constrs )
```

Query a char-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** The constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
char[] Get ( GRB.CharAttr attr,
             GRBConstr[]  constrs,
             int          start,
             int          len )
```

Query a char-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A one-dimensional array of constraints whose attribute values are being queried.

**start:** The index of the first constraint of interest in the list.

**len:** The number of constraints.

**Return value:**

The current values of the requested attribute for each input constraint.

```
char[,] Get ( GRB.CharAttr attr,
              GRBConstr[,]  constrs )
```

Query a char-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A two-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
char[,,] Get ( GRB.CharAttr attr,
               GRBConstr[,,]  constrs )
```

Query a char-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A three-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
char[] Get ( GRB.CharAttr attr,  
             GRBQConstr[] qconstrs )
```

Query a char-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** The quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
char[] Get ( GRB.CharAttr attr,  
             GRBQConstr[] qconstrs,  
             int start,  
             int len )
```

Query a char-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being queried.

**start:** The index of the first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
char[,] Get ( GRB.CharAttr attr,  
              GRBQConstr[,] qconstrs )
```

Query a char-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
char[,,] Get ( GRB.CharAttr attr,  
               GRBQConstr[,,] qconstrs )
```

Query a char-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
double Get ( GRB.DoubleAttr attr )
```

Query the value of a double-valued model attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
double[] Get ( GRB.DoubleAttr attr,  
              GRBVar[] vars )
```

Query a double-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** The variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
double[] Get ( GRB.DoubleAttr attr,  
              GRBVar[] vars,  
              int start,  
              int len )
```

Query a double-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A one-dimensional array of variables whose attribute values are being queried.

**start:** The index of the first variable of interest in the list.

**len:** The number of variables.

**Return value:**

The current values of the requested attribute for each input variable.

```
double[,] Get ( GRB.DoubleAttr attr,  
               GRBVar[,] vars )
```

Query a double-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A two-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
double[,,] Get ( GRB.DoubleAttr attr,  
                GRBVar[,,] vars )
```

Query a double-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A three-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
double[] Get ( GRB.DoubleAttr attr,  
              GRBConstr[]   constrs )
```

Query a double-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** The constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
double[] Get ( GRB.DoubleAttr attr,  
              GRBConstr[]   constrs,  
              int           start,  
              int           len )
```

Query a double-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A one-dimensional array of constraints whose attribute values are being queried.

**start:** The first constraint of interest in the list.

**len:** The number of constraints.

**Return value:**

The current values of the requested attribute for each input constraint.

```
double[,] Get ( GRB.DoubleAttr attr,  
               GRBConstr[,]   constrs )
```

Query a double-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A two-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
double[,,] Get ( GRB.DoubleAttr attr,  
                GRBConstr[,,]   constrs )
```

Query a double-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A three-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
double[] Get ( GRB.DoubleAttr attr,  
              GRBQConstr[] qconstrs )
```

Query a double-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** The quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
double[] Get ( GRB.DoubleAttr attr,  
              GRBQConstr[] qconstrs,  
              int start,  
              int len )
```

Query a double-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being queried.

**start:** The first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
double[,] Get ( GRB.DoubleAttr attr,  
               GRBQConstr[,] qconstrs )
```

Query a double-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
double[,,] Get ( GRB.DoubleAttr attr,  
                 GRBQConstr[,,] qconstrs )
```

Query a double-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
int Get ( GRB.IntAttr attr )
```

Query the value of an int-valued model attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
int[] Get ( GRB.IntAttr attr,
            GRBVar[] vars )
```

Query an int-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** The variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
int[] Get ( GRB.IntAttr attr,
            GRBVar[] vars,
            int start,
            int len )
```

Query an int-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A one-dimensional array of variables whose attribute values are being queried.

**start:** The index of the first variable of interest in the list.

**len:** The number of variables.

**Return value:**

The current values of the requested attribute for each input variable.

```
int[,] Get ( GRB.IntAttr attr,
             GRBVar[,] vars )
```

Query an int-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A two-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
int[,] Get ( GRB.IntAttr attr,
             GRBVar[,] vars )
```

Query an int-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A three-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
int[] Get ( GRB.IntAttr attr,  
            GRBConstr[] constrs )
```

Query an int-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** The constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
int[] Get ( GRB.IntAttr attr,  
            GRBConstr[] constrs,  
            int start,  
            int len )
```

Query an int-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A one-dimensional array of constraints whose attribute values are being queried.

**start:** The index of the first constraint of interest in the list.

**len:** The number of constraints.

**Return value:**

The current values of the requested attribute for each input constraint.

```
int[,] Get ( GRB.IntAttr attr,  
             GRBConstr[,] constrs )
```

Query an int-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A two-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
int[,,] Get ( GRB.IntAttr attr,  
              GRBConstr[,,] constrs )
```

Query an int-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A three-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
string Get ( GRB.StringAttr attr )
```

Query the value of a string-valued model attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
string[] Get ( GRB.StringAttr attr,  
              GRBVar[] vars )
```

Query a string-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** The variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
string[] Get ( GRB.StringAttr attr,  
              GRBVar[] vars,  
              int start,  
              int len )
```

Query a string-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A one-dimensional array of variables whose attribute values are being queried.

**start:** The index of the first variable of interest in the list.

**len:** The number of variables.

**Return value:**

The current values of the requested attribute for each input variable.

```
string[,] Get ( GRB.StringAttr attr,  
               GRBVar[,] vars )
```

Query a string-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A two-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
string[,] Get ( GRB.StringAttr attr,  
               GRBVar[,] vars )
```

Query a string-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being queried.

**vars:** A three-dimensional array of variables whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input variable.

```
string[] Get ( GRB.StringAttr attr,  
              GRBConstr[]   constrs )
```

Query a string-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** The constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
string[] Get ( GRB.StringAttr attr,  
              GRBConstr[]   constrs,  
              int           start,  
              int           len )
```

Query a string-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A one-dimensional array of constraints whose attribute values are being queried.

**start:** The index of the first constraint of interest in the list.

**len:** The number of constraints.

**Return value:**

The current values of the requested attribute for each input constraint.

```
string[,] Get ( GRB.StringAttr attr,  
               GRBConstr[,]   constrs )
```

Query a string-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A two-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
string[,,] Get ( GRB.StringAttr attr,  
                GRBConstr[,,]   constrs )
```

Query a string-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being queried.

**constrs:** A three-dimensional array of constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input constraint.

```
string[] Get ( GRB.StringAttr attr,  
              GRBQConstr[] qconstrs )
```

Query a string-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** The quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
string[] Get ( GRB.StringAttr attr,  
              GRBQConstr[] qconstrs,  
              int start,  
              int len )
```

Query a string-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being queried.

**start:** The index of the first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
string[,] Get ( GRB.StringAttr attr,  
               GRBQConstr[,] qconstrs )
```

Query a string-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

```
string[,,] Get ( GRB.StringAttr attr,  
                GRBQConstr[,,] qconstrs )
```

Query a string-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being queried.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being queried.

**Return value:**

The current values of the requested attribute for each input quadratic constraint.

## GRBModel.GetCoeff()

Query the coefficient of variable `var` in linear constraint `constr` (note that the result can be zero).

```
double GetCoeff ( GRBConstr  constr,  
                  GRBVar     var )
```

**Arguments:**

**constr:** The requested constraint.

**var:** The requested variable.

**Return value:**

The current value of the requested coefficient.

## GRBModel.GetCol()

Retrieve the list of constraints in which a variable participates, and the associated coefficients. The result is returned as a [GRBColumn](#) object.

```
GRBColumn GetCol ( GRBVar  var )
```

**Arguments:**

**var:** The variable of interest.

**Return value:**

A [GRBColumn](#) object that captures the set of constraints in which the variable participates.

## GRBModel.GetConcurrentEnv()

Create/retrieve a concurrent environment for a model.

This method provides fine-grained control over the concurrent optimizer. By creating your own concurrent environments and setting appropriate parameters on these environments (e.g., the [Method](#) parameter), you can control exactly which strategies the concurrent optimizer employs. For example, if you create two concurrent environments, and set [Method](#) to primal simplex for one and dual simplex for the other, subsequent concurrent optimizer runs will use the two simplex algorithms rather than the default choices.

Note that you must create contiguously numbered concurrent environments, starting with `num=0`. For example, if you want three concurrent environments, they must be numbered 0, 1, and 2.

Once you create concurrent environments, they will be used for every subsequent concurrent optimization on that model. Use [DiscardConcurrentEnvs](#) to revert back to default concurrent optimizer behavior.

```
GRBEnv GetConcurrentEnv ( int  num )
```

**Arguments:**

**num:** The concurrent environment number.

**Return value:**

The concurrent environment for the model.

### GRBModel.GetConstrByName()

Retrieve a linear constraint from its name. If multiple linear constraints have the same name, this method chooses one arbitrarily.

```
| GRBConstr GetConstrByName ( string name )
```

**Arguments:**

**name:** The name of the desired linear constraint.

**Return value:**

The requested linear constraint.

### GRBModel.GetConstrs()

Retrieve an array of all linear constraints in the model.

```
| GRBConstr[] GetConstrs ( )
```

**Return value:**

All linear constraints in the model.

### GRBModel.GetEnv()

Query the environment associated with the model. Note that each model makes its own copy of the environment when it is created. To change parameters for a model, for example, you should use this method to obtain the appropriate environment object.

```
| GRBEnv GetEnv ( )
```

**Return value:**

The environment for the model.

### GRBModel.GetGenConstrMax()

Retrieve the data of a general constraint of type MAX. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [AddGenConstrMax](#) for a description of the semantics of this general constraint type.

```
| void GetGenConstrMax ( GRBGenConstr genc,  
                        out GRBVar resvar,  
                        out GRBVar[] vars,  
                        out double constant )
```

**Arguments:**

**genc:** The index of the general constraint.

**resvar:** Stores the resultant variable of the constraint.

**vars:** Stores the array of operand variables of the constraint.  
**constant:** Stores the additional constant operand of the constraint.

### GRBModel.GetGenConstrMin()

Retrieve the data of a general constraint of type MIN. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [AddGenConstrMin](#) for a description of the semantics of this general constraint type.

```
void GetGenConstrMin ( GRBGenConstr genc,  
                      out GRBVar resvar,  
                      out GRBVar[] vars,  
                      out double constant )
```

#### Arguments:

**genc:** The index of the general constraint.  
**resvar:** Stores the resultant variable of the constraint.  
**vars:** Stores the array of operand variables of the constraint.  
**constant:** Stores the additional constant operand of the constraint.

### GRBModel.GetGenConstrAbs()

Retrieve the data of a general constraint of type ABS. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [AddGenConstrAbs](#) for a description of the semantics of this general constraint type.

```
void GetGenConstrAbs ( GRBGenConstr genc,  
                      out GRBVar resvar,  
                      out GRBVar argvar )
```

#### Arguments:

**genc:** The index of the general constraint.  
**resvar:** Stores the resultant variable of the constraint.  
**argvar:** Stores the argument variable of the constraint.

### GRBModel.GetGenConstrAnd()

Retrieve the data of a general constraint of type AND. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [AddGenConstrAnd](#) for a description of the semantics of this general constraint type.

```
void GetGenConstrAnd ( GRBGenConstr genc,  
                      out GRBVar resvar,  
                      out GRBVar[] vars )
```

**Arguments:**

- genc:** The index of the general constraint.
- resvar:** Stores the resultant variable of the constraint.
- vars:** Stores the array of operand variables of the constraint.

**GRBModel.GetGenConstrOr()**

Retrieve the data of a general constraint of type OR. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [AddGenConstrOr](#) for a description of the semantics of this general constraint type.

```
void GetGenConstrOr ( GRBGenConstr genc,
                    out GRBVar resvar,
                    out GRBVar[] vars )
```

**Arguments:**

- genc:** The index of the general constraint.
- resvar:** Stores the resultant variable of the constraint.
- vars:** Stores the array of operand variables of the constraint.

**GRBModel.GetGenConstrIndicator()**

Retrieve the data of a general constraint of type INDICATOR. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [AddGenConstrIndicator](#) for a description of the semantics of this general constraint type.

```
void GetGenConstrIndicator ( GRBGenConstr genc,
                            out GRBVar binvar,
                            out int binval,
                            out GRBLinExpr expr,
                            out char sense,
                            out double rhs )
```

**Arguments:**

- genc:** The index of the general constraint.
- binvar:** Stores the binary indicator variable of the constraint.
- binval:** Stores the value that the indicator variable has to take in order to trigger the linear constraint.
- expr:** Stores the left-hand-side expression of the linear constraint that is triggered by the indicator.
- sense:** Stores the sense for the linear constraint. Options are `GRB_LESS_EQUAL`, `GRB_EQUAL`, or `GRB_GREATER_EQUAL`.
- rhs:** Stores the right-hand-side value for the linear constraint.

## GRBModel.GetGenConstrs()

Retrieve an array of all general constraints in the model.

```
| GRBGenConstr[] GetGenConstrs ( )
```

**Return value:**

All general constraints in the model.

## GRBModel.GetObjective()

Retrieve the model objective.

Note that the constant and linear portions of the objective can also be retrieved using the [ObjCon](#) and [Obj](#) attributes.

```
| GRBExpr GetObjective ( )
```

**Return value:**

The model objective.

## GRBModel.GetPWLObj()

Retrieve the piecewise-linear objective function for a variable. The return value gives the number of points that define the function, and the  $x$  and  $y$  arguments give the coordinates of the points, respectively. The  $x$  and  $y$  arguments must be large enough to hold the result. Call this method with `null` values for  $x$  and  $y$  if you just want the number of points.

Refer to the description of [SetPWLObj](#) for additional information on what the values in  $x$  and  $y$  mean.

```
| int GetPWLObj ( GRBVar var,  
                 double[] x,  
                 double[] y )
```

**Arguments:**

**var:** The variable whose objective function is being retrieved.

**x:** The  $x$  values for the points that define the piecewise-linear function. These will always be in non-decreasing order.

**y:** The  $y$  values for the points that define the piecewise-linear function.

**Return value:**

The number of points that define the piecewise-linear objective function.

## GRBModel.GetQConstr()

Retrieve the left-hand side expression from a quadratic constraint. The result is returned as a [GRBQuadExpr](#) object.

```
| GRBQuadExpr GetQConstr ( GRBQConstr qconstr )
```

**Arguments:**

**qconstr:** The quadratic constraint of interest.

**Return value:**

A [GRBQuadExpr](#) object that captures the left-hand side of the quadratic constraint.

## GRBModel.GetQConstrs()

Retrieve an array of all quadratic constraints in the model.

```
| GRBQConstr[] GetQConstrs ( )
```

**Return value:**

All quadratic constraints in the model.

## GRBModel.GetQCRow()

Retrieve the left-hand side expression for a quadratic constraint. The result is returned as a [GRBQuadExpr](#) object.

```
| GRBQuadExpr GetQCRow ( GRBQConstr qc )
```

**Arguments:**

**qc:** The quadratic constraint of interest.

**Return value:**

A [GRBQuadExpr](#) object that captures the left-hand side of the quadratic constraint.

## GRBModel.GetRow()

Retrieve a list of variables that participate in a constraint, and the associated coefficients. The result is returned as a [GRBLinExpr](#) object.

```
| GRBLinExpr GetRow ( GRBConstr constr )
```

**Arguments:**

**constr:** The constraint of interest.

**Return value:**

A [GRBLinExpr](#) object that captures the set of variables that participate in the constraint.

## GRBModel.GetSOS()

Retrieve the list of variables that participate in an SOS constraint, and the associated coefficients. The return value is the length of this list. Note that the argument arrays must be long enough to accommodate the result. Call the method with null array arguments to determine the appropriate array lengths.

```
| int GetSOS ( GRBSOS sos,  
              GRBVar[] vars,  
              double[] weights,  
              int[] type )
```

**Arguments:**

**sos:** The SOS set of interest.

**vars:** A list of variables that participate in sos. Can be null.

**weights:** The SOS weights for each participating variable. Can be null.

**type:** The type of the SOS set (either `GRB.SOS_TYPE1` or `GRB.SOS_TYPE2`) is returned in `type[0]`.

**Return value:**

The number of entries placed in the output arrays. Note that you should consult the return value to determine the length of the result; the arrays sizes won't necessarily match the result size.

**GRBModel.GetSOSs()**

Retrieve an array of all SOS constraints in the model.

```
| GRBSOS[] GetSOSs ( )
```

**Return value:**

All SOS constraints in the model.

**GRBModel.GetTuneResult()**

Use this method to retrieve the results of a previous [Tune](#) call. Calling this method with argument `n` causes tuned parameter set `n` to be copied into the model. Parameter sets are stored in order of decreasing quality, with parameter set 0 being the best. The number of available sets is stored in attribute [TuneResultCount](#).

Once you have retrieved a tuning result, you can call [optimize](#) to use these parameter settings to optimize the model, or [write](#) to write the changed parameters to a `.prm` file.

Please refer to the [parameter tuning](#) section for details on the tuning tool.

```
| void GetTuneResult ( int n )
```

`n`: The index of the tuning result to retrieve. The best result is available as index 0. The number of stored results is available in attribute [TuneResultCount](#).

**GRBModel.GetVarByName()**

Retrieve a variable from its name. If multiple variable have the same name, this method chooses one arbitrarily.

```
| GRBVar GetVarByName ( string name )
```

**Arguments:**

`name`: The name of the desired variable.

**Return value:**

The requested variable.

**GRBModel.GetVars()**

Retrieve an array of all variables in the model.

```
| GRBVar[] GetVars ( )
```

**Return value:**

All variables in the model.

## GRBModel.Optimize()

Optimize the model. The algorithm used for the optimization depends on the model type (simplex or barrier for a continuous model; branch-and-cut for a MIP model). Upon successful completion, this method will populate the solution related attributes of the model. See the [Attributes](#) section for more information on attributes.

Please consult [this section](#) for a discussion of some of the practical issues associated with solving a precisely defined mathematical model using finite-precision floating-point arithmetic.

Note that this method will process all pending model modifications.

```
| void Optimize ( )
```

## GRBModel::OptimizeAsync()

Optimize a model asynchronously. This routine returns immediately. Your program can perform other computations while optimization proceeds in the background. To check the state of the asynchronous optimization, query the [Status](#) attribute for the model. A value of `IN_PROGRESS` indicates that the optimization has not yet completed. When you are done with your foreground tasks, you must call [sync](#) to sync your foreground program with the asynchronous optimization task.

Note that the set of Gurobi calls that you are allowed to make while optimization is running in the background is severely limited. Specifically, you can only perform attribute queries, and only for a few attributes (listed below). Any other calls on the running model, *or on any other models that were built within the same Gurobi environment*, will fail with error code `OPTIMIZATION_IN_PROGRESS`.

Note that there are no such restrictions on models built in other environments. Thus, for example, you could create multiple environments, and then have a single foreground program launch multiple simultaneous asynchronous optimizations, each in its own environment.

As already noted, you are allowed to query the value of the [Status](#) attribute while an asynchronous optimization is in progress. The other attributes that can be queried are: [ObjVal](#), [ObjBound](#), [IterCount](#), [NodeCount](#), and [BarIterCount](#). In each case, the returned value reflects progress in the optimization to that point. Any attempt to query the value of an attribute not on this list will return an `OPTIMIZATION_IN_PROGRESS` error.

```
| void OptimizeAsync ( )
```

## GRBModel.Presolve()

Perform presolve on a model.

```
| GRBModel Presolve ( )
```

**Return value:**

Presolved version of original model.

## GRBModel.Read()

This method is the general entry point for importing data from a file into a model. It can be used to read basis files for continuous models, start vectors for MIP models, or parameter settings. The type of data read is determined by the file suffix. File formats are described in the [File Format](#) section.

Note that this is **not** the method to use if you want to read a new model from a file. For that, use the [GRBModel constructor](#). One variant of the constructor takes the name of the file that contains the new model as its argument.

```
| void Read ( string filename )
```

**Arguments:**

**filename:** Name of the file to read. The suffix on the file must be either `.bas` (for an LP basis), `.mst` or `.sol` (for a MIP start), `.hnt` (for MIP hints), `.ord` (for a priority order), or `.prm` (for a parameter file). The suffix may optionally be followed by `.zip`, `.gz`, `.bz2`, or `.7z`.

## GRBModel.Remove()

Remove a variable, constraint, or SOS from a model.

```
| void Remove ( GRBConstr constr )
```

Remove a constraint from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel.Update](#)), optimize the model (using [GRBModel.Optimize](#)), or write the model to disk (using [GRBModel.Write](#)).

**Arguments:**

**constr:** The constraint to remove.

```
| void Remove ( GRBGenConstr genconstr )
```

Remove a general constraint from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel.Update](#)), optimize the model (using [GRBModel.Optimize](#)), or write the model to disk (using [GRBModel.Write](#)).

**Arguments:**

**genconstr:** The general constraint to remove.

```
| void Remove ( GRBQConstr qconstr )
```

Remove a quadratic constraint from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel.Update](#)), optimize the model (using [GRBModel.Optimize](#)), or write the model to disk (using [GRBModel.Write](#)).

**Arguments:**

**qconstr:** The constraint to remove.

```
| void Remove ( GRBSOS sos )
```

Remove an SOS constraint from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel.Update](#)), optimize the model (using [GRBModel.Optimize](#)), or write the model to disk (using [GRBModel.Write](#)).

**Arguments:**

**sos:** The SOS constraint to remove.

```
| void Remove ( GRBVar var )
```

Remove a variable from the model. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [GRBModel.Update](#)), optimize the model (using [GRBModel.Optimize](#)), or write the model to disk (using [GRBModel.Write](#)).

**Arguments:**

**var:** The variable to remove.

## GRBModel.Reset()

Reset the model to an unsolved state, discarding any previously computed solution information.

```
| void Reset ( )
```

## GRBModel.SetCallback()

Set the callback object for a model. The `Callback()` method on this object will be called periodically from the Gurobi solver. You will have the opportunity to obtain more detailed information about the state of the optimization from this callback. See the documentation for [GRBCallback](#) for additional information.

Note that a model can only have a single callback method, so this call will replace an existing callback. To disable a previously set callback, call this method with a `null` argument.

```
| void SetCallback ( GRBCallback cb )
```

## GRBModel.Set()

Set the value(s) of a parameter or attribute. Use this method for parameters, for scalar model attributes, or for arrays of constraint or variable attributes.

```
| void Set ( GRB.DoubleParam param,  
            double          newvalue )
```

Set the value of a double-valued parameter.

The difference between setting a parameter on a model and setting it on an environment (i.e., through [GRBEnv.Set](#)) is that the former modifies the parameter for a single model, while the latter modifies the parameter for every model that is subsequently built using that environment (and leaves the parameter unchanged for models that were previously built using that environment).

**Arguments:**

**param:** The parameter being modified.

**newvalue:** The desired new value for the parameter.

```
| void Set ( GRB.IntParam param,  
            int          newvalue )
```

Set the value of an int-valued parameter.

The difference between setting a parameter on a model and setting it on an environment (i.e., through [GRBEnv.Set](#)) is that the former modifies the parameter for a single model, while the latter modifies the parameter for every model that is subsequently built using that environment (and leaves the parameter unchanged for models that were previously built using that environment).

**Arguments:**

**param:** The parameter being modified.  
**newvalue:** The desired new value for the parameter.

```
void Set ( GRB.StringParam param,  
          string          newvalue )
```

Set the value of a string-valued parameter.

The difference between setting a parameter on a model and setting it on an environment (i.e., through `GRBEnv.Set`) is that the former modifies the parameter for a single model, while the latter modifies the parameter for every model that is subsequently built using that environment (and leaves the parameter unchanged for models that were previously built using that environment).

**Arguments:**

**param:** The parameter being modified.  
**newvalue:** The desired new value for the parameter.

```
void Set ( GRB.CharAttr attr,  
          GRBVar[]     vars,  
          char[]       newvalues )
```

Set a char-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being modified.  
**vars:** The variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void Set ( GRB.CharAttr attr,  
          GRBVar[]     vars,  
          char[]       newvalues,  
          int          start,  
          int          len )
```

Set a char-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being modified.  
**vars:** A one-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.  
**start:** The index of the first variable of interest in the list.  
**len:** The number of variables.

```
void Set ( GRB.CharAttr attr,  
          GRBVar[,]     vars,  
          char[,]       newvalues )
```

Set a char-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** A two-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void Set ( GRB.CharAttr attr,  
          GRBVar[,] vars,  
          char[,] newvalues )
```

Set a char-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being modified.  
**vars:** A three-dimensional array of variables whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input variable.

```
void Set ( GRB.CharAttr attr,  
          GRBConstr[] constrs,  
          char[] newvalues )
```

Set a char-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** The constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void Set ( GRB.CharAttr attr,  
          GRBConstr[] constrs,  
          char[] newvalues,  
          int start,  
          int len )
```

Set a char-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A one-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.  
**start:** The index of the first constraint of interest in the list.  
**len:** The number of constraints.

```
void Set ( GRB.CharAttr attr,  
          GRBConstr[,] constrs,  
          char[,] newvalues )
```

Set a char-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.  
**constrs:** A two-dimensional array of constraints whose attribute values are being modified.  
**newvalues:** The desired new values for the attribute for each input constraint.

```
void Set ( GRB.CharAttr attr,
           GRBConstr[,] constrs,
           char[,] newvalues )
```

Set a char-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** A three-dimensional array of constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

```
void Set ( GRB.CharAttr attr,
           GRBQConstr[] qconstrs,
           char[] newvalues )
```

Set a char-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** The quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void Set ( GRB.CharAttr attr,
           GRBQConstr[] qconstrs,
           char[] newvalues,
           int start,
           int len )
```

Set a char-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

**start:** The index of the first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

```
void Set ( GRB.CharAttr attr,
           GRBQConstr[,] qconstrs,
           char[,] newvalues )
```

Set a char-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void Set ( GRB.CharAttr attr,
           GRBQConstr[,] qconstrs,
           char[,] newvalues )
```

Set a char-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void Set ( GRB.DoubleAttr attr,
           double newvalue )
```

Set the value of a double-valued model attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value for the attribute.

```
void Set ( GRB.DoubleAttr attr,
           GRBVar[] vars,
           double[] newvalues )
```

Set a double-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** The variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

```
void Set ( GRB.DoubleAttr attr,
           GRBVar[] vars,
           double[] newvalues,
           int start,
           int len )
```

Set a double-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** A one-dimensional array of variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

**start:** The index of the first variable of interest in the list.

**len:** The number of variables.

```
void Set ( GRB.DoubleAttr attr,
           GRBVar[,] vars,
           double[,] newvalues )
```

Set a double-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** A two-dimensional array of variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

```
void Set ( GRB.DoubleAttr attr,  
          GRBVar[,,] vars,  
          double[,,] newvalues )
```

Set a double-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** A three-dimensional array of variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

```
void Set ( GRB.DoubleAttr attr,  
          GRBConstr[] constrs,  
          double[] newvalues )
```

Set a double-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** The constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

```
void Set ( GRB.DoubleAttr attr,  
          GRBConstr[] constrs,  
          double[] newvalues,  
          int start,  
          int len )
```

Set a double-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** A one-dimensional array of constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

**start:** The first constraint of interest in the list.

**len:** The number of constraints.

```
void Set ( GRB.DoubleAttr attr,  
          GRBConstr[,] constrs,  
          double[,] newvalues )
```

Set a double-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** A two-dimensional array of constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

```
void Set ( GRB.DoubleAttr attr,  
           GRBConstr[,]   constrs,  
           double[,]      newvalues )
```

Set a double-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** A three-dimensional array of constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

```
void Set ( GRB.DoubleAttr attr,  
           GRBQConstr[]   qconstrs,  
           double[]       newvalues )
```

Set a double-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** The quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void Set ( GRB.DoubleAttr attr,  
           GRBQConstr[]   qconstrs,  
           double[]       newvalues,  
           int             start,  
           int             len )
```

Set a double-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

**start:** The first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

```
void Set ( GRB.DoubleAttr attr,  
           GRBQConstr[,]   qconstrs,  
           double[,]      newvalues )
```

Set a double-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void Set ( GRB.DoubleAttr attr,  
           GRBQConstr[,] qconstrs,  
           double[,] newvalues )
```

Set a double-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void Set ( GRB.IntAttr attr,  
           int newvalue )
```

Set the value of an int-valued model attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value for the attribute.

```
void Set ( GRB.IntAttr attr,  
           GRBVar[] vars,  
           int[] newvalues )
```

Set an int-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** The variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

```
void Set ( GRB.IntAttr attr,  
           GRBVar[] vars,  
           int[] newvalues,  
           int start,  
           int len )
```

Set an int-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** A one-dimensional array of variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

**start:** The index of the first variable of interest in the list.

**len:** The number of variables.

```
void Set ( GRB.IntAttr attr,
           GRBVar[,] vars,
           int[,] newvalues )
```

Set an int-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** A two-dimensional array of variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

```
void Set ( GRB.IntAttr attr,
           GRBVar[,,] vars,
           int[,,] newvalues )
```

Set an int-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** A three-dimensional array of variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

```
void Set ( GRB.IntAttr attr,
           GRBConstr[] constra,
           int[] newvalues )
```

Set an int-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constra:** The constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

```
void Set ( GRB.IntAttr attr,
           GRBConstr[] constra,
           int[] newvalues,
           int start,
           int len )
```

Set an int-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constra:** A one-dimensional array of constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

**start:** The index of the first constraint of interest in the list.

**len:** The number of constraints.

```
void Set ( GRB.IntAttr attr,
           GRBConstr[,] constra,
           int[,] newvalues )
```

Set an int-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** A two-dimensional array of constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

```
void Set ( GRB.IntAttr attr,
           GRBConstr[,] constrs,
           int[,] newvalues )
```

Set an int-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** A three-dimensional array of constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

```
void Set ( GRB.StringAttr attr,
           string newvalue )
```

Set the value of a string-valued model attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value for the attribute.

```
void Set ( GRB.StringAttr attr,
           GRBVar[] vars,
           string[] newvalues )
```

Set a string-valued variable attribute for an array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** The variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

```
void Set ( GRB.StringAttr attr,
           GRBVar[] vars,
           string[] newvalues,
           int start,
           int len )
```

Set a string-valued variable attribute for a sub-array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** A one-dimensional array of variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

**start:** The index of the first variable of interest in the list.

**len:** The number of variables.

```
void Set ( GRB.StringAttr attr,
           GRBVar[,]      vars,
           string[,]      newvalues )
```

Set a string-valued variable attribute for a two-dimensional array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** A two-dimensional array of variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

```
void Set ( GRB.StringAttr attr,
           GRBVar[,,]     vars,
           string[,,]     newvalues )
```

Set a string-valued variable attribute for a three-dimensional array of variables.

**Arguments:**

**attr:** The attribute being modified.

**vars:** A three-dimensional array of variables whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input variable.

```
void Set ( GRB.StringAttr attr,
           GRBConstr[]    constrs,
           string[]       newvalues )
```

Set a string-valued constraint attribute for an array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** The constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

```
void Set ( GRB.StringAttr attr,
           GRBConstr[]    constrs,
           string[]       newvalues,
           int            start,
           int            len )
```

Set a string-valued constraint attribute for a sub-array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** A one-dimensional array of constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

**start:** The index of the first constraint of interest in the list.

**len:** The number of constraints.

```
void Set ( GRB.StringAttr attr,
           GRBConstr[,]   constrs,
           string[,]      newvalues )
```

Set a string-valued constraint attribute for a two-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** A two-dimensional array of constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

```
void Set ( GRB.StringAttr attr,
           GRBConstr[,]   constrs,
           string[,]      newvalues )
```

Set a string-valued constraint attribute for a three-dimensional array of constraints.

**Arguments:**

**attr:** The attribute being modified.

**constrs:** A three-dimensional array of constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input constraint.

```
void Set ( GRB.StringAttr attr,
           GRBQConstr[]   qconstrs,
           string[]       newvalues )
```

Set a string-valued quadratic constraint attribute for an array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** The quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void Set ( GRB.StringAttr attr,
           GRBQConstr[]   qconstrs,
           string[]       newvalues,
           int             start,
           int             len )
```

Set a string-valued quadratic constraint attribute for a sub-array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A one-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

**start:** The index of the first quadratic constraint of interest in the list.

**len:** The number of quadratic constraints.

```
void Set ( GRB.StringAttr attr,
           GRBQConstr[,]   qconstrs,
           string[,]       newvalues )
```

Set a string-valued quadratic constraint attribute for a two-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A two-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

```
void Set ( GRB.StringAttr attr,  
           GRBQConstr[,] qconstrs,  
           string[,] newvalues )
```

Set a string-valued quadratic constraint attribute for a three-dimensional array of quadratic constraints.

**Arguments:**

**attr:** The attribute being modified.

**qconstrs:** A three-dimensional array of quadratic constraints whose attribute values are being modified.

**newvalues:** The desired new values for the attribute for each input quadratic constraint.

## GRBModel.SetObjective()

Set the model objective equal to a linear or quadratic expression.

Note that you can also modify the linear portion of a model objective using the [Obj](#) variable attribute. If you wish to mix and match these two approaches, please note that this method replaces the entire existing objective, while the [Obj](#) attribute can be used to modify individual linear terms.

```
void SetObjective ( GRBExpr expr,  
                   int sense )
```

Set the model objective, and the objective sense ([GRB.MINIMIZE](#) for minimization, [GRB.MAXIMIZE](#) for maximization).

**Arguments:**

**expr:** New model objective.

**sense:** New optimization sense ([GRB.MINIMIZE](#) for minimization, [GRB.MAXIMIZE](#) for maximization).

```
void SetObjective ( GRBExpr expr )
```

Set the model objective. The sense of the objective is determined by the value of the [ModelSense](#) attribute.

**Arguments:**

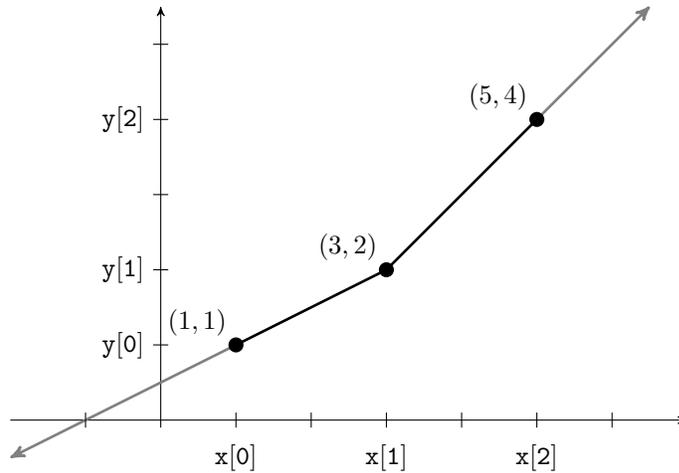
**expr:** New model objective.

## GRBModel.SetPWLObj()

Set a piecewise-linear objective function for a variable.

The arguments to this method specify a list of points that define a piecewise-linear objective function for a single variable. Specifically, the  $x$  and  $y$  arguments give coordinates for the vertices of the function.

For example, suppose we want to define the function  $f(x)$  shown below:



The vertices of the function occur at the points (1, 1), (3, 2) and (5, 4), so  $x$  is {1, 3, 5} and  $y$  is {1, 2, 4}. With these arguments we define  $f(1) = 1$ ,  $f(3) = 2$  and  $f(5) = 4$ . Other objective values are linearly interpolated between neighboring points. The first pair and last pair of points each define a ray, so values outside the specified  $x$  values are extrapolated from these points. Thus, in our example,  $f(-1) = 0$  and  $f(6) = 5$ .

More formally, a set of  $n$  points

$$\mathbf{x} = \{x_1, \dots, x_n\}, \quad \mathbf{y} = \{y_1, \dots, y_n\}$$

define the following piecewise-linear function:

$$f(v) = \begin{cases} y_1 + \frac{y_2 - y_1}{x_2 - x_1}(v - x_1), & \text{if } v \leq x_1, \\ y_i + \frac{y_{i+1} - y_i}{x_{i+1} - x_i}(v - x_i), & \text{if } v \geq x_i \text{ and } v \leq x_{i+1}, \\ y_n + \frac{y_n - y_{n-1}}{x_n - x_{n-1}}(v - x_n), & \text{if } v \geq x_n. \end{cases}$$

The  $x$  entries must appear in non-decreasing order. Two points can have the same  $x$  coordinate — this can be useful for specifying a discrete jump in the objective function.

Note that a piecewise-linear objective can change the type of a model. Specifically, including a non-convex piecewise linear objective function in a continuous model will transform that model into a MIP. This can significantly increase the cost of solving the model.

Setting a piecewise-linear objective for a variable will set the **Obj attribute** on that variable to 0. Similarly, setting the **Obj** attribute will delete the piecewise-linear objective on that variable.

Each variable can have its own piecewise-linear objective function. They must be specified individually, even if multiple variables share the same function.

```
void SetPWLObj ( GRBvar   var,
                 double[] x,
                 double[] y )
```

Set the piecewise-linear objective function for a variable.

**Arguments:**

- var:** The variable whose objective function is being set.
- x:** The  $x$  values for the points that define the piecewise-linear function. Must be in non-decreasing order.
- y:** The  $y$  values for the points that define the piecewise-linear function.

### **GRBModel.Terminate()**

Generate a request to terminate the current optimization. This method can be called at any time during an optimization.

```
| void Terminate ( )
```

### **GRBModel.Tune()**

Perform an automated search for parameter settings that improve performance. Upon completion, this method stores the best parameter sets it found. The number of stored parameter sets can be determined by querying the value of the [TuneResultCount](#) attribute. The actual settings can be retrieved using [GetTuneResult](#)

Please refer to the [parameter tuning](#) section for details on the tuning tool.

```
| void Tune ( )
```

### **GRBModel.Update()**

Process any pending model modifications.

```
| void Update ( )
```

### **GRBModel.Write()**

This method is the general entry point for writing model data to a file. It can be used to write optimization models, IIS submodels, solutions, basis vectors, MIP start vectors, or parameter settings. The type of file is determined by the file suffix. File formats are described in the [File Format](#) section.

Note that writing a model to a file will process all pending model modifications. However, writing other model information (solutions, bases, etc.) will not.

```
| void Write ( string filename )
```

#### **Arguments:**

**filename:** Name of the file to write. The file type is encoded in the file name suffix. Valid suffixes for writing the model itself are `.mps`, `.rew`, `.lp`, or `.rlp`. An IIS can be written by using an `.ilp` suffix. Use `.sol` for a solution file, `.mst` for a MIP start, `.hnt` for MIP hints, `.bas` for a basis file, or `.prm` for a parameter file. The suffix may optionally be followed by `.gz`, `.bz2`, or `.7z`, which produces a compressed result.

## 5.3 GRBVar

Gurobi variable object. Variables are always associated with a particular model. You create a variable object by adding a variable to a model (using `GRBModel.AddVar`), rather than by using a `GRBVar` constructor.

The methods on variable objects are used to get and set variable attributes. For example, solution information can be queried by calling `Get(GRB.DoubleAttr.X)`. Note, however, that it is generally more efficient to query attributes for a set of variables at once. This is done using the attribute query method on the `GRBModel` object (`GRBModel.Get`).

### GRBVar.Get()

Query the value of a variable attribute.

```
| char Get ( GRB.CharAttr attr )
```

Query the value of a char-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| double Get ( GRB.DoubleAttr attr )
```

Query the value of a double-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| int Get ( GRB.IntAttr attr )
```

Query the value of an int-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| string Get ( GRB.StringAttr attr )
```

Query the value of a string-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

### GRBVar.SameAs()

```
| bool SameAs ( GRBVar var2 )
```

Check whether two variable objects refer to the same variable.

**Arguments:**

**var2:** The other variable.

**Return value:**

Boolean result indicates whether the two variable objects refer to the same model variable.

## GRBVar.Set()

Set the value of a variable attribute.

```
void Set ( GRB.CharAttr attr,  
           char          newvalue )
```

Set the value of a char-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void Set ( GRB.DoubleAttr attr,  
           double         newvalue )
```

Set the value of a double-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void Set ( GRB.IntAttr  attr,  
           int          newvalue )
```

Set the value of an int-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void Set ( GRB.StringAttr attr,  
           string         newvalue )
```

Set the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

## 5.4 GRBConstr

Gurobi constraint object. Constraints are always associated with a particular model. You create a constraint object by adding a constraint to a model (using [GRBModel.AddConstr](#)), rather than by using a `GRBConstr` constructor.

The methods on constraint objects are used to get and set constraint attributes. For example, constraint right-hand sides can be queried by calling `Get(GRB.DoubleAttr.RHS)`. Note, however, that it is generally more efficient to query attributes for a set of constraints at once. This is done using the attribute query method on the `GRBModel` object ([GRBModel.Get](#)).

### GRBConstr.Get()

Query the value of a constraint attribute.

```
| char Get ( GRB.CharAttr attr )
```

Query the value of a char-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| double Get ( GRB.DoubleAttr attr )
```

Query the value of a double-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| int Get ( GRB.IntAttr attr )
```

Query the value of an int-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| string Get ( GRB.StringAttr attr )
```

Query the value of a string-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

### GRBConstr.SameAs()

```
| bool SameAs ( GRBConstr constr2 )
```

Check whether two constraint objects refer to the same constraint.

**Arguments:**

**constr2:** The other constraint.

**Return value:**

Boolean result indicates whether the two constraint objects refer to the same model constraint.

## GRBConstr.Set()

Set the value of a constraint attribute.

```
void Set ( GRB.CharAttr attr,  
           char          newvalue )
```

Set the value of a char-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void Set ( GRB.DoubleAttr attr,  
           double         newvalue )
```

Set the value of a double-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void Set ( GRB.IntAttr  attr,  
           int          newvalue )
```

Set the value of an int-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void Set ( GRB.StringAttr attr,  
           string         newvalue )
```

Set the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

## 5.5 GRBQConstr

Gurobi quadratic constraint object. Quadratic constraints are always associated with a particular model. You create a quadratic constraint object by adding a quadratic constraint to a model (using [GRBModel.AddQConstr](#)), rather than by using a `GRBQConstr` constructor.

The methods on quadratic constraint objects are used to get and set quadratic constraint attributes. For example, quadratic constraint right-hand sides can be queried by calling `Get(GRB.DoubleAttr.QCRHS)`. Note, however, that it is generally more efficient to query attributes for a set of constraints at once. This is done using the attribute query method on the `GRBModel` object ([GRBModel.Get](#)).

### GRBQConstr.Get()

Query the value of a quadratic constraint attribute.

```
| char Get ( GRB.CharAttr attr )
```

Query the value of a char-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| double Get ( GRB.DoubleAttr attr )
```

Query the value of a double-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| int Get ( GRB.IntAttr attr )
```

Query the value of an int-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| string Get ( GRB.StringAttr attr )
```

Query the value of a string-valued attribute.

**Arguments:**

`attr`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

### GRBQConstr.Set()

Set the value of a quadratic constraint attribute.

```
void Set ( GRB.CharAttr attr,  
           char          newvalue )
```

Set the value of a char-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void Set ( GRB.DoubleAttr attr,  
           double         newvalue )
```

Set the value of a double-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

```
void Set ( GRB.StringAttr attr,  
           string         newvalue )
```

Set the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

## 5.6 GRBSOS

Gurobi SOS constraint object. SOS constraints are always associated with a particular model. You create an SOS object by adding an SOS constraint to a model (using [GRBModel.AddSOS](#)), rather than by using a `GRBSOS` constructor. Similarly, SOS constraints are removed using the [GRBModel.Remove](#) method.

An SOS constraint can be of type 1 or 2 (`GRB.SOS_TYPE1` or `GRB.SOS_TYPE2`). A type 1 SOS constraint is a set of variables for which at most one variable in the set may take a value other than zero. A type 2 SOS constraint is an ordered set of variables where at most two variables in the set may take non-zero values. If two take non-zero values, they must be contiguous in the ordered set.

SOS constraint objects have one attribute, `IISOS`, which can be queried with the [GRBSOS.Get](#) method.

### **GRBSOS.Get()**

Query the value of an SOS attribute.

```
| int Get ( GRB.IntAttr attr )
```

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

## 5.7 GRBGenConstr

Gurobi general constraint object. General constraints are always associated with a particular model. You create a general constraint object by adding a general constraint to a model (using [GRBModel.AddGenConstr](#)), rather than by using a `GRBGenConstr` constructor.

General constraint objects have a number of attributes, which can be queried with the [GRBGenConstr.Get](#) method. The full list can be found in the [Attributes](#) section of this document.

### GRBGenConstr.Get()

Query the value of a general constraint attribute.

```
| int Get ( GRB.IntAttr attr )
```

Query the value of a int-valued attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

```
| string Get ( GRB.StringAttr attr )
```

Query the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

### GRBGenConstr.Set()

Set the value of a general constraint attribute.

```
| void Set ( GRB.StringAttr attr,  
            string          newvalue )
```

Set the value of a string-valued attribute.

**Arguments:**

**attr:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

## 5.8 GRBExpr

Abstract base class for the [GRBLinExpr](#) and [GRBQuadExpr](#) classes. Expressions are used to build objectives and constraints. They are temporary objects that typically have short lifespans.

### **GRBExpr.Value**

(Property) The value of an expression for the current solution.

## 5.9 GRBLinExpr

Gurobi linear expression object. A linear expression consists of a constant term, plus a list of coefficient-variable pairs that capture the linear terms. Linear expressions are used to build constraints. They are temporary objects that typically have short lifespans.

The `GRBLinExpr` class is a sub-class of the abstract base class `GRBExpr`.

In .NET languages that support operator overloading, you generally build linear expressions using overloaded operators. For example, if `x` is a `GRBVar` object, then `x + 1` is a `GRBLinExpr` object. Expressions can be built from constants (e.g., `expr = 0`), variables (e.g., `expr = 1 * x + 2 * y`), or from other expressions (e.g., `expr2 = 2 * expr1 + x`, or `expr3 = expr1 + 2 * expr2`). You can also modify existing expressions (e.g., `expr += x`, or `expr2 -= expr1`).

The other option for building expressions is to start with an empty expression (using the `GRBLinExpr` constructor), and then add terms. Terms can be added individually (using `AddTerm`) or in groups (using `AddTerms` or `MultAdd`). Terms can also be removed from an expression, using `Remove`.

Note that the cost of building expressions depends heavily on the approach you use. While you can generally ignore this issue when building small expressions, you should be aware of a few efficiency issues when building large expressions:

- You should avoid using `expr = expr + x` or `expr += x` in a loop. It will lead to runtimes that are quadratic in the number of terms in the expression.
- Using `AddTerm` in a loop is reasonably efficient, but it isn't the most efficient approach.
- The most efficient way to build a large expression is to make a single call to `AddTerms`.

Individual terms in a linear expression can be queried using the `GetVar` and `GetCoeff` methods. The constant can be queried using the `Constant` property. You can query the number of terms in the expression using the `Size` property.

Note that a linear expression may contain multiple terms that involve the same variable. These duplicate terms are merged when creating a constraint from an expression, but they may be visible when inspecting individual terms in the expression (e.g., when using `GetVar`).

### GRBLinExpr()

Linear expression constructor. Create an empty linear expression, or copy an existing expression.

```
GRBLinExpr GRBLinExpr ( )
```

Create an empty linear expression.

**Return value:**

An empty expression object.

```
GRBLinExpr GRBLinExpr ( double a )
```

Create a constant linear expression.

**Return value:**

A linear expression object.

```
GRBLinExpr GRBLinExpr ( GRBLinExpr orig )
```

Copy an existing linear expression.

**Arguments:**

**orig:** Existing expression to copy.

**Return value:**

A copy of the input expression object.

**GRBLinExpr.Add()**

Add one linear expression into another. Upon completion, the invoking linear expression will be equal to the sum of itself and the argument expression.

```
| void Add ( GRBLinExpr le )
```

**Arguments:**

**le:** Linear expression to add.

**GRBLinExpr.AddConstant()**

Add a constant into a linear expression.

```
| void AddConstant ( double c )
```

**Arguments:**

**c:** Constant to add to expression.

**GRBLinExpr.AddTerm()**

Add a single term into a linear expression.

```
| void AddTerm ( double coeff,  
                GRBVar var )
```

**Arguments:**

**coeff:** Coefficient for new term.

**var:** Variable for new term.

**GRBLinExpr.AddTerms()**

Add new terms into a linear expression.

```
| void AddTerms ( double[] coeffs,  
                GRBVar[] vars )
```

Add a list of terms into a linear expression. Note that the lengths of the two argument arrays must be equal.

**Arguments:**

**coeffs:** Coefficients for new terms.

**vars:** Variables for new terms.

```
void AddTerms ( double[] coeffs,
                 GRBVar[] vars,
                 int start,
                 int len )
```

Add new terms into a linear expression. This signature allows you to use arrays to hold the coefficients and variables that describe the terms in an array without being forced to add a term for each entry in the array. The `start` and `len` arguments allow you to specify which terms to add.

**Arguments:**

- coeffs:** Coefficients for new terms.
- vars:** Variables for new terms.
- start:** The first term in the list to add.
- len:** The number of terms to add.

### **GRBLinExpr.Clear()**

Set a linear expression to 0.

You should use the overloaded `expr = 0` instead. The `clear` method is mainly included for consistency with our interfaces to non-overloaded languages.

```
void Clear ( )
```

### **GRBLinExpr.Constant**

(Property) The constant term from the linear expression.

### **GRBLinExpr.GetCoeff()**

Retrieve the coefficient from a single term of the expression.

```
double GetCoeff ( int i )
```

**Return value:**

Coefficient for the term at index `i` in the expression.

### **GRBLinExpr.GetVar()**

Retrieve the variable object from a single term of the expression.

```
GRBVar GetVar ( int i )
```

**Return value:**

Variable for the term at index `i` in the expression.

### **GRBLinExpr.MultAdd()**

Add a constant multiple of one linear expression into another. Upon completion, the invoking linear expression is equal the sum of itself and the constant times the argument expression.

```
void MultAdd ( double m,
              GRBLinExpr le )
```

**Arguments:**

**m:** Constant multiplier for added expression.

**le:** Linear expression to add.

**GRBLinExpr.Remove()**

Remove a term from a linear expression.

```
| void Remove ( int i )
```

Remove the term stored at index **i** of the expression.

**Arguments:**

**i:** The index of the term to be removed.

```
| boolean Remove ( GRBVar var )
```

Remove all terms associated with variable **var** from the expression.

**Arguments:**

**var:** The variable whose term should be removed.

**Return value:**

Returns **true** if the variable appeared in the linear expression (and was removed).

**GRBLinExpr.Size**

(Property) The number of terms in the linear expression (not including the constant).

**GRBLinExpr.Value**

(Property) The value of an expression for the current solution.

## 5.10 GRBQuadExpr

Gurobi quadratic expression object. A quadratic expression consists of a linear expression, plus a list of coefficient-variable-variable triples that capture the quadratic terms. Quadratic expressions are used to build quadratic objective functions and quadratic constraints. They are temporary objects that typically have short lifespans.

The `GRBQuadExpr` class is a sub-class of the abstract base class `GRBExpr`.

In .NET languages that support operator overloading, you generally build quadratic expressions using overloaded operators. For example, if `x` is a `GRBVar` object, then `x * x` is a `GRBQuadExpr` object. Expressions can be built from constants (e.g., `expr = 0`), variables (e.g., `expr = 1 * x * x + 2 * x * y`), or from other expressions (e.g., `expr2 = 2 * expr1 + x`, or `expr3 = expr1 + 2 * expr2`). You can also modify existing expressions (e.g., `expr += x * x`, or `expr2 -= expr1`).

The other option for building expressions is to start with an empty expression (using the `GRBQuadExpr` constructor), and then add terms. Terms can be added individually (using `AddTerm`) or in groups (using `AddTerms` or `MultAdd`). Terms can also be removed from an expression (using `Remove`).

Note that the cost of building expressions depends heavily on the approach you use. While you can generally ignore this issue when building small expressions, you should be aware of a few efficiency issues when building large expressions:

- You should avoid using `expr = expr + x*x` or `expr += x*x` in a loop. It will lead to runtimes that are quadratic in the number of terms in the expression.
- Using `AddTerm` in a loop is reasonably efficient, but it isn't the most efficient approach.
- The most efficient way to build a large expression is to make a single call to `AddTerms`.

Individual quadratic terms in a quadratic expression can be queried using the `GetVar1`, `GetVar2`, and `GetCoeff` methods. You can query the number of quadratic terms in the expression using the `Size` property. To query the constant and linear terms associated with a quadratic expression, first obtain the linear portion of the quadratic expression using `LinExpr`, and then use the `Constant`, `GetCoeff`, or `GetVar` on the resulting `GRBLinExpr` object.

Note that a quadratic expression may contain multiple terms that involve the same variable pair. These duplicate terms are merged when creating the model objective from an expression, but they may be visible when inspecting individual quadratic terms in the expression (e.g., when using `GetVar1` and `GetVar2`).

### GRBQuadExpr()

Quadratic expression constructor. Create an empty quadratic expression, or copy an existing expression.

```
| GRBQuadExpr GRBQuadExpr ( )  
    Create an empty quadratic expression.  
    Return value:  
        An empty expression object.  
| GRBQuadExpr GRBQuadExpr ( double a )
```

Create a constant quadratic expression.

**Return value:**

A quadratic expression object.

```
| GRBQuadExpr GRBQuadExpr ( GRBLinExpr orig )
```

Initialize a quadratic expression from an existing linear expression.

**Arguments:**

**orig:** Existing linear expression to copy.

**Return value:**

Quadratic expression object whose initial value is taken from the input linear expression.

```
| GRBQuadExpr GRBQuadExpr ( GRBQuadExpr orig )
```

Copy an existing quadratic expression.

**Arguments:**

**orig:** Existing expression to copy.

**Return value:**

A copy of the input expression object.

### **GRBQuadExpr.Add()**

Add an expression into a quadratic expression. Upon completion, the invoking quadratic expression will be equal to the sum of itself and the argument expression.

```
| void Add ( GRBLinExpr le )
```

Add a linear expression.

**Arguments:**

**le:** Linear expression to add.

```
| void Add ( GRBQuadExpr qe )
```

Add a quadratic expression.

**Arguments:**

**qe:** Quadratic expression to add.

### **GRBQuadExpr.AddConstant()**

Add a constant into a quadratic expression.

```
| void AddConstant ( double c )
```

**Arguments:**

**c:** Constant to add to expression.

### **GRBQuadExpr.AddTerm()**

Add a single term into a quadratic expression.

```
void AddTerm ( double coeff,
                GRBVar var )
```

Add a single linear term ( $\text{coeff} \cdot \text{var}$ ) into a quadratic expression.

**Arguments:**

**coeff:** Coefficient for new term.  
**var:** Variable for new term.

```
void AddTerm ( double coeff,
                GRBVar var1,
                GRBVar var2 )
```

Add a single quadratic term ( $\text{coeff} \cdot \text{var1} \cdot \text{var2}$ ) into a quadratic expression.

**Arguments:**

**coeff:** Coefficient for new quadratic term.  
**var1:** First variable for new quadratic term.  
**var2:** Second variable for new quadratic term.

## GRBQuadExpr.AddTerms()

Add new terms into a quadratic expression.

```
void AddTerms ( double[] coeffs,
                 GRBVar[] vars )
```

Add a list of linear terms into a quadratic expression. Note that the lengths of the two argument arrays must be equal.

**Arguments:**

**coeffs:** Coefficients for new terms.  
**vars:** Variables for new terms.

```
void AddTerms ( double[] coeffs,
                 GRBVar[] vars,
                 int start,
                 int len )
```

Add new linear terms into a quadratic expression. This signature allows you to use arrays to hold the coefficients and variables that describe the linear terms in an array without being forced to add a term for each entry in the array. The **start** and **len** arguments allow you to specify which terms to add.

**Arguments:**

**coeffs:** Coefficients for new terms.  
**vars:** Variables for new terms.  
**start:** The first term in the list to add.  
**len:** The number of terms to add.

```
void AddTerms ( double[] coeffs,
                 GRBVar[] vars1,
                 GRBVar[] vars2 )
```

Add a list of quadratic terms into a quadratic expression. Note that the lengths of the three argument arrays must be equal.

**Arguments:**

- coeffs:** Coefficients for new quadratic terms.
- vars1:** First variables for new quadratic terms.
- vars2:** Second variables for new quadratic terms.

```
void AddTerms ( double[] coeffs,
                GRBVar[] vars1,
                GRBVar[] vars2,
                int start,
                int len )
```

Add new quadratic terms into a quadratic expression. This signature allows you to use arrays to hold the coefficients and variables that describe the terms in an array without being forced to add a term for each entry in the array. The **start** and **len** arguments allow you to specify which terms to add.

**Arguments:**

- coeffs:** Coefficients for new quadratic terms.
- vars1:** First variables for new quadratic terms.
- vars2:** Second variables for new quadratic terms.
- start:** The first term in the list to add.
- len:** The number of terms to add.

### GRBQuadExpr.Clear()

Set a quadratic expression to 0.

You should use the overloaded `expr = 0` instead. The `clear` method is mainly included for consistency with our interfaces to non-overloaded languages.

```
void Clear ( )
```

### GRBQuadExpr.GetCoeff()

Retrieve the coefficient from a single quadratic term of the quadratic expression.

```
double GetCoeff ( int i )
```

**Return value:**

Coefficient for the quadratic term at index `i` in the expression.

### GRBQuadExpr.GetVar1()

Retrieve the first variable object associated with a single quadratic term from the expression.

```
GRBVar GetVar1 ( int i )
```

**Return value:**

First variable for the quadratic term at index `i` in the quadratic expression.

## GRBQuadExpr.GetVar2()

Retrieve the second variable object associated with a single quadratic term from the expression.

```
GRBVar GetVar2 ( int i )
```

### Return value:

Second variable for the quadratic term at index *i* in the quadratic expression.

## GRBQuadExpr.LinExpr()

(Property) A quadratic expression is represented as a linear expression, plus a list of quadratic terms. This method retrieves the linear expression associated with the quadratic expression.

## GRBQuadExpr.MultAdd()

Add a constant multiple of one quadratic expression into another. Upon completion, the invoking quadratic expression is equal the sum of itself and the constant times the argument expression.

```
void MultAdd ( double m,
              GRBLinExpr le )
```

Add a linear expression into a quadratic expression.

### Arguments:

*m*: Constant multiplier for added expression.

*le*: Linear expression to add.

```
void MultAdd ( double m,
              GRBQuadExpr qe )
```

Add a quadratic expression into a quadratic expression.

### Arguments:

*m*: Constant multiplier for added expression.

*qe*: Quadratic expression to add.

## GRBQuadExpr.Remove()

Remove a quadratic term from a quadratic expression.

```
void Remove ( int i )
```

Remove the quadratic term stored at index *i* of the expression.

### Arguments:

*i*: The index of the quadratic term to be removed.

```
boolean Remove ( GRBVar var )
```

Remove all quadratic terms associated with variable *var* from the expression.

### Arguments:

*var*: The variable whose quadratic term should be removed.

### Return value:

Returns `true` if the variable appeared in the quadratic expression (and was removed).

**GRBQuadExpr.Size**

(Property) The number of quadratic terms in the quadratic expression. Use [GRBQuadExpr.LinExpr](#) to retrieve constant or linear terms from the quadratic expression.

**GRBQuadExpr.Value**

(Property) The value of an expression for the current solution.

## 5.11 GRBTempConstr

Gurobi temporary constraint object. Objects of this class are created as intermediate results when building constraints using overloaded operators. There are no public methods on this class. Instead, `GRBTempConstr` objects are created by operators `==`, `<=`, or `>=`. You will generally never store objects of this class in your own variables.

Consider the following examples:

```
model.AddConstr(x + y <= 1);  
model.AddQConstr(x*x + y*y <= 1);
```

The overloaded `<=` operator creates an object of type `GRBTempConstr`, which is then immediately passed to [GRBModel.AddConstr](#) or [GRBModel.AddQConstr](#).

## 5.12 GRBColumn

Gurobi column object. A column consists of a list of coefficient, constraint pairs. Columns are used to represent the set of constraints in which a variable participates, and the associated coefficients. They are temporary objects that typically have short lifespans.

You generally build columns by starting with an empty column (using the [GRBColumn](#) constructor), and then adding terms. Terms can be added individually, using [AddTerm](#), or in groups, using [AddTerms](#). Terms can also be removed from a column, using [Remove](#).

Individual terms in a column can be queried using the [GetConstr](#), and [GetCoeff](#) methods. You can query the number of terms in the column using the [Size](#) property.

### GRBColumn()

Column constructor. Create an empty column, or copy an existing column.

```
| GRBColumn GRBColumn ( )
```

Create an empty column.

**Return value:**

An empty column object.

```
| GRBColumn GRBColumn ( GRBColumn orig )
```

Copy an existing column.

**Return value:**

A copy of the input column object.

### GRBColumn.AddTerm()

Add a single term into a column.

```
| void AddTerm ( double coeff,  
                GRBConstr constr )
```

**Arguments:**

**coeff:** Coefficient for new term.

**constr:** Constraint for new term.

### GRBColumn.AddTerms()

Add new terms into a column.

```
| void AddTerms ( double[] coeffs,  
                 GRBConstr[] constrs )
```

Add a list of terms into a column. Note that the lengths of the two argument arrays must be equal.

**Arguments:**

**coeffs:** Coefficients for added constraints.

**constrs:** Constraints to add to column.

```
void AddTerms ( double[]   coeffs,  
                GRBConstr[] constrs,  
                int       start,  
                int       len )
```

Add new terms into a column. This signature allows you to use arrays to hold the coefficients and constraints that describe the terms in an array without being forced to add a term for each member in the array. The `start` and `len` arguments allow you to specify which terms to add.

**Arguments:**

**coeffs:** Coefficients for added constraints.  
**constrs:** Constraints to add to column.  
**start:** The first term in the list to add.  
**len:** The number of terms to add.

### **GRBColumn.Clear()**

Remove all terms from a column.

```
void Clear ( )
```

### **GRBColumn.GetCoeff()**

Retrieve the coefficient from a single term in the column.

```
double GetCoeff ( int i )
```

**Return value:**

Coefficient for the term at index `i` in the column.

### **GRBColumn.GetConstr()**

Retrieve the constraint object from a single term in the column.

```
GRBConstr GetConstr ( int i )
```

**Return value:**

Constraint for the term at index `i` in the column.

### **GRBColumn.Remove()**

Remove a single term from a column.

```
GRBConstr Remove ( int i )
```

Remove the term stored at index `i` of the column.

**Arguments:**

**i:** The index of the term to be removed.

**Return value:**

The constraint whose term was removed from the column. Returns `null` if the specified index is out of range.

```
boolean Remove ( GRBConstr constr )
```

Remove the term associated with constraint `constr` from the column.

**Arguments:**

`constr`: The constraint whose term should be removed.

**Return value:**

Returns `true` if the constraint appeared in the column (and was removed).

**GRBColumn.Size**

(Property) The number of terms in the column.

## 5.13 Overloaded Operators

The Gurobi .NET interface overloads several arithmetic and comparison operators. Overloaded arithmetic operators (+, -, \*, /) are used to create linear and quadratic expressions. Overloaded comparison operators (<=, >=, and ==) are used to build linear and quadratic constraints.

Note that the results of overloaded comparison operators are generally never stored in user variables. They are immediately passed to [GRBModel.AddConstr](#) or [GRBModel.AddQConstr](#).

### operator <=

Create an inequality constraint.

```
GRBTempConstr operator <= ( GRBQuadExpr lhsExpr,  
                           GRBQuadExpr rhsExpr )
```

**Arguments:**

**lhsExpr:** Left-hand side of inequality constraint.

**rhsExpr:** Right-hand side of inequality constraint.

**Return value:**

A constraint of type [GRBTempConstr](#). The result is typically immediately passed to method [GRBModel.AddConstr](#).

### operator >=

Create an inequality constraint.

```
GRBTempConstr operator >= ( GRBQuadExpr lhsExpr,  
                           GRBQuadExpr rhsExpr )
```

**Arguments:**

**lhsExpr:** Left-hand side of inequality constraint.

**rhsExpr:** Right-hand side of inequality constraint.

**Return value:**

A constraint of type [GRBTempConstr](#). The result is typically immediately passed to method [GRBModel.AddConstr](#).

### operator ==

Create an equality constraint.

```
GRBTempConstr operator == ( GRBLinExpr lhsExpr,  
                           GRBLinExpr rhsExpr )
```

**Arguments:**

**lhsExpr:** Left-hand side of equality constraint.

**rhsExpr:** Right-hand side of equality constraint.

**Return value:**

A constraint of type [GRBTempConstr](#). The result is typically immediately passed to method [GRBModel.AddConstr](#).

## operator +

Create a new expression by adding a pair of Gurobi objects.

```
GRBLinExpr operator + ( GRBLinExpr expr1,  
                        GRBLinExpr expr2 )
```

### Arguments:

**expr1:** First linear expression argument.

**expr2:** Second linear expression argument.

### Return value:

A linear expression that is equal to the sum of the two argument expressions.

```
GRBLinExpr operator + ( GRBLinExpr expr,  
                        GRBVar      var )
```

### Arguments:

**expr:** Linear expression argument.

**var:** Variable argument.

### Return value:

A linear expression that is equal to the sum of the argument linear expression and the argument variable.

```
GRBLinExpr operator + ( GRBVar      var,  
                        GRBLinExpr expr )
```

### Arguments:

**var:** Variable argument.

**expr:** Linear expression argument.

### Return value:

A linear expression that is equal to the sum of the argument linear expression and the argument variable.

```
GRBLinExpr operator + ( GRBVar var1,  
                        GRBVar var2 )
```

### Arguments:

**var1:** First variable argument.

**var2:** Second variable argument.

### Return value:

A linear expression that is equal to the sum of the two argument variables.

```
GRBLinExpr operator + ( double a,  
                        GRBVar var )
```

### Arguments:

**a:** Constant.

**var:** Variable.

**Return value:**

A linear expression that is equal to the sum of the constant and the variable argument.

```
GRBLinExpr operator + ( GRBVar var,
                        double a )
```

**Arguments:**

**var:** Variable.

**a:** Constant.

**Return value:**

A linear expression that is equal to the sum of the constant and the variable argument.

```
GRBQuadExpr operator + ( GRBQuadExpr expr1,
                         GRBQuadExpr expr2 )
```

**Arguments:**

**expr1:** First quadratic expression argument.

**expr2:** Second quadratic expression argument.

**Return value:**

A quadratic expression that is equal to the sum of the two argument quadratic expressions.

```
GRBQuadExpr operator + ( GRBQuadExpr expr,
                         GRBVar var )
```

**Arguments:**

**expr:** Quadratic expression argument.

**var:** Variable argument.

**Return value:**

A quadratic expression that is equal to the sum of the argument quadratic expression and the argument variable.

```
GRBQuadExpr operator + ( GRBVar var,
                         GRBQuadExpr expr )
```

**Arguments:**

**var:** Variable argument.

**expr:** Quadratic expression argument.

**Return value:**

A quadratic expression that is equal to the sum of the argument quadratic expression and the argument variable.

**operator -**

Create a new expression by subtracting one Gurobi object from another.

```
GRBLinExpr operator - ( GRBLinExpr expr1,
                       GRBLinExpr expr2 )
```

**Arguments:**

**expr1:** First linear expression argument.  
**expr2:** Second linear expression argument.

**Return value:**

A linear expression that is equal to the first expression minus the second.

```
GRBQuadExpr operator - ( GRBQuadExpr expr1,
                        GRBQuadExpr expr2 )
```

**Arguments:**

**expr1:** First quadratic expression argument.  
**expr2:** Second quadratic expression argument.

**Return value:**

A quadratic expression that is equal to the first expression minus the second.

**operator \***

Create a new expression by multiplying a pair of Gurobi objects.

```
GRBLinExpr operator * ( double multiplier,
                       GRBLinExpr expr )
```

**Arguments:**

**multiplier:** Multiplier for expression argument.  
**expr:** Expression argument.

**Return value:**

A linear expression that is equal to the input expression times the input multiplier.

```
GRBLinExpr operator * ( GRBLinExpr expr,
                       double multiplier )
```

**Arguments:**

**expr:** Linear expression argument.  
**multiplier:** Multiplier for expression argument.

**Return value:**

A linear expression that is equal to the input expression times the input multiplier.

```
GRBLinExpr operator * ( double multiplier,
                       GRBVar var )
```

**Arguments:**

**multiplier:** Multiplier for variable argument.  
**var:** Variable argument.

**Return value:**

A linear expression that is equal to the input variable times the input multiplier.

```
GRBLinExpr operator * ( GRBVar var,
                       double multiplier )
```

**Arguments:**

**var:** Variable argument.  
**multiplier:** Multiplier for variable argument.

**Return value:**

A linear expression that is equal to the input variable times the input multiplier.

```
GRBQuadExpr operator * ( double multiplier,
                        GRBQuadExpr expr )
```

**Arguments:**

**multiplier:** Multiplier for expression argument.  
**expr:** Quadratic expression argument.

**Return value:**

A quadratic expression that is equal to the input expression times the input multiplier.

```
GRBQuadExpr operator * ( GRBQuadExpr expr,
                        double multiplier )
```

**Arguments:**

**expr:** Quadratic expression argument.  
**multiplier:** Multiplier for expression argument.

**Return value:**

A quadratic expression that is equal to the input expression times the input multiplier.

```
GRBQuadExpr operator * ( GRBVar var1,
                        GRBVar var2 )
```

**Arguments:**

**var1:** First variable argument.  
**var2:** Second variable argument.

**Return value:**

A quadratic expression that is equal to the product of the two input variables.

```
GRBQuadExpr operator * ( GRBVar var,
                        GRBLinExpr expr )
```

**Arguments:**

**var:** Input variable.  
**expr:** Input linear expression.

**Return value:**

A quadratic expression that is equal to the input linear expression times the input variable.

```
GRBQuadExpr operator * ( GRBLinExpr expr,
                        GRBVar var )
```

**Arguments:**

**expr:** Input linear expression.  
**var:** Input variable.

**Return value:**

A quadratic expression that is equal to the input linear expression times the input variable.

```
GRBQuadExpr operator * ( GRBLinExpr expr1,
                        GRBLinExpr expr2 )
```

**Arguments:**

**expr1:** First linear expression argument.

**expr2:** Second linear expression argument.

**Return value:**

A quadratic expression that is equal to the product of the two input linear expressions.

**operator /**

Create a new expression by dividing a Gurobi variable by a constant.

```
GRBLinExpr operator / ( GRBVar var,
                       double divisor )
```

**Arguments:**

**var:** Variable argument.

**divisor:** Divisor for variable argument.

**Return value:**

A linear expression that is equal to the input variable divided by the input divisor.

**implicit cast**

Create an expression from an implicit cast (e.g., `expr = 0.0` or `expr = x`).

```
GRBLinExpr GRBLinExpr ( double value )
```

**Arguments:**

**value:** Desired value for linear expression.

**Return value:**

A linear expression that is equal to specified constant.

```
GRBQuadExpr GRBQuadExpr ( double value )
```

**Arguments:**

**value:** Desired value for quadratic expression.

**Return value:**

A quadratic expression that is equal to specified constant.

```
GRBLinExpr GRBLinExpr ( GRBVar var )
```

**Arguments:**

**value:** Desired value for linear expression.

**Return value:**

A linear expression that is equal to specified variable.

| GRBQuadExpr **GRBQuadExpr** ( GRBVar var )

**Arguments:**

**value:** Desired value for quadratic expression.

**Return value:**

A quadratic expression that is equal to specified variable.

| GRBQuadExpr **GRBQuadExpr** ( GRBLinExpr expr )

**Arguments:**

**expr:** Desired value for quadratic expression.

**Return value:**

A quadratic expression that is equal to specified linear expression.

## 5.14 GRBCallback

Gurobi callback class. This is an abstract class. To implement a callback, you should create a subclass of this class and implement a `callback()` method. If you pass an object of this subclass to method `GRBModel.SetCallback` before calling `GRBModel.Optimize`, the `callback()` method of the class will be called periodically. Depending on where the callback is called from, you will be able to obtain various information about the progress of the optimization.

Note that this class contains one protected *int* member variable: `where`. You can query this variable from your `callback()` method to determine where the callback was called from.

Gurobi callbacks can be used both to monitor the progress of the optimization and to modify the behavior of the Gurobi optimizer. A simple user callback function might call the `GRBCallback.GetIntInfo` or `GRBCallback.GetDoubleInfo` methods to produce a custom display, or perhaps to terminate optimization early (using `GRBCallback.Abort`). More sophisticated MIP callbacks might use `GRBCallback.GetNodeRel` or `GRBCallback.GetSolution` to retrieve values from the solution to the current node, and then use `GRBCallback.AddCut` or `GRBCallback.AddLazy` to add a constraint to cut off that solution, or `GRBCallback.SetSolution` to import a heuristic solution built from that solution.

When solving a model using multiple threads, note that the user callback is only ever called from a single thread, so you don't need to worry about the thread-safety of your callback.

You can look at the `callback_cs.cs` example for details of how to use Gurobi callbacks.

### GRBCallback()

Callback constructor.

```
| GRBCallback GRBCallback ( )
```

**Return value:**

A callback object.

### GRBCallback.Abort()

Abort optimization. When the optimization stops, the `Status` attribute will be equal to `GRB.Status.INTERRUPTED`.

```
| void Abort ( )
```

### GRBCallback.AddCut()

Add a cutting plane to the MIP model from within a callback function. Note that this method can only be invoked when the `where` member variable is equal to `GRB.Callback.MIPNODE` (see the [Callback Codes](#) section for more information).

Cutting planes can be added at any node of the branch-and-cut tree. However, they should be added sparingly, since they increase the size of the relaxation model that is solved at each node and can significantly degrade node processing speed.

Cutting planes are typically used to cut off the current relaxation solution. To retrieve the relaxation solution at the current node, you should first call `GetNodeRel`.

When adding your own cuts, you must set parameter `PreCrush` to value 1. This setting shuts off a few presolve reductions that sometimes prevent cuts on the original model from being applied to the presolved model.

Note that cutting planes added through this method must truly be cutting planes — they can cut off continuous solutions, but they may not cut off integer solutions that respect the original constraints of the model. Ignoring this restriction will lead to incorrect solutions.

```
void AddCut ( GRBLinExpr lhsExpr,  
              char       sense,  
              double     rhsVal )
```

**Arguments:**

**lhsExpr**: Left-hand side expression for new cutting plane.

**sense**: Sense for new cutting plane (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhsVal**: Right-hand side value for new cutting plane.

```
void AddConstr ( GRBTempConstr tempConstr )
```

**Arguments:**

**tempConstr**: Temporary constraint object, created by an overloaded comparison operator.

### GRBCallback.AddLazy()

Add a lazy constraint to the MIP model from within a callback function. Note that this method can only be invoked when the **where** member variable is GRB.Callback.MIPNODE or GRB.Callback.MIPSOL (see the [Callback Codes](#) section for more information).

Lazy constraints are typically used when the full set of constraints for a MIP model is too large to represent explicitly. By only including the constraints that are actually violated by solutions found during the branch-and-cut search, it is sometimes possible to find a proven optimal solution while only adding a fraction of the full set of constraints.

You would typically add a lazy constraint by first querying the current node solution (by calling [GetSolution](#) from a GRB.Callback.MIPSOL callback, or [GetNodeRel](#) from a GRB.Callback.MIPNODE callback), and then calling `AddLazy()` to add a constraint that cuts off the solution. Gurobi guarantees that you will have the opportunity to cut off any solutions that would otherwise be considered feasible.

Your callback should be prepared to cut off solutions that violate any of your lazy constraints, including those that have already been added. Node solutions will usually respect previously added lazy constraints, but not always.

Note that you must set the [LazyConstraints](#) parameter if you want to use lazy constraints.

```
void AddLazy ( GRBLinExpr lhsExpr,  
               char       sense,  
               double     rhsVal )
```

**Arguments:**

**lhsExpr**: Left-hand side expression for new lazy constraint.

**sense**: Sense for new lazy constraint (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhsVal**: Right-hand side value for new lazy constraint.

```
void AddConstr ( GRBTempConstr tempConstr )
```

**Arguments:**

**tempConstr:** Temporary constraint object, created by an overloaded comparison operator.

**GRBCallback.GetDoubleInfo()**

Request double-valued callback information. The available information depends on the value of the **where** member. For information on possible values of **where**, and the double-valued information that can be queried for different values of **where**, please refer to the [Callback](#) section.

```
| double GetDoubleInfo ( int what )
```

**Arguments:**

**what:** Information requested (refer the list of Gurobi [Callback Codes](#) for possible values).

**Return value:**

Value of requested callback information.

**GRBCallback.GetIntInfo()**

Request int-valued callback information. The available information depends on the value of the **where** member. For information on possible values of **where**, and the int-valued information that can be queried for different values of **where**, please refer to the [Callback](#) section.

```
| int GetIntInfo ( int what )
```

**Arguments:**

**what:** Information requested (refer the list of Gurobi [Callback Codes](#) for possible values).

**Return value:**

Value of requested callback information.

**GRBCallback.GetNodeRel()**

Retrieve values from the node relaxation solution at the current node. Only available when the **where** member variable is equal to `GRB.Callback.MIPNODE`, and `GRB.Callback.MIPNODE_STATUS` is equal to `GRB.Status.OPTIMAL`.

```
| double GetNodeRel ( GRBVar v )
```

**Arguments:**

**v:** The variable whose value is desired.

**Return value:**

The value of the specified variable in the node relaxation for the current node.

```
| double[] GetNodeRel ( GRBVar[] xvars )
```

**Arguments:**

**xvars:** The list of variables whose values are desired.

**Return value:**

The values of the specified variables in the node relaxation for the current node.

```
| double[][] GetNodeRel ( GRBVar[][] xvars )
```

**Arguments:**

**xvars:** The array of variables whose values are desired.

**Return value:**

The values of the specified variables in the node relaxation for the current node.

**GRBCallback.GetSolution()**

Retrieve values from the current solution vector. Only available when the **where** member variable is equal to `GRB.Callback.MIPSOL`.

```
| double GetSolution ( GRBVar v )
```

**Arguments:**

**v:** The variable whose value is desired.

**Return value:**

The value of the specified variable in the current solution vector.

```
| double[] GetSolution ( GRBVar[] xvars )
```

**Arguments:**

**xvars:** The list of variables whose values are desired.

**Return value:**

The values of the specified variables in the current solution.

```
| double[][] GetSolution ( GRBVar[][] xvars )
```

**Arguments:**

**xvars:** The array of variables whose values are desired.

**Return value:**

The values of the specified variables in the current solution.

**GRBCallback.GetStringInfo()**

Request string-valued callback information. The available information depends on the value of the **where** member. For information on possible values of **where**, and the string-valued information that can be queried for different values of **where**, please refer to the [Callback](#) section.

```
| string GetStringInfo ( int what )
```

**Arguments:**

**what:** Information requested (refer the list of Gurobi [Callback Codes](#) for possible values).

**Return value:**

Value of requested callback information.

**GRBCallback.SetSolution()**

Import solution values for a heuristic solution. Only available when the **where** member variable is equal to `GRB.Callback.MIPNODE`.

When you specify a heuristic solution from a callback, variables initially take undefined values. You should use this method to specify variable values. You can make multiple calls to `SetSolution`

from one callback invocation to specify values for multiple sets of variables. At the end of the callback, if values have been specified for any variables, the Gurobi optimizer will try to compute a feasible solution from the specified values, possibly filling in values for variables whose values were left undefined.

```
void SetSolution ( GRBVar v,  
                  double val )
```

**Arguments:**

**v**: The variable whose values is being set.  
**val**: The value of the variable in the new solution.

```
void SetSolution ( GRBVar[] xvars,  
                  double[] sol )
```

**Arguments:**

**xvars**: The variables whose values are being set.  
**sol**: The desired values of the specified variables in the new solution.

## 5.15 GRBException

Gurobi exception object. This is a sub-class of the .NET `Exception` class. A number of useful properties, including `Message()` and `StackTrace()`, are inherited from the parent class. For a list of parent class methods, visit [this site](#).

### GRBException()

Exception constructor.

```
GRBException GRBException ( int errcode )
```

Create a Gurobi exception.

**Arguments:**

`errcode`: Error code for exception.

**Return value:**

An exception object.

```
GRBException GRBException ( string errmsg )
```

Create a Gurobi exception.

**Arguments:**

`errmsg`: Error message for exception.

**Return value:**

An exception object.

```
GRBException GRBException ( string errmsg,  
                             int errcode )
```

Create a Gurobi exception.

**Arguments:**

`errmsg`: Error message for exception.

`errcode`: Error code for exception.

**Return value:**

An exception object.

### GRBException.ErrorCode

(Property) The error code associated with a Gurobi exception.

## 5.16 GRB

Class for .NET enums and constants. The enums are used to get or set Gurobi attributes or parameters.

### Constants

The following list contains the set of constants needed by the Gurobi .NET interface. You would refer to them using a GRB. prefix (e.g., GRB.Status.OPTIMAL).

```
// Model status codes (after call to optimize())

public class Status
{
    public const int LOADED          = 1;
    public const int OPTIMAL         = 2;
    public const int INFEASIBLE     = 3;
    public const int INF_OR_UNBD    = 4;
    public const int UNBOUNDED      = 5;
    public const int CUTOFF         = 6;
    public const int ITERATION_LIMIT = 7;
    public const int NODE_LIMIT     = 8;
    public const int TIME_LIMIT     = 9;
    public const int SOLUTION_LIMIT = 10;
    public const int INTERRUPTED    = 11;
    public const int NUMERIC        = 12;
    public const int SUBOPTIMAL     = 13;
    public const int INPROGRESS     = 14;
    public const int USER_OBJ_LIMIT = 15;
}

// Basis status info

public const int BASIC          = 0;
public const int NONBASIC_LOWER = -1;
public const int NONBASIC_UPPER = -2;
public const int SUPERBASIC    = -3;

// Constraint senses

public const char LESS_EQUAL    = '<';
public const char GREATER_EQUAL = '>';
public const char EQUAL        = '=';

// Variable types
```

```

public const char CONTINUOUS    = 'C';
public const char BINARY       = 'B';
public const char INTEGER      = 'I';
public const char SEMICONT     = 'S';
public const char SEMIINT      = 'N';

// Objective sense

public const int MINIMIZE = 1;
public const int MAXIMIZE = -1;

// SOS types

public const int SOS_TYPE1 = 1;
public const int SOS_TYPE2 = 2;

// General constraint types

public const int GENCONSTR_MAX      = 0;
public const int GENCONSTR_MIN      = 1;
public const int GENCONSTR_ABS      = 2;
public const int GENCONSTR_AND      = 3;
public const int GENCONSTR_OR       = 4;
public const int GENCONSTR_INDICATOR = 5;

// Numeric constants

public const double INFINITY      = 1e100;
public const double UNDEFINED     = 1e101;

// Limits

public const int MAX_STRLEN = 512;

// Callback constants

public class Callback
{
    public const int POLLING      = 0;
    public const int PRESOLVE    = 1;
    public const int SIMPLEX     = 2;
    public const int MIP         = 3;
    public const int MIPSOL      = 4;
    public const int MIPNODE     = 5;
}

```

```

public const int MESSAGE      = 6;
public const int BARRIER    = 7;

public const int PRE_COLDEL   = 1000;
public const int PRE_ROWDEL   = 1001;
public const int PRE_SENCHG   = 1002;
public const int PRE_BNDCHG   = 1003;
public const int PRE_COECHG   = 1004;
public const int SPX_ITRCNT    = 2000;
public const int SPX_OBJVAL    = 2001;
public const int SPX_PRIMINF   = 2002;
public const int SPX_DUALINF   = 2003;
public const int SPX_ISPERT    = 2004;
public const int MIP_OBJBST    = 3000;
public const int MIP_OBJBND    = 3001;
public const int MIP_NODCNT    = 3002;
public const int MIP_SOLCNT    = 3003;
public const int MIP_CUTCNT    = 3004;
public const int MIP_NODLFT    = 3005;
public const int MIP_ITRCNT    = 3006;
public const int MIPSOL_SOL    = 4001;
public const int MIPSOL_OBJ    = 4002;
public const int MIPSOL_OBJBST = 4003;
public const int MIPSOL_OBJBND = 4004;
public const int MIPSOL_NODCNT = 4005;
public const int MIPSOL_SOLCNT = 4006;
public const int MIPNODE_STATUS = 5001;
public const int MIPNODE_REL    = 5002;
public const int MIPNODE_OBJBST = 5003;
public const int MIPNODE_OBJBND = 5004;
public const int MIPNODE_NODCNT = 5005;
public const int MIPNODE_SOLCNT = 5006;
public const int BARRIER_ITRCNT = 7001;
public const int BARRIER_PRIMOBJ = 7002;
public const int BARRIER_DUALOBJ = 7003;
public const int BARRIER_PRIMINF = 7004;
public const int BARRIER_DUALINF = 7005;
public const int BARRIER_COMPL = 7006;
public const int MSG_STRING      = 6001;
public const int RUNTIME        = 6002;
}

// Errors

public class Error

```

```

{
public const int OUT_OF_MEMORY           = 10001;
public const int NULL_ARGUMENT           = 10002;
public const int INVALID_ARGUMENT        = 10003;
public const int UNKNOWN_ATTRIBUTE       = 10004;
public const int DATA_NOT_AVAILABLE    = 10005;
public const int INDEX_OUT_OF_RANGE      = 10006;
public const int UNKNOWN_PARAMETER       = 10007;
public const int VALUE_OUT_OF_RANGE      = 10008;
public const int NO_LICENSE               = 10009;
public const int SIZE_LIMIT_EXCEEDED     = 10010;
public const int CALLBACK                 = 10011;
public const int FILE_READ                = 10012;
public const int FILE_WRITE              = 10013;
public const int NUMERIC                  = 10014;
public const int IIS_NOT_INFEASIBLE      = 10015;
public const int NOT_FOR_MIP              = 10016;
public const int OPTIMIZATION_IN_PROGRESS = 10017;
public const int DUPLICATES               = 10018;
public const int NODEFILE                 = 10019;
public const int Q_NOT_PSD                = 10020;
public const int QCP_EQUALITY_CONSTRAINT = 10021;
public const int NETWORK                  = 10022;
public const int JOB_REJECTED             = 10023;
public const int NOT_SUPPORTED            = 10024;
public const int EXCEED_2B_NONZEROS      = 10025;
public const int INVALID_PIECEWISE_OBJ   = 10026;
public const int UPDATEMODE_CHANGE       = 10027;
public const int CLOUD                    = 10028;
public const int MODEL_MODIFICATION       = 10029;
public const int NOT_IN_MODEL             = 20001;
public const int FAILED_TO_CREATE_MODEL  = 20002;
public const int INTERNAL                 = 20003;
}

public const int METHOD_AUTO               = -1;
public const int METHOD_PRIMAL              = 0;
public const int METHOD_DUAL                = 1;
public const int METHOD_BARRIER            = 2;
public const int METHOD_CONCURRENT          = 3;
public const int METHOD_DETERMINISTIC_CONCURRENT = 4;

public const int FEASRELAX_LINEAR         = 0;
public const int FEASRELAX_QUADRATIC      = 1;
public const int FEASRELAX_CARDINALITY    = 2;

```

## **GRB.CharAttr**

This enum is used to get or set char-valued attributes (through [GRBModel.Get](#) or [GRBModel.Set](#)). Please refer to the [Attributes](#) section to see a list of all char attributes and their functions.

## **GRB.DoubleAttr**

This enum is used to get or set double-valued attributes (through [GRBModel.Get](#) or [GRBModel.Set](#)). Please refer to the [Attributes](#) section to see a list of all double attributes and their functions.

## **GRB.DoubleParam**

This enum is used to get or set double-valued parameters (through [GRBModel.Get](#), [GRBModel.Set](#), [GRBEnv.Get](#), or [GRBEnv.Set](#)). Please refer to the [Parameters](#) section to see a list of all double parameters and their functions.

## **GRB.IntAttr**

This enum is used to get or set int-valued attributes (through [GRBModel.Get](#) or [GRBModel.Set](#)). Please refer to the [Attributes](#) section to see a list of all int attributes and their functions.

## **GRB.IntParam**

This enum is used to get or set int-valued parameters (through [GRBModel.Get](#), [GRBModel.Set](#), [GRBEnv.Get](#), or [GRBEnv.Set](#)). Please refer to the [Parameters](#) section to see a list of all int parameters and their functions.

## **GRB.StringAttr**

This enum is used to get or set string-valued attributes (through [GRBModel.Get](#) or [GRBModel.Set](#)). Please refer to the [Attributes](#) section to see a list of all string attributes and their functions.

## **GRB.StringParam**

This enum is used to get or set string-valued parameters (through [GRBModel.Get](#), [GRBModel.Set](#), [GRBEnv.Get](#), or [GRBEnv.Set](#)). Please refer to the [Parameters](#) section to see a list of all string parameters and their functions.

This section documents the Gurobi Python interface. It begins with an overview of the global functions, which can be called without referencing any Python objects. It then discusses the different types of objects that are available in the interface, and the most important methods on those objects. Finally, it gives a [comprehensive presentation of all of the available classes and methods](#).

**Important note for AIX users:** due to limited Python support on AIX, our AIX port does not include the Python interface.

## Global Functions

The Gurobi shell contains a set of [Global Functions](#) that can be called without referring to any Gurobi objects. The most important of these functions is probably the [read](#) function, which allows you to read a model from a file. Other useful global functions are [system](#), which allows you to issue shell commands from within the Gurobi shell, [models](#), which gives you a list of the currently loaded models, and [disposeDefaultEnv](#), which disposes of the default environment. Other global functions allow you to read, modify, or write Gurobi parameters ([readParams](#), [setParameter](#), and [writeParams](#)).

## Models

Most actions in the Gurobi Python interface are performed by calling methods on Gurobi objects. The most commonly used object is the [Model](#). A model consists of a set of decision variables (objects of class [Var](#)), a linear or quadratic objective function on these variables (specified using [Model.setObjective](#)), and a set of constraints on these variables (objects of class [Constr](#), [QConstr](#), [SOS](#), or [GenConstr](#)). Each variable has an associated lower bound, upper bound, and type (continuous, binary, etc.). Each linear or quadratic constraint has an associated sense (less-than-or-equal, greater-than-or-equal, or equal), and right-hand side value. Refer to [this section](#) for more information on variables and constraints.

An optimization model may be specified all at once, by loading the model from a file (using the previously mentioned [read](#) function), or it may be built incrementally, by first constructing an empty object of class [Model](#) and then subsequently calling [Model.addVar](#) or [Model.addVars](#) to add additional variables, and [Model.addConstr](#), [Model.addConstrs](#), [Model.addQConstr](#), [Model.addSOS](#), or any of the [Model.addGenConstrXxx](#) methods to add additional constraints.

Linear constraints are specified by building linear expressions (objects of class [LinExpr](#)), and then specifying relationships between these expressions (for example, requiring that one expression be equal to another). Quadratic constraints are built in a similar fashion, but using quadratic expressions (objects of class [QuadExpr](#)) instead.

Models are dynamic entities; you can always add or remove variables or constraints.

We often refer to the *class* of an optimization model. A model with a linear objective function, linear constraints, and continuous variables is a *Linear Program (LP)*. If the objective is quadratic, the model is a *Quadratic Program (QP)*. If any of the constraints are quadratic, the model is a *Quadratically-Constrained Program (QCP)*. We'll sometimes also discuss a special case of QCP, the *Second-Order Cone Program (SOCP)*. If the model contains any integer variables, semi-continuous

variables, semi-integer variables, Special Ordered Set (SOS) constraints, or general constraints, the model is a *Mixed Integer Program (MIP)*. We'll also sometimes discuss special cases of MIP, including *Mixed Integer Linear Programs (MILP)*, *Mixed Integer Quadratic Programs (MIQP)*, *Mixed Integer Quadratically-Constrained Programs (MIQCP)*, and *Mixed Integer Second-Order Cone Programs (MISOCP)*. The Gurobi Optimizer handles all of these model classes.

## Environments

Environments play a much smaller role in the Gurobi Python interface than they do in our other language APIs, mainly because the Python interface has a default environment. Unless you explicitly pass your own environment to routines that require an environment, the default environment will be used.

The main situation where you may want to create your own environment is when you want precise control over when the resources associated with an environment (specifically, a licensing token or a Compute Server) are released. If you use your own environment to create models (using `read` or the `Model` constructor), then the resources associated with the environment will be released as soon your program no longer references your environment or any models created with that environment.

Note that you can manually remove the reference to the default environment, thus making it available for garbage collection, by calling `disposeDefaultEnv`. After calling this, and after all models built within the default environment are garbage collected, the default environment will be garbage collected as well. A new default environment will be created automatically if you call a routine that needs one.

## Solving a Model

Once you have built a model, you can call `Model.optimize` to compute a solution. By default, `optimize` will use the `concurrent optimizer` to solve LP models, the barrier algorithm to solve QP and QCP models, and the branch-and-cut algorithm to solve mixed integer models. The solution is stored in a set of *attributes* of the model, which can be subsequently queried (we will return to this topic shortly).

The Gurobi algorithms keep careful track of the state of the model, so calls to `Model.optimize` will only perform further optimization if relevant data has changed since the model was last optimized. If you would like to discard previously computed solution information and restart the optimization from scratch without changing the model, you can call `Model.reset`.

After a MIP model has been solved, you can call `Model.fixed` to compute the associated *fixed* model. This model is identical to the input model, except that all integer variables are fixed to their values in the MIP solution. In some applications, it is useful to compute information on this continuous version of the MIP model (e.g., dual variables, sensitivity information, etc.).

## Multiple Solutions and Multiple Objectives

By default, the Gurobi Optimizer assumes that your goal is to find one proven optimal solution to a model with a single objective function. Gurobi provides features that allow you to relax either of these assumptions. You should refer to the section on `Solution Pools` for information on how to request more than one solution, or the section on `Multiple Objectives` for information on how to specify multiple objective functions and control the tradeoff between them.

## Infeasible Models

You have a few options if a model is found to be infeasible. You can try to diagnose the cause of the infeasibility, attempt to repair the infeasibility, or both. To obtain information that can be useful for diagnosing the cause of an infeasibility, call [Model.computeIIS](#) to compute an Irreducible Inconsistent Subsystem (IIS). This method can be used for both continuous and MIP models, but you should be aware that the MIP version can be quite expensive. This method populates a set of IIS attributes.

To attempt to repair an infeasibility, call [Model.feasRelaxS](#) or [Model.feasRelax](#) to compute a feasibility relaxation for the model. This relaxation allows you to find a solution that minimizes the magnitude of the constraint violation.

## Querying and Modifying Attributes

Most of the information associated with a Gurobi model is stored in a set of attributes. Some attributes are associated with the variables of the model, some with the constraints of the model, and some with the model itself. To give a simple example, solving an optimization model causes the `x` variable attribute to be populated. Attributes such as `x` that are computed by the Gurobi optimizer cannot be modified directly by the user, while others, such as the variable lower bound (the `lb` attribute) can.

Attributes can be accessed in two ways in the Python interface. The first is to use the `getAttr()` and `setAttr()` methods, which are available on variables ([Var.getAttr/ Var.setAttr](#)), linear constraints ([Constr.getAttr/ Constr.setAttr](#)), quadratic constraints ([QConstr.getAttr/ QConstr.setAttr](#)), SOSs ([SOS.getAttr](#)), and general constraints ([GenConstr.getAttr/ GenConstr.setAttr](#)), models ([Model.getAttr/ Model.setAttr](#)). These are called with the attribute name as the first argument (e.g., `var.getAttr("x")` or `constr.setAttr("rhs", 0.0)`). The full list of available attributes can be found in the [Attributes](#) section of this manual.

Attributes can also be accessed more directly: you can follow an object name by a period, followed by the name of an attribute of that object. Note that upper/lower case is ignored when referring to attributes. Thus, `b = constr.rhs` is equivalent to `b = constr.getAttr("rhs")`, and `constr.rhs = 0.0` is equivalent to `constr.setAttr("rhs", 0.0)`.

## Additional Model Modification Information

Most modifications to an existing model are done through the attribute interface (e.g., changes to variable bounds, constraint right-hand sides, etc.). The main exceptions are modifications to the constraint matrix and to the objective function.

The constraint matrix can be modified in a few ways. The first is to call the [Model.chgCoeff](#) method. This method can be used to modify the value of an existing non-zero, to set an existing non-zero to zero, or to create a new non-zero. The constraint matrix is also modified when you remove a variable or constraint from the model (through the [Model.remove](#) method). The non-zero values associated with the deleted constraint or variable are removed along with the constraint or variable itself.

The model objective function can also be modified in a few ways. The easiest is to build an expression that captures the objective function (a [LinExpr](#) or [QuadExpr](#) object), and then pass that expression to method [Model.setObjective](#). If you wish to modify the objective, you can simply call `setObjective` again with a new [LinExpr](#) or [QuadExpr](#) object.

For linear objective functions, an alternative to `setObjective` is to use the `Obj` variable attribute to modify individual linear objective coefficients.

If your variables have piecewise-linear objectives, you can specify them using the [Model.setPWLObj](#) method. Call this method once for each relevant variable. The Gurobi simplex solver includes algorithmic support for convex piecewise-linear objective functions, so for continuous models you should see a substantial performance benefit from using this feature. To clear a previously specified piecewise-linear objective function, simply set the `Obj` attribute on the corresponding variable to 0.

## Lazy Updates

One important item to note about model modification in the Gurobi optimizer is that it is performed in a *lazy* fashion, meaning that modifications don't affect the model immediately. Rather, they are queued and applied later. If your program simply creates a model and solves it, you will probably never notice this behavior. However, if you ask for information about the model before your modifications have been applied, the details of the lazy update approach may be relevant to you.

As we just noted, model modifications (bound changes, right-hand side changes, objective changes, etc.) are placed in a queue. These queued modifications can be applied to the model in three different ways. The first is by an explicit call to [Model.update](#). The second is by a call to [Model.optimize](#). The third is by a call to [Model.write](#) to write out the model. The first case gives you fine-grained control over when modifications are applied. The second and third make the assumption that you want all pending modifications to be applied before you optimize your model or write it to disk.

Why does the Gurobi interface behave in this manner? There are a few reasons. The first is that this approach makes it much easier to perform multiple modifications to a model, since the model remains unchanged between modifications. The second is that processing model modifications can be expensive, particularly in a Compute Server environment, where modifications require communication between machines. Thus, it is useful to have visibility into exactly when these modifications are applied. In general, if your program needs to make multiple modifications to the model, you should aim to make them in phases, where you make a set of modifications, then update, then make more modifications, then update again, etc. Updating after each individual modification can be extremely expensive.

If you forget to call `update`, your program won't crash. Your query will simply return the value of the requested data from the point of the last update. If the object you tried to query didn't exist then, you'll get a `NOT_IN_MODEL` exception instead.

The semantics of lazy updates have changed in this release. While the vast majority of programs will continue to work unmodified, you can use the [UpdateMode](#) parameter to revert to the previous behavior if you run into an issue.

## Managing Parameters

The Gurobi optimizer provides a set of parameters that allow you to control many of the details of the optimization process. Factors like feasibility and optimality tolerances, choices of algorithms, strategies for exploring the MIP search tree, etc., can be controlled by modifying Gurobi parameters before beginning the optimization. Parameters are set using method [Model.setParam](#). Current values may also be retrieved with [Model.getParamInfo](#). You can also access parameters more directly through the `Model.Params` class. To set the [MIPGap](#) parameter to 0.0 for model `m`, for example, you can do either `m.setParam('MIPGap', 0)` or `m.Params.MIPGap = 0`.

You can read a set of parameter settings from a file using [Model.read](#), or write the set of changed

parameters using [Model.write](#).

We also include an automated parameter tuning tool that explores many different sets of parameter changes in order to find a set that improves performance. You can call [Model.tune](#) to invoke the tuning tool on a model. Refer to the [parameter tuning tool](#) section for more information.

One thing we should note is that changing a parameter for one model has no effect on the parameter value for other models. Use the global [setParam](#) method to set a parameter for all loaded models.

The full list of Gurobi parameters can be found in the [Parameters](#) section.

### Monitoring Progress - Logging and Callbacks

Progress of the optimization can be monitored through Gurobi logging. By default, Gurobi will send output to the screen. A few simple controls are available for modifying the default logging behavior. You can set the [LogFile](#) parameter if you wish to also direct the Gurobi log to a file. The frequency of logging output can be controlled with the [DisplayInterval](#) parameter, and logging can be turned off entirely with the [OutputFlag](#) parameter.

More detailed progress monitoring can be done through a callback function. If you pass a function taking two arguments, `model` and `where`, to [Model.optimize](#), your function will be called periodically from within the optimization. Your callback can then call [Model.cbGet](#) to retrieve additional information on the state of the optimization. You can refer to the [Callback](#) class for additional information.

### Modifying Solver Behavior - Callbacks

Callbacks can also be used to modify the behavior of the Gurobi optimizer. The simplest control callback is [Model.terminate](#), which asks the optimizer to terminate at the earliest convenient point. Method [Model.cbSetSolution](#) allows you to inject a feasible solution (or partial solution) during the solution of a MIP model. Methods [Model.cbCut](#) and [Model.cbLazy](#) allow you to add *cutting planes* and *lazy constraints* during a MIP optimization, respectively.

### Error Handling

All of the methods in the Gurobi Python library can throw an exception of type [GurobiError](#). When an exception occurs, additional information on the error can be obtained by retrieving the `errno` or `message` members of the [GurobiError](#) object. A list of possible values for the `errno` field can be found in the [Error Code](#) section.

## 6.1 Global Functions

Gurobi global functions. These functions can be accessed from the main Gurobi shell prompt. In contrast to all other methods in the Gurobi Python interface, these functions do not require a Gurobi object to invoke them.

### **models()**

| **models** ( )

Print a list of loaded models.

Note that this function will only list models stored in global variables. Models stored in Python data structures (lists, dictionaries, etc.), or inside user classes aren't listed.

**Example usage:**

```
a = Model("a")
b = Model("b")
models()
```

### **disposeDefaultEnv()**

| **disposeDefaultEnv** ( )

Dispose of the default environment.

Calling this function releases the default environment created by the Gurobi Python module. This function is particularly useful in a long-running Python session (e.g., within a Jupyter notebook), where the Gurobi environment would otherwise continue to exist for the full duration of the session.

Note that models built with the default environment must be garbage collected before the default environment can be freed. You can force a model `m` be garbage collected with the statement `del m`. If no references to the default environment remain, `disposeDefaultEnv` prints the message

```
Freed default Gurobi environment
```

to confirm it was able to dispose of the default environment.

**Example usage:**

```
disposeDefaultEnv()
```

### **multidict()**

| **multidict** ( data )

This function splits a single dictionary into multiple dictionaries. The input dictionary should map each key to a list of `n` values. The function returns a list of the shared keys as its first result, followed by the `n` individual Gurobi tuple dictionaries (stored as `tupledict` objects).

**Arguments:**

**data:** A Python dictionary. Each key should map to a list of values.

**Return value:**

A list, where the first member contains the shared key values, and the following members contain the dictionaries that result from splitting the value lists from the input dictionary.

**Example usage:**

```
keys, dict1, dict2 = multidict( {
    'key1': [1, 2],
    'key2': [1, 3],
    'key3': [1, 4] } )
```

**paramHelp()**

| **paramHelp** ( paramname )

Obtain help about a Gurobi parameter.

**Arguments:**

**paramname:** String containing the name of parameter that you would like help with. The name can include '\*' and '?' wildcards. If more than one parameter matches, the matching names are listed. Note that case is ignored.

**Example usage:**

```
paramHelp("Cuts")
paramHelp("Heu*")
paramHelp("*cuts")
```

**quicksum()**

| **quicksum** ( data )

A version of the Python `sum` function that is much more efficient for building large Gurobi expressions ([LinExpr](#) or [QuadExpr](#) objects). The function takes a list of terms as its argument.

Note that while `quicksum` is much faster than `sum`, it isn't the fastest approach for building a large expression. Use [addTerms](#) or the [LinExpr\(\)](#) constructor if you want the quickest possible expression construction.

**Arguments:**

**data:** List of terms to add. The terms can be constants, [Var](#) objects, [LinExpr](#) objects, or [QuadExpr](#) objects.

**Return value:**

An expression that represents the sum of the terms in the input list.

**Example usage:**

```
expr = quicksum([2*x, 3*y+1, 4*z*z])
expr = quicksum(model.getVars())
```

**read()**

| **read** ( filename, env=defaultEnv )

Read a model from a file.

**Arguments:**

**filename:** Name of file containing model. Note that the type of the file is encoded in the file name suffix. Valid suffixes are `.mps`, `.rew`, `.lp`, `.rlp`, `.ilp`, or `.opb`. The files can be compressed, so additional suffixes of `.gz`, `.bz2`, `.zip`, or `.7z` are accepted. The file name may contain `*` or `?` wildcards. No file is read when no wildcard match is found. If more than one match is found, this routine will attempt to read the first matching file.

**env:** Environment in which to create the model. Creating your environment (using the [Env constructor](#)) gives you more control over Gurobi licensing, but it can make your program more complex. Use the default environment unless you know that you need to control your own environments.

**Return value:**

[Model](#) object containing the model that was read from the input file.

**Example usage:**

```
m = read("afiro.mps")
m.optimize()
```

## readParams()

| **readParams** ( filename )

Read a set of parameter settings from a file. The file name must end in `.prm`, and the file must be in [PRM](#) format.

**Arguments:**

**filename:** Name of file containing parameter settings.

**Example usage:**

```
readParams("params.prm")
```

## resetParams()

| **resetParams** ( )

Reset the values of all parameters to their default values. Note that existing models that are stored inside Python data structures (lists, dictionaries, etc.), or inside user classes aren't affected.

**Example usage:**

```
resetParams()
```

## setParam()

| **setParam** ( paramname, newvalue )

Set the value of a parameter to a new value. Note that existing models that are stored inside Python data structures (lists, dictionaries, etc.), or inside user classes aren't affected.

**Arguments:**

**paramname:** String containing the name of parameter that you would like to modify. The name can include '\*' and '?' wildcards. If more than one parameter matches, the matching names are listed and none are modified. Note that case is ignored.

**newvalue:** Desired new value for parameter. Can be 'default', which indicates that the parameter should be reset to its default value.

**Example usage:**

```
setParam("Cuts", 2)
setParam("Heu*", 0.5)
setParam("*Interval", 10)
```

## system()

| **system** ( command )

Issue a system command.

**Arguments:**

**command:** A string containing the desired system command.

**Example usage:**

```
system("ls")
system("rm junk")
```

## writeParams()

| **writeParams** ( filename )

Write all modified parameters to a file. The file is written in [PRM](#) format.

**Example usage:**

```
setParam("Heu*", 0.5)
writeParams("params.prm") # file will contain changed parameter
system("cat params.prm")
```

## 6.2 Model

Gurobi model object. Commonly used methods on the model object in the Gurobi shell include [optimize](#) (optimizes the model), [printStats](#) (prints statistics about the model), [printAttr](#) (prints the values of an attribute), and [write](#) (writes information about the model to a file). Commonly used methods when building a model include [addVar](#) (adds a new variable), [addVars](#) (adds multiple new variables), [addConstr](#) (adds a new constraint), and [addConstrs](#) (adds multiple new constraints).

### Model()

```
| Model ( name="", env=defaultEnv )
```

Model constructor.

#### Arguments:

**name:** Name of new model.

**env:** Environment in which to create the model. Creating your environment (using the [Env constructor](#)) gives you more control over Gurobi licensing, but it can make your program more complex. Use the default environment unless you know that you need to control your own environments.

#### Return value:

New model object. Model initially contains no variables or constraints.

#### Example usage:

```
m = Model("NewModel")
x0 = m.addVar()

env = Env("my.log")
m2 = Model("NewModel2", env)
```

### Model.addConstr()

```
| addConstr ( lhs, sense, rhs, name="" )
```

Add a linear constraint to a model.

Note that this method also accepts a [TempConstr](#) as its first argument (with the name as its second argument). This allows you to use operator overloading to create constraints. See [TempConstr](#) for more information.

#### Arguments:

**lhs:** Left-hand side for new linear constraint. Can be a constant, a [Var](#), or a [LinExpr](#).

**sense:** Sense for new linear constraint (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhs:** Right-hand side for new linear constraint. Can be a constant, a [Var](#), or a [LinExpr](#).

**name:** Name for new constraint.

#### Return value:

New constraint object.

#### Example usage:

```
model.addConstr(x + 2*y, GRB.EQUAL, 3*z, "c0")
model.addConstr(x + y <= 2.0, "c1")
```

## Model.addConstrs()

**addConstrs** ( genexpr, name="" )

Add multiple constraints to a model using a Python generator expression. Returns a Gurobi [tupledict](#) that contains the newly created constraints, indexed by the values generated by the generator expression.

The first argument is a Python generator expression, a special feature of the Python language that allows you to iterate over a Python expression. For `addConstrs`, the expression should be a valid Gurobi constraint, and the result will be that a new constraint is added to the model for each iteration of the generator expression.

To give an example, if `x` is a Gurobi variable, then

```
m.addConstr(x <= 1, name='c0')
```

would add a single linear constraint involving this variable. In contrast, if `x` is a list of Gurobi variables, then

```
m.addConstrs((x[i] <= 1 for i in range(4)), name='c')
```

would add four constraints to the model. The entire first argument is a generator expression, where the indexing is controlled by the statement `for i in range(4)`. The first constraint that results from this expression would be named `c[0]`, and would involve variable `x[0]`. The second would be named `c[1]`, and would involve variable `x[1]`.

Generator expressions can be much more complex than this. They can involve multiple variables and conditional tests. For example, you could do:

```
m.addConstrs((x[i,j] == 0 for i in range(4)
              for j in range(4)
              if i != j), name='c')
```

Note that if you supply a name argument, the generator expression must be enclosed in parenthesis. This requirement comes from the Python language interpreter.

### Arguments:

**genexpr:** A generator expression, where each iteration produces a constraint.

**name:** Name pattern for new constraints. The given name will be subscripted by the index of the generator expression (so, for example, `c` would become `c[0]`, `c[1]`, etc.).

### Return value:

A dictionary of [Constr](#) objects, indexed by the values specified by the generator expression.

### Example usage:

```
model.addConstrs(x.sum(i, '*') <= capacity[i] for i in range(5))
model.addConstrs(x[i] + x[j] <= 1 for i in range(5) for j in range(5))
```

## Model.addGenConstrXxx()

Each of the functions described below adds a new *general constraint* to a model.

Mathematical programming has traditionally defined a set of fundamental constraint types: variable bound constraints, linear constraints, quadratic constraints, integrality constraints, and SOS constraints. These are typically treated directly by the underlying solver (although not always), and are fundamental to the overall algorithm.

Gurobi accepts a number of additional constraint types, which we collectively refer to as *general constraints*. These are typically *not* treated directly by the solver. Rather, they are transformed by presolve into mathematically equivalent sets of constraints (and variables), chosen from among the fundamental types listed above. These general constraints are provided as a convenience to users. If such constraints appear in your model, but if you prefer to reformulate them yourself using fundamental constraint types instead, you can certainly do so. However, note that Gurobi can sometimes exploit information contained in the other constraints in the model to build a more efficient formulation than what you might create.

The additional constraint types that fall under this *general constraint* umbrella are:

- MAX ([Model.addGenConstrMax](#)): set a decision variable equal to the maximum value from among a set of decision variables
- MIN ([Model.addGenConstrMin](#)): set a decision variable equal to the minimum value from among a set of decision variables
- ABS ([Model.addGenConstrAbs](#)): set a decision variable equal to the absolute value of some other decision variable
- AND ([Model.addGenConstrAnd](#)): set a binary variable equal to one if and only if all of a set of binary decision variables are equal to one
- OR ([Model.addGenConstrOr](#)): set a binary variable equal to one if and only if at least one variable out of a set of binary decision variables is equal to one
- INDICATOR ([Model.addGenConstrIndicator](#)): a given binary variable may only take a certain value if a given linear constraint is satisfied

Please refer to [this section](#) for additional details on general constraints.

## Model.addGenConstrMax()

```
| addGenConstrMax ( resvar, vars, constant=None, name="" )
```

Add a new general constraint of type `GRB.GENCONSTR_MAX` to a model.

A MAX constraint  $r = \max\{x_1, \dots, x_n, c\}$  states that the resultant variable  $r$  should be equal to the maximum of the operand variables  $x_1, \dots, x_n$  and the constant  $c$ .

### Arguments:

**resvar** (**Var**): The variable whose value will be equal to the max of the other variables.

**vars** (**list of Var**): The variables over which the max will be taken. Note that this list may also contain constants (type int, long, or float).

**constant (float, optional):** An additional operand that allows you to include a constant among the arguments of the max operation.

**name (string, optional):** Name for the new general constraint.

**Example usage:**

```
# x5 = max(x1, x3, x4, 2.0)
model.addGenConstrMax(x5, [x1, x3, x4], 2.0, "maxconstr")

# alternative form
model.addGenConstrMax(x5, [x1, x3, x4, 2.0], name="maxconstr")
```

## Model.addGenConstrMin()

```
| addGenConstrMin ( resvar, vars, constant=None, name="" )
```

Add a new general constraint of type `GRB.GENCONSTR_MIN` to a model.

A MIN constraint  $r = \min\{x_1, \dots, x_n, c\}$  states that the resultant variable  $r$  should be equal to the minimum of the operand variables  $x_1, \dots, x_n$  and the constant  $c$ .

**Arguments:**

**resvar (Var):** The variable whose value will be equal to the min of the other variables.

**vars (list of Var):** The variables over which the min will be taken. Note that this list may also contain constants (type int, long, or float).

**constant (float, optional):** An additional operand that allows you to include a constant among the arguments of the min operation.

**name (string, optional):** Name for the new general constraint.

**Example usage:**

```
# x5 = min(x1, x3, x4, 2.0)
model.addGenConstrMin(x5, [x1, x3, x4], 2.0, "minconstr")

# alternative form
model.addGenConstrMin(x5, [x1, x3, x4, 2.0], name="minconstr")
```

## Model.addGenConstrAbs()

```
| addGenConstrAbs ( resvar, argvar, name="" )
```

Add a new general constraint of type `GRB.GENCONSTR_ABS` to a model.

An ABS constraint  $r = \text{abs}\{x\}$  states that the resultant variable  $r$  should be equal to the absolute value of the argument variable  $x$ .

**Arguments:**

**resvar (Var):** The variable whose value will be to equal the absolute value of the argument variable.

**argvar (var):** The variable for which the absolute value will be taken.

**name (string, optional):** Name for the new general constraint.

**Example usage:**

```
# x5 = abs(x1)
model.addGenConstrAbs(x5, x1, "absconstr")
```

## Model.addGenConstrAnd()

```
| addGenConstrAnd ( resvar, vars, name="" )
```

Add a new general constraint of type `GRB.GENCONSTR_AND` to a model.

An AND constraint  $r = \text{and}\{x_1, \dots, x_n\}$  states that the binary resultant variable  $r$  should be 1 if and only if all of the operand variables  $x_1, \dots, x_n$  are equal to 1. If any of the operand variables is 0, then the resultant should be 0 as well.

Note that all variables participating in such a constraint will be forced to be binary; independently of how they were created.

### Arguments:

**resvar (Var):** The variable whose value will be equal to the AND concatenation of the other variables.

**vars (list of Var):** The variables over which the AND concatenation will be taken.

**name (string, optional):** Name for the new general constraint.

### Example usage:

```
# x5 = and(x1, x3, x4)
model.addGenConstrAnd(x5, [x1, x3, x4], "andconstr")
```

## Model.addGenConstrOr()

```
| addGenConstrOr ( resvar, vars, name="" )
```

Add a new general constraint of type `GRB.GENCONSTR_OR` to a model.

An OR constraint  $r = \text{or}\{x_1, \dots, x_n\}$  states that the binary resultant variable  $r$  should be 1 if and only if any of the operand variables  $x_1, \dots, x_n$  is equal to 1. If all operand variables are 0, then the resultant should be 0 as well.

Note that all variables participating in such a constraint will be forced to be binary; independently of how they were created.

### Arguments:

**resvar (Var):** The variable whose value will be equal to the OR concatenation of the other variables.

**vars (list of Var):** The variables over which the OR concatenation will be taken.

**name (string, optional):** Name for the new general constraint.

### Example usage:

```
# x5 = or(x1, x3, x4)
model.addGenConstrOr(x5, [x1, x3, x4], "orconstr")
```

## Model.addGenConstrIndicator()

```
| addGenConstrIndicator ( binvar, binval, lhs, sense=None, rhs=None, name="" )
```

Add a new general constraint of type `GRB.GENCONSTR_INDICATOR` to a model.

An INDICATOR constraint  $z = f \rightarrow a^T x \leq b$  states that if the binary indicator variable  $z$  is equal to  $f \in \{0, 1\}$ , then the linear constraint  $a^T x \leq b$  should hold. On the other hand, if  $z = 1 - f$ , the linear constraint may be violated. The sense of the linear constraint can also be specified to be  $=$  or  $\geq$ .

Note that the indicator variable  $z$  of a constraint will be forced to be binary; independently of how it was created.

**Arguments:**

**binvar** (**Var**): The binary indicator variable.

**binval** (**Boolean**): The value for the binary indicator variable that would force the linear constraint to be satisfied.

**lhs** (**float, Var, LinExpr, or TempConstr**): Left-hand side expression for the linear constraint triggered by the indicator. Can be a constant, a [Var](#), or a [LinExpr](#). Alternatively, a temporary constraint object can be used to define the linear constraint that is triggered by the indicator. The temporary constraint object is created using an overloaded comparison operator. See [TempConstr](#) for more information. In this case, the “sense” and “rhs” parameters must stay at their default values `None`.

**sense** (**char**): Sense for the linear constraint. Options are `GRB.LESS_EQUAL`, `GRB.EQUAL`, or `GRB.GREATER_EQUAL`.

**rhs** (**float**): Right-hand-side value for the linear constraint.

**name** (**string, optional**): Name for the new general constraint.

**Example usage:**

```
# x7 = 1 -> x1 + 2 x3 + x4 = 1
model.addGenConstrIndicator(x7, True, x1 + 2*x2 + x4, GRB.EQUAL, 1.0)

# alternative form
model.addGenConstrIndicator(x7, True, x1 + 2*x2 + x4 == 1.0)
```

## Model.addQConstr()

```
| addQConstr ( lhs, sense, rhs, name="" )
```

Add a quadratic constraint to a model.

Important note: the algorithms that Gurobi uses to solve quadratically constrained problems can only handle certain types of quadratic constraints. Constraints of the following forms are always accepted:

- $x^T Q x + q^T x \leq b$ , where  $Q$  is Positive Semi-Definite (PSD)
- $x^T x \leq y^2$ , where  $x$  is a vector of variables, and  $y$  is a non-negative variable (a Second-Order Cone)
- $x^T x \leq yz$ , where  $x$  is a vector of variables, and  $y$  and  $z$  are non-negative variables (a rotated Second-Order Cone)

If you add a constraint that isn't in one of these forms (and Gurobi presolve is unable to transform the constraint into one of these forms), you'll get an error when you try to solve the model. Constraints where the quadratic terms only involve binary variables will always be transformed into one of these forms.

Note that this method also accepts a [TempConstr](#) as its first argument (with the name as its second argument). This allows you to use operator overloading to create constraints. See [TempConstr](#) for more information.

**Arguments:**

**lhs:** Left-hand side for new quadratic constraint. Can be a constant, a [Var](#), a [LinExpr](#), or a [QuadExpr](#).

**sense:** Sense for new quadratic constraint (GRB.LESS\_EQUAL or GRB.GREATER\_EQUAL).

**rhs:** Right-hand side for new quadratic constraint. Can be a constant, a [Var](#), a [LinExpr](#), or a [QuadExpr](#).

**name:** Name for new constraint.

**Return value:**

New quadratic constraint object.

**Example usage:**

```
model.addQConstr(x*x + y*y, GRB.LESS_EQUAL, z*z, "c0")
model.addQConstr(x*x + y*y <= 2.0, "c1")
```

## Model.addRange()

| **addRange** ( expr, lower, upper, name="" )

Add a range constraint to a model. A range constraint states that the value of the input expression must be between the specified **lower** and **upper** bounds in any solution.

Note that range constraints are stored internally as equality constraints. We add an extra variable to the model to capture the range information. Thus, the [Sense](#) attribute on a range constraint will always be GRB.EQUAL.

**Arguments:**

**expr:** Linear expression for new range constraint. Can be a [Var](#) or a [LinExpr](#).

**lower:** Lower bound for linear expression.

**upper:** Upper bound for linear expression.

**name:** Name for new constraint.

**Return value:**

New constraint object.

**Example usage:**

```
# 1 <= x + y <= 2
model.addRange(x + y, 1.0, 2.0, "range0")
```

## Model.addSOS()

| **addSOS** ( type, vars, wts=None )

Add an SOS constraint to the model. Please refer to [this section](#) for details on SOS constraints.

**Arguments:**

**type:** SOS type (can be GRB.SOS\_TYPE1 or GRB.SOS\_TYPE2).

**vars:** List of variables that participate in the SOS constraint.

**weights (optional):** Weights for the variables in the SOS constraint. Default weights are 1, 2, ...

**Return value:**

New [SOS](#) object.

**Example usage:**

```
model.addSOS(GRB.SOS_TYPE1, [x, y, z], [1, 2, 4])
```

## Model.addVar()

```
addVar ( lb=0.0, ub=GRB.INFINITY, obj=0.0, vtype=GRB.CONTINUOUS, name="",
         column=None )
```

Add a decision variable to a model.

### Arguments:

**lb** (optional): Lower bound for new variable.

**ub** (optional): Upper bound for new variable.

**obj** (optional): Objective coefficient for new variable.

**vtype** (optional): Variable type for new variable (GRB.CONTINUOUS, GRB.BINARY, GRB.INTEGER, GRB.SEMICONT, or GRB.SEMIINT).

**name** (optional): Name for new variable.

**column** (optional): Column object that indicates the set of constraints in which the new variable participates, and the associated coefficients.

### Return value:

New variable object.

### Example usage:

```
x = model.addVar()                # all default arguments
y = model.addVar(vtype=GRB.INTEGER, obj=1.0, name="y") # arguments by name
z = model.addVar(0.0, 1.0, 1.0, GRB.BINARY, "z")     # arguments by position
```

## Model.addVars()

```
addVars ( *indices, lb=0.0, ub=GRB.INFINITY, obj=0.0, vtype=GRB.CONTINUOUS,
          name="" )
```

Add multiple decision variables to a model.

Returns a Gurobi [tupledict](#) object that contains the newly created variables. The keys for the `tupledict` are derived from the `indices` argument(s). The arguments for this method can take several different forms, which will be described now.

The first arguments provide the indices that will be used as keys to access the variables in the returned `tupledict`. In its simplest version, you would specify one or more integer values, and this method would create the equivalent of a multi-dimensional array of variables. For example, `x = model.addVars(2, 3)` would create six variables, accessed as `x[0,0]`, `x[0,1]`, `x[0,2]`, `x[1,0]`, `x[1,1]`, and `x[1,2]`.

In a more complex version, you can specify arbitrary lists of immutable objects, and this method will create variables for each member of the cross product of these lists. For example, `x = model.addVars([3, 7], ['a', 'b', 'c'])` would create six variables, accessed as `x[3,'a']`, `x[7,'c']`, etc.

You can also provide your own list of tuples as indices. For example, `x = model.addVars([(3,'a'), (3,'b')], (3,'b'))`, would be accessed in the same way as the previous example (`x[3,'a']`, `x[7,'c']`, etc.), except that not all combinations will be present. This is typically how sparse indexing is handled.

The named arguments (`lb`, `obj`, etc.) can take several forms. If you provide a scalar value (or use the default), then every variable will use that value. Thus, for example, `lb=1.0` will give every created variable a lower bound of 1.0. Note that a scalar value for the name argument has a special meaning, which will be discussed separately.

You can also provide a Python `dict` as the argument. In that case, the value for each variable will be pulled from the dict, using the indices argument to build the keys. For example, if the variables created by this method are indexed as `x[i,j]`, then the `dict` provided for the argument should have an entry for each possible `(i,j)` value.

Finally, if your `indices` argument is a single list, you can provide a Python `list` of the same length for the named arguments. For each variable, it will pull the value from the corresponding position in the list.

As noted earlier, the `name` argument is special. If you provide a scalar argument for the name, that argument will be transformed to have a subscript that corresponds to the index of the associated variable. For example, if you do `x = model.addVars(2,3,name="x")`, the variables will get names `x[0,0]`, `x[0,1]`, etc.

#### Arguments:

**indices:** Indices for accessing the new variables.  
**lb (optional):** Lower bound(s) for new variables.  
**ub (optional):** Upper bound(s) for new variables.  
**obj (optional):** Objective coefficient(s) for new variables.  
**vtype (optional):** Variable type(s) for new variables.  
**name (optional):** Names for new variables.

#### Return value:

New `tupledict` object that contains the new variables as values, using the provided indices as keys.

#### Example usage:

```
# 3-D array of binary variables
x = model.addVars(3, 4, 5, vtype=GRB.BINARY)

# variables index by tuplelist
l = tuplelist([(1, 2), (1, 3), (2, 3)])
y = model.addVars(l, ub=[1, 2, 3])
```

## Model.cbCut()

**cbCut** ( lhs, sense, rhs )

Add a new cutting plane to a MIP model from within a callback function. Note that this method can only be invoked when the `where` value on the callback function is equal to `GRB.Callback.MIPNODE` (see the [Callback Codes](#) section for more information).

Cutting planes can be added at any node of the branch-and-cut tree. However, they should be added sparingly, since they increase the size of the relaxation model that is solved at each node and can significantly degrade node processing speed.

Cutting planes are typically used to cut off the current relaxation solution. To retrieve the relaxation solution at the current node, you should first call `cbGetNodeRel`.

When adding your own cuts, you must set parameter `PreCrush` to value 1. This setting shuts off a few presolve reductions that sometimes prevent cuts on the original model from being applied to the presolved model.

One very important note: you should only add cuts that are implied by the constraints in your model. If you cut off an integer solution that is feasible according to the original model constraints,

you are likely to obtain an incorrect solution to your MIP problem.

**Arguments:**

- lhs:** Left-hand side for new cut. Can be a constant, a [Var](#), or a [LinExpr](#).
- sense:** Sense for new cut (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).
- rhs:** Right-hand side for new cut. Can be a constant, a [Var](#), or a [LinExpr](#).

**Example usage:**

```
def mycallback(model, where):
    if where == GRB.Callback.MIPNODE:
        status = model.cbGet(GRB.Callback.MIPNODE_STATUS)
        if status == GRB.OPTIMAL:
            rel = model.cbGetNodeRel([model._vars[0], model._vars[1]])
            if rel[0] + rel[1] > 1.1:
                model.cbCut(model._vars[0] + model._vars[1] <= 1)

model._vars = model.getVars()
model.optimize(mycallback)
```

## Model.cbGet()

| **cbGet** ( what )

Query the optimizer from within the user callback.

**Arguments:**

- what:** Integer code that indicates what type of information is being requested by the callback. The set of valid codes depends on the **where** value that is passed into the user callback function. Please refer to the [Callback Codes](#) section for a list of possible **where** and **what** values.

**Example usage:**

```
def mycallback(model, where):
    if where == GRB.Callback.SIMPLEX:
        print(model.cbGet(GRB.Callback.SPX_OBJVAL))

model.optimize(mycallback)
```

## Model.cbGetNodeRel()

| **cbGetNodeRel** ( vars )

Retrieve values from the node relaxation solution at the current node. Note that this method can only be invoked when the **where** value on the callback function is equal to `GRB.Callback.MIPNODE`, and `GRB.Callback.MIPNODE_STATUS` is equal to `GRB.OPTIMAL` (see the [Callback Codes](#) section for more information).

**Arguments:**

- vars:** The variables whose relaxation values are desired. Can be a list of variables or a single variable.

**Return value:**

The values of the specified variables in the node relaxation for the current node.

**Example usage:**

```
def mycallback(model, where):
    if where == GRB.Callback.MIPNODE:
        print model.cbGetNodeRel(model._vars)

    model._vars = model.getVars()
    model.optimize(mycallback)
```

## Model.cbGetSolution()

| **cbGetSolution** ( vars )

Retrieve values from the new MIP solution. Note that this method can only be invoked when the `where` value on the callback function is equal to `GRB.Callback.MIPSOL` (see the [Callback Codes](#) section for more information).

**Arguments:**

**vars:** The variables whose solution values are desired. Can be a list of variables or a single variable.

**Return value:**

The values of the specified variables in the solution.

**Example usage:**

```
def mycallback(model, where):
    if where == GRB.Callback.MIPSOL:
        print model.cbGetSolution(model._vars)

    model._vars = model.getVars()
    model.optimize(mycallback)
```

## Model.cbLazy()

| **cbLazy** ( lhs, sense, rhs )

Add a new lazy constraint to a MIP model from within a callback function. Note that this method can only be invoked when the `where` value on the callback function is `GRB.Callback.MIPNODE` or `GRB.Callback.MIPSOL` (see the [Callback Codes](#) section for more information).

Lazy constraints are typically used when the full set of constraints for a MIP model is too large to represent explicitly. By only including the constraints that are actually violated by solutions found during the branch-and-cut search, it is sometimes possible to find a proven optimal solution while only adding a fraction of the full set of constraints.

You would typically add a lazy constraint by first querying the current node solution (by calling [cbGetSolution](#) from a `GRB.CB_MIPSOL` callback, or [cbGetNodeRel](#) from a `GRB.CB_MIPNODE` callback), and then calling `cbLazy()` to add a constraint that cuts off the solution. Gurobi guarantees that you will have the opportunity to cut off any solutions that would otherwise be considered feasible.

Your callback should be prepared to cut off solutions that violate any of your lazy constraints, including those that have already been added. Node solutions will usually respect previously added

lazy constraints, but not always.

Note that you must set the [LazyConstraints](#) parameter if you want to use lazy constraints.

**Arguments:**

**lhs:** Left-hand side for new lazy constraint. Can be a constant, a [Var](#), or a [LinExpr](#).

**sense:** Sense for new lazy constraint (GRB.LESS\_EQUAL, GRB.EQUAL, or GRB.GREATER\_EQUAL).

**rhs:** Right-hand side for new lazy constraint. Can be a constant, a [Var](#), or a [LinExpr](#).

**Example usage:**

```
def mycallback(model, where):
    if where == GRB.Callback.MIPSOL:
        sol = model.cbGetSolution([model._vars[0], model._vars[1]])
        if sol[0] + sol[1] > 1.1:
            model.cbLazy(model._vars[0] + model._vars[1] <= 1)

model._vars = model.getVars()
model.optimize(mycallback)
```

## Model.cbSetSolution()

| **cbSetSolution** ( vars, solution )

Import solution values for a heuristic solution. Only available when the **where** value on the callback function is equal to `GRB.CB_MIPNODE`. (see the [Callback Codes](#) section for more information).

When you specify a heuristic solution from a callback, variables initially take undefined values. You should use this method to specify variable values. You can make multiple calls to `cbSetSolution` from one callback invocation to specify values for multiple sets of variables. At the end of the callback, if values have been specified for any variables, the Gurobi optimizer will try to compute a feasible solution from the specified values, possibly filling in values for variables whose values were left undefined.

**Arguments:**

**vars:** The variables whose values are being set. This can be a list of variables or a single variable.

**solution:** The desired values of the specified variables in the new solution.

**Example usage:**

```
def mycallback(model, where):
    if where == GRB.Callback.MIPNODE:
        model.cbSetSolution(vars, newsolution)

model.optimize(mycallback)
```

## Model.chgCoeff()

| **chgCoeff** ( constr, var, newvalue )

Change one coefficient in the model. The desired change is captured using a [Var](#) object, a [Constr](#) object, and a desired coefficient for the specified variable in the specified constraint. If you

make multiple changes to the same coefficient, the last one will be applied.

Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [Model.update](#)), optimize the model (using [Model.optimize](#)), or write the model to disk (using [Model.write](#)).

**Arguments:**

**constr:** Constraint for coefficient to be changed.

**var:** Variable for coefficient to be changed.

**newvalue:** Desired new value for coefficient.

**Example usage:**

```
model.chgCoeff(c0, x, 2.0)
```

## Model.computeIIS()

| `computeIIS` ( void )

Compute an Irreducible Inconsistent Subsystem (IIS). An IIS is a subset of the constraints and variable bounds of the original model. If all constraints in the model except those in the IIS are removed, the model is still infeasible. However, further removing any one member of the IIS produces a feasible result.

This method populates the `IISCONSTR`, `IISQCONSTR`, and `IISGENCONSTR` constraint attributes, the `IISOS` SOS attribute, and the `IISLB`, and `IISUB` variable attributes. You can also obtain information about the results of the IIS computation by writing an `.ilp` format file (see [Model.write](#)). This file contains only the IIS from the original model.

Note that this method can be used to compute IISs for both continuous and MIP models.

**Example usage:**

```
model.computeIIS()  
model.write("model.ilp")
```

## Model.copy()

| `copy` ( )

Copy a model.

**Return value:**

Copy of model.

**Example usage:**

```
copy = model.copy()
```

## Model.discardConcurrentEnvs()

| `discardConcurrentEnvs` ( )

Discard concurrent environments for a model.

The concurrent environments created by [getConcurrentEnv](#) will be used by every subsequent call to the concurrent optimizer until the concurrent environments are discarded.

**Example usage:**

```
env0 = model.getConcurrentEnv(0)
```

```

env1 = model.getConcurrentEnv(1)

env0.setParam('Method', 0)
env1.setParam('Method', 1)

model.optimize()

model.discardConcurrentEnvs()

```

## Model.feasRelaxS()

**feasRelaxS** ( relaxobjtype, minrelax, vrelax, crelax )

Modifies the `Model` object to create a feasibility relaxation. Note that you need to call `optimize` on the result to compute the actual relaxed solution. Note also that this is a simplified version of this method - use `feasRelax` for more control over the relaxation performed.

The feasibility relaxation is a model that, when solved, minimizes the amount by which the solution violates the bounds and linear constraints of the original model. This method provides a number of options for specifying the relaxation.

If you specify `relaxobjtype=0`, the objective of the feasibility relaxation is to minimize the sum of the magnitudes of the bound and constraint violations.

If you specify `relaxobjtype=1`, the objective of the feasibility relaxation is to minimize the sum of the squares of the bound and constraint violations.

If you specify `relaxobjtype=2`, the objective of the feasibility relaxation is to minimize the total number of bound and constraint violations.

To give an example, if a constraint is violated by 2.0, it would contribute 2.0 to the feasibility relaxation objective for `relaxobjtype=0`, it would contribute 2.0\*2.0 for `relaxobjtype=1`, and it would contribute 1.0 for `relaxobjtype=2`.

The `minrelax` argument is a boolean that controls the type of feasibility relaxation that is created. If `minrelax=False`, optimizing the returned model gives a solution that minimizes the cost of the violation. If `minrelax=True`, optimizing the returned model finds a solution that minimizes the original objective, but only from among those solutions that minimize the cost of the violation. Note that `feasRelaxS` must solve an optimization problem to find the minimum possible relaxation when `minrelax=True`, which can be quite expensive.

Note that this is a destructive method: it modifies the model on which it is invoked. If you don't want to modify your original model, use `copy` to create a copy before invoking this method.

### Arguments:

- relaxobjtype:** The cost function used when finding the minimum cost relaxation.
- minrelax:** The type of feasibility relaxation to perform.
- vrelax:** Indicates whether variable bounds can be relaxed.
- crelax:** Indicates whether constraints can be relaxed.

### Return value:

Zero if `minrelax` is `False`. If `minrelax` is `True`, the return value is the objective value for the relaxation performed. If the value is less than 0, it indicates that the method failed to create the feasibility relaxation.

### Example usage:

```

if model.status == GRB.INFEASIBLE:
    model.feasRelaxS(1, False, False, True)
    model.optimize()

```

## Model.feasRelax()

**feasRelax** ( relaxobjtype, minrelax, vars, lbpen, ubpen, constrs, rhspen )

Modifies the `Model` object to create a feasibility relaxation. Note that you need to call `optimize` on the result to compute the actual relaxed solution. Note also that this is a more complex version of this method - use `feasRelaxS` for a simplified version.

The feasibility relaxation is a model that, when solved, minimizes the amount by which the solution violates the bounds and linear constraints of the original model. This method provides a number of options for specifying the relaxation.

If you specify `relaxobjtype=0`, the objective of the feasibility relaxation is to minimize the sum of the weighted magnitudes of the bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the cost per unit violation in the lower bounds, upper bounds, and linear constraints, respectively.

If you specify `relaxobjtype=1`, the objective of the feasibility relaxation is to minimize the weighted sum of the squares of the bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the coefficients on the squares of the lower bound, upper bound, and linear constraint violations, respectively.

If you specify `relaxobjtype=2`, the objective of the feasibility relaxation is to minimize the weighted count of bound and constraint violations. The `lbpen`, `ubpen`, and `rhspen` arguments specify the cost of violating a lower bound, upper bound, and linear constraint, respectively.

To give an example, if a constraint with `rhspen` value `p` is violated by 2.0, it would contribute  $2 * p$  to the feasibility relaxation objective for `relaxobjtype=0`, it would contribute  $2 * 2 * p$  for `relaxobjtype=1`, and it would contribute `p` for `relaxobjtype=2`.

The `minrelax` argument is a boolean that controls the type of feasibility relaxation that is created. If `minrelax=False`, optimizing the returned model gives a solution that minimizes the cost of the violation. If `minrelax=True`, optimizing the returned model finds a solution that minimizes the original objective, but only from among those solutions that minimize the cost of the violation. Note that `feasRelax` must solve an optimization problem to find the minimum possible relaxation when `minrelax=True`, which can be quite expensive.

Note that this is a destructive method: it modifies the model on which it is invoked. If you don't want to modify your original model, use `copy` to create a copy before invoking this method.

### Arguments:

**relaxobjtype:** The cost function used when finding the minimum cost relaxation.

**minrelax:** The type of feasibility relaxation to perform.

**vars:** Variables whose bounds are allowed to be violated.

**lbpen:** Penalty for violating a variable lower bound. One entry for each variable in argument `vars`.

**ubpen:** Penalty for violating a variable upper bound. One entry for each variable in argument `vars`.

**constr:** Linear constraints that are allowed to be violated.

**rhspen:** Penalty for violating a linear constraint. One entry for each variable in argument `constr`.

**Return value:**

Zero if `minrelax` is `False`. If `minrelax` is `True`, the return value is the objective value for the relaxation performed. If the value is less than 0, it indicates that the method failed to create the feasibility relaxation.

**Example usage:**

```
if model.status == GRB.INFEASIBLE:
    vars = model.getVars()
    ubpen = [1.0]*model.numVars
    model.feasRelax(1, False, vars, None, ubpen, None, None)
    model.optimize()
```

## Model.fixed()

| **fixed** ( )

Create the fixed model associated with a MIP model. The MIP model must have a solution loaded (e.g., after a call to the [optimize](#) method). In the fixed model, each integer variable is fixed to the value that variable takes in the MIP solution.

**Return value:**

Fixed model associated with calling object.

**Example usage:**

```
fixed = model.fixed()
```

## Model.getAttr()

| **getAttr** ( attrname, objs=None )

Query the value of an attribute. When called with a single argument, it returns the value of a model attribute. When called with two arguments, it returns the value of an attribute for either a list or a dictionary containing either variables or constraints. If called with a list, the result is a list. If called with a dictionary, the result is a dictionary that uses the same keys, but is populated with the requested attribute values. The full list of available attributes can be found in the [Attributes](#) section.

Raises an `AttributeError` if the requested attribute doesn't exist or can't be queried.

**Arguments:**

**attrname:** Name of the attribute.

**objs (optional):** List or dictionary containing either constraints or variables

**Example usage:**

```
print(model.numintvars)
print(model.getAttr("numIntVars"))
print(model.getAttr(GRB.Attr.numIntVars))
print(model.getAttr("X", m.getVars()))
print(model.getAttr("Pi", m.getConstrs()))
```

## Model.getCoeff()

`getCoeff` ( `constr`, `var` )

Query the coefficient of variable `var` in linear constraint `constr` (note that the result can be zero).

**Arguments:**

`constr`: The requested constraint.

`var`: The requested variable.

**Return value:**

The current value of the requested coefficient.

**Example usage:**

```
print(model.getCoeff(constr, var))
```

## Model.getCol()

`getCol` ( `var` )

Retrieve the list of constraints in which a variable participates, and the associated coefficients. The result is returned as a [Column](#) object.

**Arguments:**

`var`: The variable of interest.

**Return value:**

A [Column](#) object that captures the set of constraints in which the variable participates.

**Example usage:**

```
print(model.getCol(x))
```

## Model.getConcurrentEnv()

`getConcurrentEnv` ( `num` )

Create/retrieve a concurrent environment for a model.

This method provides fine-grained control over the concurrent optimizer. By creating your own concurrent environments and setting appropriate parameters on these environments (e.g., the [Method](#) parameter), you can control exactly which strategies the concurrent optimizer employs. For example, if you create two concurrent environments, and set `Method` to primal simplex for one and dual simplex for the other, subsequent concurrent optimizer runs will use the two simplex algorithms rather than the default choices.

Note that you must create contiguously numbered concurrent environments, starting with `num=0`. For example, if you want three concurrent environments, they must be numbered 0, 1, and 2.

Once you create concurrent environments, they will be used for every subsequent concurrent optimization on that model. Use [discardConcurrentEnvs](#) to revert back to default concurrent optimizer behavior.

**Arguments:**

`num`: The concurrent environment number.

**Return value:**

The concurrent environment for the model.

**Example usage:**

```
env0 = model.getConcurrentEnv(0)
env1 = model.getConcurrentEnv(1)

env0.setParam('Method', 0)
env0.setParam('Method', 1)

model.optimize()

model.discardConcurrentEnvs()
```

## Model.getConstrByName()

| **getConstrByName** ( name )

Retrieve a linear constraint from its name. If multiple linear constraints have the same name, this method chooses one arbitrarily.

**Arguments:**

**name:** Name of desired constraint.

**Return value:**

Constraint with the specified name.

**Example usage:**

```
c0 = model.getConstrByName("c0")
```

## Model.getConstrs()

| **getConstrs** ( )

Retrieve a list of all linear constraints in the model.

**Return value:**

All linear constraints in the model.

**Example usage:**

```
constrs = model.getConstrs()
c0 = constrs[0]
```

## Model.getGenConstrMax()

| **getGenConstrMax** ( genconstr )

Retrieve the data of a general constraint of type MAX. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [addGenConstrMax](#) for a description of the semantics of this general constraint type.

**Arguments:**

**genconstr:** The general constraint object of interest.

**Return value:**

A tuple (resvar, vars, constant) that contains the data of the general constraint:  
**resvar** (**Var**): Resultant variable of the MAX constraint.  
**vars** (**list of Var**): Operand variables of the MAX constraint.  
**constant** (**float**): Additional constant operand of the MAX constraint.

**Example usage:**

```
(resvar, vars, constant) = model.getGenConstrMax(model.getGenConstrs()[0])
```

## Model.getGenConstrMin()

| **getGenConstrMin** ( genconstr )

Retrieve the data of a general constraint of type MIN. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [addGenConstrMin](#) for a description of the semantics of this general constraint type.

**Arguments:**

**genconstr**: The general constraint object of interest.

**Return value:**

A tuple (resvar, vars, constant) that contains the data of the general constraint:

**resvar** (**Var**): Resultant variable of the MIN constraint.

**vars** (**list of Var**): Operand variables of the MIN constraint.

**constant** (**float**): Additional constant operand of the MIN constraint.

**Example usage:**

```
(resvar, vars, constant) = model.getGenConstrMin(model.getGenConstrs()[0])
```

## Model.getGenConstrAbs()

| **getGenConstrAbs** ( genconstr )

Retrieve the data of a general constraint of type ABS. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [addGenConstrAbs](#) for a description of the semantics of this general constraint type.

**Arguments:**

**genconstr**: The general constraint object of interest.

**Return value:**

A tuple (resvar, argvar) that contains the data of the general constraint:

**resvar** (**Var**): Resultant variable of ABS constraint.

**argvar** (**Var**): Argument variable of ABS constraint.

**Example usage:**

```
(resvar, argvar) = model.getGenConstrAbs(model.getGenConstrs()[0])
```

## Model.getGenConstrAnd()

| **getGenConstrAnd** ( genconstr )

Retrieve the data of a general constraint of type AND. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [addGenConstrAnd](#) for a description of the semantics of this general constraint type.

**Arguments:**

**genconstr:** The general constraint object of interest.

**Return value:**

A tuple (resvar, vars) that contains the data of the general constraint:

**resvar (Var):** Resultant variable of AND constraint.

**vars (list of Var):** Operand variables of AND constraint.

**Example usage:**

```
(resvar, vars) = model.getGenConstrAnd(model.getGenConstrs()[0])
```

## Model.getGenConstrOr()

| **getGenConstrOr** ( genconstr )

Retrieve the data of a general constraint of type OR. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [addGenConstrOr](#) for a description of the semantics of this general constraint type.

**Arguments:**

**genconstr:** The general constraint object of interest.

**Return value:**

A tuple (resvar, vars) that contains the data of the general constraint:

**resvar (Var):** Resultant variable of OR constraint.

**vars (list of Var):** Operand variables of OR constraint.

**Example usage:**

```
(resvar, vars) = model.getGenConstrOr(model.getGenConstrs()[0])
```

## Model.getGenConstrIndicator()

| **getGenConstrIndicator** ( genconstr )

Retrieve the data of a general constraint of type INDICATOR. Calling this function for a general constraint of different type leads to an exception. You can query the [GenConstrType](#) attribute to determine the type of the general constraint.

See also [addGenConstrIndicator](#) for a description of the semantics of this general constraint type.

**Arguments:**

**genconstr:** The general constraint object of interest.

**Return value:**

A tuple (binvar, binval, expr, sense, rhs) that contains the data of the general constraint:

**binvar (Var):** Antecedent variable of indicator constraint.

**binval (Boolean):** Value of antecedent variable that activates the linear constraint.

**expr** (`LinExpr`): `LinExpr` object containing the left-hand side of the constraint triggered by the indicator.

**sense** (`char`): Sense of linear constraint triggered by the indicator (e.g., `GRB.LESS_EQUAL`).

**rhs** (`float`): Right-hand side of linear constraint triggered by the indicator.

**Example usage:**

```
(binvar, binval, expr, sense, rhs) = model.getGenConstr(model.getGenConstrs()[3])
```

## Model.getGenConstrs()

| `getGenConstrs` ( )

Retrieve a list of all general constraints in the model.

**Return value:**

All general constraints in the model.

**Example usage:**

```
gencons = model.getGenConstrs()
for gc in gencons:
    print(model.getGenConstr(gc))
```

## Model.getObjective()

| `getObjective` ( )

Retrieve the model objective (as a linear or quadratic expression).

**Return value:**

The model objective. A `LinExpr` object for a linear model, or a `QuadExpr` object for a quadratic model.

**Example usage:**

```
obj = model.getObjective()
print(obj.getValue())
```

## Model.getParamInfo()

| `getParamInfo` ( paramname )

Retrieve information about a Gurobi parameter, including the type, the current value, the minimum and maximum allowed values, and the default value.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

**Arguments:**

**paramname:** String containing the name of the parameter of interest. The name can include '\*' and '?' wildcards. If more than one parameter matches, the matching names are listed and the method returns `None`.

**Return value:**

Returns a 6-entry tuple that contains: the parameter name, the parameter type, the current value, the minimum value, the maximum value, and the default value.

**Example usage:**

```
print(model.getParamInfo('Heuristics'))
```

## Model.getPWLObj()

| `getPWLObj` ( `var` )

Retrieve the piecewise-linear objective function for a variable. The function returns a list of tuples, where each provides the  $x$  and  $y$  coordinates for the points that define the piecewise-linear objective function.

Refer to the description of [setPWLObj](#) for additional information on how the points relate to the overall function.

### Arguments:

`var`: A [Var](#) object that gives the variable whose objective function is being retrieved.

### Return value:

The points that define the piecewise-linear objective function.

### Example usage:

```
> print(model.getPWLObj(var))  
[(1, 1), (2, 2), (3, 4)]
```

## Model.getQConstrs()

| `getQConstrs` ( )

Retrieve a list of all quadratic constraints in the model.

### Return value:

All quadratic constraints in the model.

### Example usage:

```
qconstrs = model.getQConstrs()  
qc0 = qconstrs[0]
```

## Model.getQCRow()

| `getQCRow` ( `qconstr` )

Retrieve the left-hand side expression from a quadratic constraint. The result is returned as a [QuadExpr](#) object.

### Arguments:

`qconstr`: The constraint of interest.

### Return value:

A [QuadExpr](#) object that captures the left-hand side of the quadratic constraint.

### Example usage:

```
print(model.getQCRow(m.getQConstrs()[0]))
```

## Model.getRow()

| `getRow` ( `constr` )

Retrieve the list of variables that participate in a constraint, and the associated coefficients. The result is returned as a [LinExpr](#) object.

**Arguments:**

`constr`: The constraint of interest.

**Return value:**

A [LinExpr](#) object that captures the set of variables that participate in the constraint.

**Example usage:**

```
print(model.getRow(c0))
```

## Model.getSOS()

| `getSOS` ( `sos` )

Retrieve information about an SOS constraint. The result is a tuple that contains the SOS type (1 or 2), the list of participating Var objects, and the list of associated SOS weights.

**Arguments:**

`sos`: The SOS object of interest.

**Return value:**

A tuple that contains the SOS type (1 or 2), a list of participating Var objects, and a list of associated SOS weights.

**Example usage:**

```
(sostype, vars, weights) = model.getSOS(s)
```

## Model.getSOSs()

| `getSOSs` ( )

Retrieve a list of all SOS constraints in the model.

**Return value:**

All SOS constraints in the model.

**Example usage:**

```
sos = model.getSOSs()
for s in sos:
    print(model.getSOS(s))
```

## Model.getTuneResult()

| `getTuneResult` ( )

Use this routine to retrieve the results of a previous [tune](#) call. Calling this method with argument `n` causes tuned parameter set `n` to be copied into the model. Parameter sets are stored in order of decreasing quality, with parameter set 0 being the best. The number of available sets is stored in attribute [TuneResultCount](#).

Once you have retrieved a tuning result, you can call `optimize` to use these parameter settings to optimize the model, or `write` to write the changed parameters to a `.prm` file.

Please refer to the [parameter tuning](#) section for details on the tuning tool.

**Arguments:**

**n:** The index of the tuning result to retrieve. The best result is available as index 0. The number of stored results is available in attribute `TuneResultCount`.

**Example usage:**

```
model.tune()
for i in range(model.tuneResultCount):
    model.getTuneResult(i)
    model.write('tune'+str(i)+'.prm')
```

## Model.getVarByName()

| `getVarByName` ( name )

Retrieve a variable from its name. If multiple variables have the same name, this method chooses one arbitrarily.

**Arguments:**

**name:** Name of desired variable.

**Return value:**

Variable with the specified name.

**Example usage:**

```
x0 = model.getVarByName("x0")
```

## Model.getVars()

| `getVars` ( )

Retrieve a list of all variables in the model.

**Return value:**

All variables in the model.

**Example usage:**

```
vars = model.getVars()
x0 = vars[0]
```

## Model.message()

| `message` ( msg )

Append a string to the Gurobi log file.

**Arguments:**

**msg:** String to append to Gurobi log file.

**Example usage:**

```
model.message('New message')
```

## Model.optimize()

| `optimize` ( `callback` )

Optimize the model. The algorithm used for the optimization depends on the model type (simplex or barrier for a continuous model; branch-and-cut for a MIP model). Upon successful completion, this method will populate the solution related attributes of the model. See the [Attributes](#) section for more information on attributes.

Please consult [this section](#) for a discussion of some of the practical issues associated with solving a precisely defined mathematical model using finite-precision floating-point arithmetic.

Note that this method will process all pending model modifications.

### Arguments:

**callback:** Callback function. The callback function should take two arguments, `model` and `where`. During the optimization, the function will be called periodically, with `model` set to the model being optimized, and `where` indicating where in the optimization the callback is called from. See the [Callback](#) class for additional information.

### Example usage:

```
model.optimize()
```

## Model.presolve()

| `presolve` ( )

Perform presolve on a model.

### Return value:

Presolved version of original model.

### Example usage:

```
p = model.presolve()
p.printStats()
```

## Model.printAttr()

| `printAttr` ( `attrs`, `filter='*'`  )

Print the value of one or more attributes. If `attrs` is a constraint or variable attribute, print all non-zero values of the attribute, along with the associate constraint or variable names. If `attrs` is a list of attributes, print attribute values for all listed attributes. The method takes an optional `filter` argument, which allows you to select which specific attribute values to print (by filtering on the constraint or variable name).

See the [Attributes](#) section for a list of all available attributes.

### Arguments:

**attrs:** Name of attribute or attributes to print. The value can be a single attribute or a list of attributes. If a list is given, all listed attributes must be of the same type (model, variable, or constraint).

**filter (optional):** Filter for values to print — name of constr/var must match filter to be printed.

### Example usage:

```
model.printAttr('x')           # all non-zero solution values
model.printAttr('lb', 'x*')    # bounds for vars whose names begin with 'x'
model.printAttr(['lb', 'ub'])  # lower and upper bounds
```

## Model.printQuality()

| `printQuality` ( )

Print statistics about the quality of the computed solution (constraint violations, integrality violations, etc.).

**Example usage:**

```
model.optimize()
model.printQuality()
```

## Model.printStats()

| `printStats` ( )

Print statistics about the model (number of constraints and variables, number of non-zeros in constraint matrix, smallest and largest coefficients, etc.).

**Example usage:**

```
model.printStats()
```

## Model.read()

| `read` ( filename )

This method is the general entry point for importing data from a file into a model. It can be used to read basis files for continuous models, start vectors for MIP models, or parameter settings. The type of data read is determined by the file suffix. File formats are described in the [File Format](#) section.

Note that this is **not** the method to use if you want to read a new model from a file. For that, use the [read](#) command.

**Arguments:**

**filename:** Name of the file to read. The suffix on the file must be either `.bas` (for an LP basis), `.mst` or `.sol` (for a MIP start), `.hnt` (for MIP hints), `.ord` (for a priority order), or `.prm` (for a parameter file). The suffix may optionally be followed by `.zip`, `.gz`, `.bz2`, or `.7z`. The file name may contain `*` or `?` wildcards. No file is read when no wildcard match is found. If more than one match is found, this method will attempt to read the first matching file.

**Example usage:**

```
model.read('input.bas')
model.read('input.mst')
```

## Model.relax()

| **relax** ( )

Create the relaxation of a MIP model. Transforms integer variables into continuous variables, and removes SOS and general constraints.

**Return value:**

Relaxed version of model.

**Example usage:**

```
r = model.relax()
```

## Model.remove()

| **remove** ( item )

Remove a variable, linear constraint, quadratic constraint, general constraint, or SOS from a model.

**Arguments:**

**item:** The item to remove from the model. The item can be a [Var](#), a [Constr](#), [QConstr](#), [SOS](#), or a [GenConstr](#).

**Example usage:**

```
model.remove(model.getVars()[0])
model.remove(model.getConstrs()[0])
model.remove(model.getQConstrs()[0])
model.remove(model.getSOSs()[0])
model.remove(model.getGenConstrs()[0])
```

## Model.reset()

| **reset** ( )

Reset the model to an unsolved state, discarding any previously computed solution information.

**Example usage:**

```
model.reset()
```

## Model.resetParams()

| **resetParams** ( )

Reset all parameters to their default values.

**Example usage:**

```
model.resetParams()
```

## Model.setAttr()

| **setAttr** ( attrname, newvalue )

Set the value of an attribute. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [Model.update](#)), optimize the model (using [Model.optimize](#)), or write the model to disk (using [Model.write](#)).

Call this method with two arguments to set a model attribute. Call it with three arguments to set the values of the attribute for a list of variables or constraints.

The full list of available attributes can be found in the [Attributes](#) section.

Raises an `AttributeError` if the specified attribute doesn't exist or can't be set.

**Arguments:**

**attrname:** Name of attribute to set.

**newvalue:** Desired new value of attribute.

**Example usage:**

```
model.setAttr("objCon", 0)
model.setAttr(GRB.Attr.objCon, 0)
model.setAttr("LB", m.getVars(), [0]*model.numVars)
model.setAttr("RHS", m.getConstrs(), [1.0]*model.numConstrs)
model.objcon = 0
```

## Model.setObjective()

| `setObjective` ( `expr`, `sense=None` )

Set the model objective equal to a linear or quadratic expression.

Note that you can also modify a linear model objective using the [Obj](#) variable attribute. If you wish to mix and match these two approaches, please note that this method will replace the existing objective.

**Arguments:**

**expr:** New objective expression. Argument can be a linear or quadratic expression (an objective of type [LinExpr](#) or [QuadExpr](#)).

**sense (optional):** Optimization sense (`GRB.MINIMIZE` for minimization, `GRB.MAXIMIZE` for maximization). Omit this argument to use the `ModelSense` attribute value to determine the sense.

**Example usage:**

```
model.setObjective(x + y, GRB.MAXIMIZE)
model.setObjective(x*x + y*y)
```

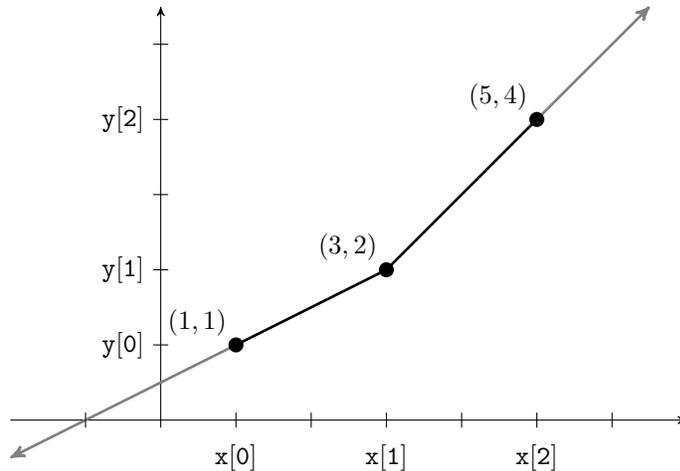
## Model.setPWLObj()

| `setPWLObj` ( `var`, `x`, `y` )

Set a piecewise-linear objective function for a variable.

The arguments to this method specify a list of points that define a piecewise-linear objective function for a single variable. Specifically, the  $x$  and  $y$  arguments give coordinates for the vertices of the function.

For example, suppose we want to define the function  $f(x)$  shown below:



The vertices of the function occur at the points (1, 1), (3, 2) and (5, 4), so  $x$  is [1, 3, 5] and  $y$  is [1, 2, 4]. With these arguments we define  $f(1) = 1$ ,  $f(3) = 2$  and  $f(5) = 4$ . Other objective values are linearly interpolated between neighboring points. The first pair and last pair of points each define a ray, so values outside the specified  $x$  values are extrapolated from these points. Thus, in our example,  $f(-1) = 0$  and  $f(6) = 5$ .

More formally, a set of  $n$  points

$$\mathbf{x} = [x_1, \dots, x_n], \quad \mathbf{y} = [y_1, \dots, y_n]$$

define the following piecewise-linear function:

$$f(v) = \begin{cases} y_1 + \frac{y_2 - y_1}{x_2 - x_1}(v - x_1), & \text{if } v \leq x_1, \\ y_i + \frac{y_{i+1} - y_i}{x_{i+1} - x_i}(v - x_i), & \text{if } v \geq x_i \text{ and } v \leq x_{i+1}, \\ y_n + \frac{y_n - y_{n-1}}{x_n - x_{n-1}}(v - x_n), & \text{if } v \geq x_n. \end{cases}$$

The  $x$  entries must appear in non-decreasing order. Two points can have the same  $x$  coordinate — this can be useful for specifying a discrete jump in the objective function.

Note that a piecewise-linear objective can change the type of a model. Specifically, including a non-convex piecewise linear objective function in a continuous model will transform that model into a MIP. This can significantly increase the cost of solving the model.

Setting a piecewise-linear objective for a variable will set the **Obj attribute** on that variable to 0. Similarly, setting the **Obj** attribute will delete the piecewise-linear objective on that variable.

Each variable can have its own piecewise-linear objective function. They must be specified individually, even if multiple variables share the same function.

**Arguments:**

**var:** A **Var** object that gives the variable whose objective function is being set.

**x:** The  $x$  values for the points that define the piecewise-linear function. Must be in non-decreasing order.

**y:** The  $y$  values for the points that define the piecewise-linear function.

**Example usage:**

```
model.setPWLObj(var, [1, 3, 5], [1, 2, 4])
```

## Model.setParam()

| `setParam` ( paramname, newvalue )

Set the value of a parameter to a new value. Note that this method only affects the parameter setting for this model. Use global function [setParam](#) to change the parameter for all models.

You can also set parameters using the `Model.Params` class. For example, to set parameter `MIPGap` to value 0 for model `m`, you can do either `m.setParam('MIPGap', 0)` or `m.Params.MIPGap=0`.

Please consult the [parameter section](#) for a complete list of Gurobi parameters, including descriptions of their purposes and their minimum, maximum, and default values.

### Arguments:

**paramname:** String containing the name of parameter that you would like to modify. The name can include '\*' and '?' wildcards. If more than one parameter matches, the matching names are listed and none are modified. Note that case is ignored.

**newvalue:** Desired new value for parameter. Can be 'default', which indicates that the parameter should be reset to its default value.

### Example usage:

```
model.setParam("heu*", 0.5)
model.setParam(GRB.Param.heuristics, 0.5)
model.setParam("heu*", "default")
```

## Model.terminate()

| `terminate` ( )

Generate a request to terminate the current optimization. This method is typically called from within a user callback (see [Callbacks](#) for more information). When the optimization stops, the [Status](#) attribute will be equal to `GRB_INTERRUPTED`.

### Example usage:

```
model.terminate()
```

## Model.tune()

| `tune` ( )

Perform an automated search for parameter settings that improve performance. Upon completion, this method stores the best parameter sets it found. The number of stored parameter sets can be determined by querying the value of the [TuneResultCount](#) attribute. The actual settings can be retrieved using [getTuneResult](#)

Please refer to the [parameter tuning](#) section for details on the tuning tool.

### Example usage:

```
model.tune()
```

## Model.update()

| `update` ( )

Process any pending model modifications.

**Example usage:**

```
model.update()
```

## Model.write()

| **write** ( filename )

This method is the general entry point for writing model data to a file. It can be used to write optimization models, IIS submodels, solutions, basis vectors, MIP start vectors, or parameter settings. The type of file is determined by the file suffix. File formats are described in the [File Format](#) section.

Note that writing a model to a file will process all pending model modifications. However, writing other model information (solutions, bases, etc.) will not.

**Arguments:**

**filename:** Name of the file to write. The file type is encoded in the file name suffix. Valid suffixes for writing the model itself are `.mps`, `.rew`, `.lp`, or `.rlp`. An IIS can be written by using an `.ilp` suffix. Use `.sol` for a solution file, `.mst` for a MIP start, `.hnt` for MIP hints, `.bas` for a basis file, or `.prm` for a parameter file. The suffix may optionally be followed by `.gz`, `.bz2`, or `.7z`, which produces a compressed result.

**Example usage:**

```
model.write("out.mst")
model.write("out.sol")
```

## 6.3 Var

Gurobi variable object. Variables are always associated with a particular model. You create a variable object by adding a variable to a model (using `Model.addVar`), rather than by using a `Var` constructor.

Variable objects have a number of attributes. The full list can be found in the [Attributes](#) section of this document. Some variable attributes can only be queried, while others can also be set. Recall that the Gurobi optimizer employs a lazy update approach, so changes to attributes don't take effect until the next call to `Model.update`, `Model.optimize`, or `Model.write` on the associated model.

We should point out a few things about variable attributes. Consider the `lb` attribute. Its value can be queried using `var.lb`. The Gurobi library ignores letter case in attribute names, so it can also be queried as `var.Lb`. It can be set using a standard assignment statement (e.g., `var.lb = 0`). However, as mentioned earlier, attribute modification is done in a lazy fashion, so you won't see the effect of the change immediately. And some attributes can not be set (e.g., the `x` attribute), so attempts to assign new values to them will raise an exception.

You can also use `Var.getAttr`/`Var.setAttr` to access attributes. The attribute name can be passed to these routines as a string, or you can use the constants defined in the `GRB.Attr` class (e.g., `GRB.Attr.lb`).

To build expressions using variable objects, you generally use operator overloading. You can build either [linear](#) or [quadratic](#) expressions:

```
expr1 = x + 2 * y + 3 * z + 4.0
expr2 = x * x + 2 * x * y + 3 * z + 4.0
```

The first expression is linear, while the second is quadratic. An expressions is typically then passed to `setObjective` (to set the optimization objective) or `addConstr` (to add a constraint).

### `Var.getAttr()`

| `getAttr` ( attrname )

Query the value of a variable attribute. The full list of available attributes can be found in the [Attributes](#) section.

Raises an `AttributeError` if the requested attribute doesn't exist or can't be queried.

**Arguments:**

**attrname:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

**Example usage:**

```
print(var.getAttr(GRB.Attr.x))
print(var.getAttr("x"))
```

### `Var.sameAs()`

| `sameAs` ( var2 )

Check whether two variable objects refer to the same variable.

**Arguments:**

**var2:** The other variable.

**Return value:**

Boolean result indicates whether the two variable objects refer to the same model variable.

**Example usage:**

```
print(model.getVars()[0].sameAs(model.getVars()[1]))
```

**Var.setAttr()**

```
| setAttr ( attrname, newvalue )
```

Set the value of a variable attribute. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [Model.update](#)), optimize the model (using [Model.optimize](#)), or write the model to disk (using [Model.write](#)).

The full list of available attributes can be found in the [Attributes](#) section.

Raises an `AttributeError` if the specified attribute doesn't exist or can't be set.

**Arguments:**

**attrname:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

**Example usage:**

```
var.setAttr(GRB.Attr.ub, 0.0)  
var.setAttr("ub", 0.0)
```

## 6.4 Constr

Gurobi constraint object. Constraints are always associated with a particular model. You create a constraint object by adding a constraint to a model (using [Model.addConstr](#)), rather than by using a `Constr` constructor.

Constraint objects have a number of attributes. The full list can be found in the [Attributes](#) section of this document. Some constraint attributes can only be queried, while others can also be set. Recall that the Gurobi optimizer employs a lazy update approach, so changes to attributes don't take effect until the next call to [Model.update](#), [Model.optimize](#), or [Model.write](#) on the associated model.

We should point out a few things about constraint attributes. Consider the `rhs` attribute. Its value can be queried using `constr.rhs`. The Gurobi library ignores letter case in attribute names, so it can also be queried as `constr.RHS`. It can be set using a standard assignment statement (e.g., `constr.rhs = 0`). However, as mentioned earlier, attribute modification is done in a lazy fashion, so you won't see the effect of the change immediately. And some attributes can not be set (e.g., the `Pi` attribute), so attempts to assign new values to them will raise an exception.

You can also use [Constr.getAttr](#)/[Constr.setAttr](#) to access attributes. The attribute name can be passed to these routines as a string, or you can use the constants defined in the [GRB.Attr](#) class (e.g., `GRB.Attr.rhs`).

### `Constr.getAttr()`

```
| getAttr ( attrname )
```

Query the value of a constraint attribute. The full list of available attributes can be found in the [Attributes](#) section.

Raises an `AttributeError` if the requested attribute doesn't exist or can't be queried.

**Arguments:**

`attrname`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

**Example usage:**

```
print(constr.getAttr(GRB.Attr.slack))
print(constr.getAttr("slack"))
```

### `Constr.sameAs()`

```
| sameAs ( constr2 )
```

Check whether two constraint objects refer to the same constraint.

**Arguments:**

`constr2`: The other constraint.

**Return value:**

Boolean result indicates whether the two constraint objects refer to the same model constraint.

**Example usage:**

```
print(model.getConstrs()[0].sameAs(model.getConstrs()[1]))
```

## Constr.setAttr()

`setAttr` ( attrname, newvalue )

Set the value of a constraint attribute. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [Model.update](#)), optimize the model (using [Model.optimize](#)), or write the model to disk (using [Model.write](#)).

The full list of available attributes can be found in the [Attributes](#) section.

Raises an `AttributeError` if the specified attribute doesn't exist or can't be set.

### Arguments:

**attrname:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

### Example usage:

```
constr.setAttr(GRB.Attr.rhs, 0.0)
constr.setAttr("rhs", 0.0)
```

## 6.5 QConstr

Gurobi quadratic constraint object. Quadratic constraints are always associated with a particular model. You create a quadratic constraint object by adding a quadratic constraint to a model (using [Model.addQConstr](#)), rather than by using a `QConstr` constructor.

Quadratic constraint objects have a number of attributes. The full list can be found in the [Attributes](#) section of this document. Some constraint attributes can only be queried, while others can also be set. Recall that the Gurobi optimizer employs a lazy update approach, so changes to attributes don't take effect until the next call to [Model.update](#), [Model.optimize](#), [Model.write](#) on the associated model.

We should point out a few things about quadratic constraint attributes. Consider the `qcrhs` attribute. Its value can be queried using `qconstr.qcrhs`. The Gurobi library ignores letter case in attribute names, so it can also be queried as `qconstr.QCRHS`. It can be set using a standard assignment statement (e.g., `qconstr.qcrhs = 0`). However, as mentioned earlier, attribute modification is done in a lazy fashion, so you won't see the effect of the change immediately. And some attributes can not be set (e.g., the `qcp_i` attribute), so attempts to assign new values to them will raise an exception.

You can also use [QConstr.getAttr](#)/[QConstr.setAttr](#) to access attributes. The attribute name can be passed to these routines as a string, or you can use the constants defined in the [GRB.Attr](#) class (e.g., `GRB.Attr.qcrhs`).

### `QConstr.getAttr()`

| `getAttr` ( attrname )

Query the value of a quadratic constraint attribute. The full list of available attributes can be found in the [Attributes](#) section.

Raises an `AttributeError` if the requested attribute doesn't exist or can't be queried.

**Arguments:**

`attrname`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

**Example usage:**

```
print(qconstr.getAttr(GRB.Attr.qcsense))
print(qconstr.getAttr("qcsense"))
```

### `QConstr.setAttr()`

| `setAttr` ( attrname, newvalue )

Set the value of a quadratic constraint attribute. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [Model.update](#)), optimize the model (using [Model.optimize](#)), or write the model to disk (using [Model.write](#)).

The full list of available attributes can be found in the [Attributes](#) section.

Raises an `AttributeError` if the specified attribute doesn't exist or can't be set.

**Arguments:**

**attrname:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

**Example usage:**

```
constr.setAttr(GRB.Attr.qcrhs, 0.0)
```

```
constr.setAttr("qcrhs", 0.0)
```

## 6.6 SOS

Gurobi SOS constraint object. SOS constraints are always associated with a particular model. You create an SOS object by adding an SOS constraint to a model (using [Model.addSOS](#)), rather than by using an SOS constructor. Similarly, SOS constraints are removed using the [Model.remove](#) method.

An SOS constraint can be of type 1 or 2 (`GRB.SOS_TYPE1` or `GRB.SOS_TYPE2`). A type 1 SOS constraint is a set of variables for which at most one variable in the set may take a value other than zero. A type 2 SOS constraint is an ordered set of variables where at most two variables in the set may take non-zero values. If two take non-zero values, they must be contiguous in the ordered set.

SOS constraint objects have one attribute, `IISOS`, which can be queried with the [SOS.getAttr](#) method.

### **SOS.getAttr()**

| `getAttr` ( attrname )

Query the value of an SOS attribute. The full list of available attributes can be found in the [Attributes](#) section.

Raises an `AttributeError` if the requested attribute doesn't exist or can't be queried.

**Arguments:**

`attrname`: The attribute being queried.

**Return value:**

The current value of the requested attribute.

**Example usage:**

```
print(sos.getAttr(GRB.Attr.IISOS))
```

## 6.7 GenConstr

Gurobi general constraint object. General constraints are always associated with a particular model. You create a general constraint object by adding a general constraint to a model (using [Model.addGenConstr](#)), rather than by using a `GenConstr` constructor.

General constraint objects have a number of attributes, which can be queried with the [GenConstr.getAttr](#) method. The full list can be found in the [Attributes](#) section of this document.

### GenConstr.getAttr()

| `getAttr` ( attrname )

Query the value of a general constraint attribute. The full list of available attributes can be found in the [Attributes](#) section.

Raises an `AttributeError` if the requested attribute doesn't exist or can't be queried.

**Arguments:**

**attrname:** The attribute being queried.

**Return value:**

The current value of the requested attribute.

**Example usage:**

```
print(genconstr.getAttr(GRB.Attr.GenConstrType))
print(genconstr.getAttr("GenConstrType"))
```

### GenConstr.setAttr()

| `setAttr` ( attrname, newvalue )

Set the value of a general constraint attribute. Note that, due to our lazy update approach, the change won't actually take effect until you update the model (using [Model.update](#)), optimize the model (using [Model.optimize](#)), or write the model to disk (using [Model.write](#)).

The full list of available attributes can be found in the [Attributes](#) section.

Raises an `AttributeError` if the specified attribute doesn't exist or can't be set.

**Arguments:**

**attrname:** The attribute being modified.

**newvalue:** The desired new value of the attribute.

## 6.8 LinExpr

Gurobi linear expression object. A linear expression consists of a constant term, plus a list of coefficient-variable pairs that capture the linear terms. Linear expressions are used to build constraints. They are temporary objects that typically have short lifespans.

You generally build linear expressions using overloaded operators. For example, if `x` is a [Var](#) object, then `x + 1` is a [LinExpr](#) object. Expressions can be built from constants (e.g., `expr = 0`), variables (e.g., `expr = 1 * x + 2 * y`), or from other expressions (e.g., `expr2 = 2 * expr1 + x`, or `expr3 = expr1 + 2 * expr2`). You can also modify existing expressions (e.g., `expr += x`, or `expr2 -= expr1`).

The full list of overloaded operators on `LinExpr` objects is as follows: `+`, `+=`, `-`, `-=`, `*`, `*=`, and `/`. In Python parlance, we've defined the following `LinExpr` functions: `__add__`, `__radd__`, `__iadd__`, `__sub__`, `__rsub__`, `__isub__`, `__mul__`, `__rmul__`, `__imul__`, and `__div__`.

We've also overloaded the comparison operators (`==`, `<=`, and `>=`), to make it easier to build constraints from linear expressions.

You can also use `add` or `addTerms` to modify expressions. The `LinExpr()` constructor can be used to build expressions. Another option is `quicksum`; it is a more efficient version of the Python `sum` function. Terms can be removed from an expression using `remove`.

Note that the cost of building expressions depends heavily on the approach you use. While you can generally ignore this issue when building small expressions, you should be aware of a few efficiency issues when building large expressions:

- While the Python `sum` function can be used to build expressions, it should be avoided. Its cost is quadratic in the length of the expression.
- For similar reasons, you should avoid using `expr = expr + x` in a loop. Building large expressions in this way also leads to quadratic runtimes.
- The `quicksum` function is much quicker than `sum`, as are loops over `expr += x` or `expr.add(x)`. These approaches are fast enough for most programs, but they may still be expensive for very large expressions.
- The two most efficient ways to build large linear expressions are `addTerms` or the `LinExpr()` constructor.

Individual terms in a linear expression can be queried using the `getVar`, `getCoeff`, and `getConstant` methods. You can query the number of terms in the expression using the `size` method.

Note that a linear expression may contain multiple terms that involve the same variable. These duplicate terms are merged when creating a constraint from an expression, but they may be visible when inspecting individual terms in the expression (e.g., when using `getVar`).

## LinExpr()

`LinExpr` ( `arg1=0.0`, `arg2=None` )

Linear expression constructor. Note that you should generally use overloaded operators instead of the explicit constructor to build linear expression objects.

This constructor takes multiple forms. You can initialize a linear expression using a constant (`LinExpr(2.0)`), a variable (`LinExpr(x)`), an expression (`LinExpr(2*x)`), a pair of lists containing coefficients and variables, respectively (`LinExpr([1.0, 2.0], [x, y])`), or a list of coefficient-variable tuples (`LinExpr([(1.0, x), (2.0, y), (1.0, z)])`).

### Return value:

A linear expression object.

### Example usage:

```
expr = LinExpr(2.0)
expr = LinExpr(2*x)
expr = LinExpr([1.0, 2.0], [x, y])
expr = LinExpr([(1.0, x), (2.0, y), (1.0, z)])
```

## LinExpr.add()

```
| add ( expr, mult=1.0 )
```

Add one linear expression into another. Upon completion, the invoking linear expression will be equal to the sum of itself and the argument expression.

### Arguments:

**expr**: Linear expression to add.

**mult (optional)**: Multiplier for argument expression.

### Example usage:

```
e1 = x + y  
e1.add(z, 3.0)
```

## LinExpr.addConstant()

```
| addConstant ( c )
```

Add a constant into a linear expression.

### Arguments:

**c**: Constant to add to expression.

### Example usage:

```
expr = x + 2 * y  
expr.addConstant(0.1)
```

## LinExpr.addTerms()

```
| addTerms ( coeffs, vars )
```

Add new terms into a linear expression.

### Arguments:

**coeffs**: Coefficients for new terms; either a list of coefficients or a single coefficient. The two arguments must have the same size.

**vars**: Variables for new terms; either a list of variables or a single variable. The two arguments must have the same size.

### Example usage:

```
expr.addTerms(1.0, x)  
expr.addTerms([2.0, 3.0], [y, z])
```

## LinExpr.clear()

```
| clear ( )
```

Set a linear expression to 0.

### Example usage:

```
expr.clear()
```

## LinExpr.copy()

| `copy` ( )

Copy a linear expression

**Return value:**

Copy of input expression.

**Example usage:**

```
e0 = 2 * x + 3
e1 = e0.copy()
```

## LinExpr.getConstant()

| `getConstant` ( )

Retrieve the constant term from a linear expression.

**Return value:**

Constant from expression.

**Example usage:**

```
e = 2 * x + 3
print(e.getConstant())
```

## LinExpr.getCoeff()

| `getCoeff` ( i )

Retrieve the coefficient from a single term of the expression.

**Return value:**

Coefficient for the term at index *i* in the expression.

**Example usage:**

```
e = x + 2 * y + 3
print(e.getCoeff(1))
```

## LinExpr.getValue()

| `getValue` ( )

Compute the value of an expression using the current solution.

**Return value:**

The value of the expression.

**Example usage:**

```
obj = model.getObjective()
print(obj.getValue())
```

## LinExpr.getVar()

| `getVar` ( *i* )

Retrieve the variable object from a single term of the expression.

### Return value:

Variable for the term at index *i* in the expression.

### Example usage:

```
e = x + 2 * y + 3
print(e.getVar(1))
```

## LinExpr.remove()

| `remove` ( *item* )

Remove a term from a linear expression.

### Arguments:

**item:** If *item* is an integer, then the term stored at index *item* of the expression is removed.  
If *item* is a Var, then all terms that involve *item* are removed.

### Example usage:

```
e = x + 2 * y + 3
e.remove(x)
```

## LinExpr.size()

| `size` ( )

Retrieve the number of terms in the linear expression (not including the constant).

### Return value:

Number of terms in the expression.

### Example usage:

```
e = x + 2 * y + 3
print(e.size())
```

## LinExpr.\_\_eq\_\_()

| `__eq__` ( )

Overloads the == operator, creating a [TempConstr](#) object that captures an equality constraint. The result is typically immediately passed to [Model.addConstr](#).

### Return value:

A [TempConstr](#) object.

### Example usage:

```
m.addConstr(x + y == 1)
```

## LinExpr.\_\_le\_\_()

| `--le--` ( )

Overloads the `<=` operator, creating a [TempConstr](#) object that captures an equality constraint. The result is typically immediately passed to [Model.addConstr](#).

**Return value:**

A [TempConstr](#) object.

**Example usage:**

```
m.addConstr(x + y <= 1)
```

## LinExpr.\_\_ge\_\_()

| `--ge--` ( arg )

Overloads the `>=` operator, creating a [TempConstr](#) object that captures an equality constraint. The result is typically immediately passed to [Model.addConstr](#).

**Return value:**

A [TempConstr](#) object.

**Example usage:**

```
m.addConstr(x + y >= 1)
```

## 6.9 QuadExpr

Gurobi quadratic expression object. A quadratic expression consists of a linear expression plus a list of coefficient-variable-variable triples that capture the quadratic terms. Quadratic expressions are used to build quadratic objective functions and quadratic constraints. They are temporary objects that typically have short lifespans.

You generally build quadratic expressions using overloaded operators. For example, if `x` is a `Var` object, then `x * x` is a `QuadExpr` object. Expressions can be built from constants (e.g., `expr = 0`), variables (e.g., `expr = 1 * x * x + 2 * x * y`), or from other expressions (e.g., `expr2 = 2 * expr1 + x * x`, or `expr3 = expr1 + 2 * expr2`). You can also modify existing expressions (e.g., `expr += x * x`, or `expr2 -= expr1`).

The full list of overloaded operators on `QuadExpr` objects is as follows: `+`, `+=`, `-`, `-=`, `*`, `*=`, and `/`. In Python parlance, we've defined the following `QuadExpr` functions: `__add__`, `__radd__`, `__iadd__`, `__sub__`, `__rsub__`, `__isub__`, `__mul__`, `__rmul__`, `__imul__`, and `__div__`.

We've also overloaded the comparison operators (`==`, `<=`, and `>=`), to make it easier to build constraints from quadratic expressions.

You can use `quicksum` to build quadratic expressions; it is a more efficient version of the Python `sum` function. You can also use `add` or `addTerms` to modify expressions. Terms can be removed from an expression using `remove`.

Note that the cost of building expressions depends heavily on the approach you use. While you can generally ignore this issue when building small expressions, you should be aware of a few efficiency issues when building large expressions:

- While the Python `sum` function can be used to build expressions, it should be avoided. Its cost is quadratic in the length of the expression.
- For similar reasons, you should avoid using `expr = expr + x*x` in a loop. Building large expressions in this way also leads to quadratic runtimes.
- The `quicksum` function is much quicker than `sum`, as are loops over `expr += x*x` or `expr.add(x*x)`. These approaches are fast enough for most programs, but they may still be expensive for very large expressions.
- The most efficient way to build a large quadratic expression is with a single call to `addTerms`.

Individual quadratic terms in a quadratic expression can be queried using the `getVar1`, `getVar2`, and `getCoeff` methods. You can query the number of quadratic terms in the expression using the `size` method. To query the constant and linear terms associated with a quadratic expression, use `getLinExpr` to obtain the linear portion of the quadratic expression, and then use the `getVar`, `getCoeff`, and `getConstant` methods on this `LinExpr` object.

Note that a quadratic expression may contain multiple terms that involve the same variable pair. These duplicate terms are merged when creating a constraint from an expression, but they may be visible when inspecting individual terms in the expression (e.g., when using `getVar1` and `getVar2`).

### QuadExpr()

| `QuadExpr` ( `expr = None` )

Quadratic expression constructor. Note that you should generally use overloaded operators instead of the explicit constructor to build quadratic expression objects.

**Arguments:**

**expr (optional):** Initial value of quadratic expression. Can be a `LinExpr` or a `QuadExpr`.  
If no argument is specified, the initial expression value is 0.

**Return value:**

A quadratic expression object.

**Example usage:**

```
expr = QuadExpr()  
expr = QuadExpr(2*x)  
expr = QuadExpr(x*x + y+y)
```

## QuadExpr.add()

| `add` ( `expr`, `mult=1.0` )

Add an expression into a quadratic expression. Argument can be either a linear or a quadratic expression. Upon completion, the invoking quadratic expression will be equal to the sum of itself and the argument expression.

**Arguments:**

**expr:** Linear or quadratic expression to add.  
**mult (optional):** Multiplier for argument expression.

**Example usage:**

```
e = x * x + 2 * y * y  
e.add(z * z, 3.0)
```

## QuadExpr.addConstant()

| `addConstant` ( `c` )

Add a constant into a quadratic expression.

**Arguments:**

**c:** Constant to add to expression.

**Example usage:**

```
e = x * x + 2 * y * y + z  
expr.addConstant(0.1)
```

## QuadExpr.addTerms()

| `addTerms` ( `coeffs`, `vars`, `vars2=None` )

Add new linear or quadratic terms into a quadratic expression.

**Arguments:**

**coeffs:** Coefficients for new terms; either a list of coefficients or a single coefficient. The arguments must have the same size.

**vars:** Variables for new terms; either a list of variables or a single variable. The arguments must have the same size.

**vars2 (optional):** Variables for new quadratic terms; either a list of variables or a single variable. Only present when you are adding quadratic terms. The arguments must have the same size.

**Example usage:**

```
expr.addTerms(1.0, x)
expr.addTerms([2.0, 3.0], [y, z])
expr.addTerms([2.0, 3.0], [x, y], [y, z])
```

## QuadExpr.clear()

| **clear** ( )

Set a quadratic expression to 0.

**Example usage:**

```
expr.clear()
```

## QuadExpr.copy()

| **copy** ( )

Copy a quadratic expression

**Return value:**

Copy of input expression.

**Example usage:**

```
e0 = x * x + 2 * y * y + z
e1 = e0.copy()
```

## QuadExpr.getCoeff()

| **getCoeff** ( i )

Retrieve the coefficient from a single term of the expression.

**Return value:**

Coefficient for the quadratic term at index *i* in the expression.

**Example usage:**

```
e = x * x + 2 * y * y + z
print(e.getCoeff(1))
```

## QuadExpr.getLinExpr()

| **getLinExpr** ( )

A quadratic expression is represented as a linear expression, plus a list of quadratic terms. This method retrieves the linear expression associated with the quadratic expression.

**Return value:**

Linear expression from quadratic expression.

**Example usage:**

```
e = x * x + 2 * y * y + z
le = e.getLinExpr()
```

### QuadExpr.getValue()

| `getValue` ( )

Compute the value of an expression using the current solution.

**Return value:**

The value of the expression.

**Example usage:**

```
obj = model.getObjective()
print(obj.getValue())
```

### QuadExpr.getVar1()

| `getVar1` ( i )

Retrieve the first variable for a single quadratic term of the quadratic expression.

**Return value:**

First variable associated with the quadratic term at index `i` in the quadratic expression.

**Example usage:**

```
e = x * x + 2 * y * y + z
print(e.getVar1(1))
```

### QuadExpr.getVar2()

| `getVar2` ( i )

Retrieve the second variable for a single quadratic term of the quadratic expression.

**Return value:**

Second variable associated with the quadratic term at index `i` in the quadratic expression.

**Example usage:**

```
e = x * x + 2 * y * y + z
print(e.getVar2(1))
```

### QuadExpr.remove()

| `remove` ( item )

Remove a term from a quadratic expression.

**Arguments:**

**item:** If `item` is an integer, then the quadratic term stored at index `item` of the expression is removed. If `item` is a `Var`, then all quadratic terms that involve `item` are removed.

**Example usage:**

```
e = x * x + 2 * y * y + z
e.remove(x)
```

## QuadExpr.size()

| **size** ( )

Retrieve the number of quadratic terms in the expression.

**Return value:**

Number of quadratic terms in the expression.

**Example usage:**

```
e = x * x + 2 * y * y + z
print(e.size())
```

## QuadExpr.\_\_eq\_\_()

| **\_\_eq\_\_** ( )

Overloads the == operator, creating a [TempConstr](#) object that captures an equality constraint. The result is typically immediately passed to [Model.addConstr](#).

**Return value:**

A TempConstr object.

**Example usage:**

```
m.addConstr(x*x + y*y == 1)
```

## QuadExpr.\_\_le\_\_()

| **\_\_le\_\_** ( )

Overloads the <= operator, creating a [TempConstr](#) object that captures an equality constraint. The result is typically immediately passed to [Model.addConstr](#).

**Return value:**

A TempConstr object.

**Example usage:**

```
m.addConstr(x*x + y*y <= 1)
```

## QuadExpr.\_\_ge\_\_()

| **\_\_ge\_\_** ( arg )

Overloads the >= operator, creating a [TempConstr](#) object that captures an equality constraint. The result is typically immediately passed to [Model.addConstr](#).

**Return value:**

A TempConstr object.

**Example usage:**

```
m.addConstr(x*x + y*y >= 1)
```

## 6.10 TempConstr

Gurobi temporary constraint object. Objects of this class are created as intermediate results when building constraints using overloaded operators. There are no member functions on this class. Instead, `TempConstr` objects are created by a set of functions on `Var`, `LinExpr`, and `QuadExpr` objects (e.g., `==`, `<=`, and `>=`). You will generally never store objects of this class in your own variables.

Consider the following examples:

```
model.addConstr(x + y <= 1);  
model.addQConstr(x*x + y*y <= 1);
```

The overloaded `<=` operator creates an object of type `TempConstr`, which is then immediately passed to method `Model.addConstr` or `Model.addQConstr`.

## 6.11 Column

Gurobi column object. A column consists of a list of coefficient, constraint pairs. Columns are used to represent the set of constraints in which a variable participates, and the associated coefficients. They are temporary objects that typically have short lifespans.

You generally build columns using the `Column` constructor. Terms can be added to an existing column using `addTerms`. Terms can also be removed from a column using `remove`.

Individual terms in a column can be queried using the `getConstr`, and `getCoeff` methods. You can query the number of terms in the column using the `size` method.

### Column()

```
| Column ( coeffs=None, constrs=None )
```

Column constructor.

#### Arguments:

**coeffs** (optional): Lists the coefficients associated with the members of **constrs**.

**constrs** (optional): Constraint or constraints that participate in expression. If **constrs** is a list, then **coeffs** must contain a list of the same length. If **constrs** is a single constraint, then **coeffs** must be a scalar.

#### Return value:

An expression object.

#### Example usage:

```
col = Column()  
col = Column(3, c1)  
col = Column([1.0, 2.0], [c1, c2])
```

### Column.addTerms()

```
| addTerms ( coeffs, constrs )
```

Add new terms into a column.

#### Arguments:

**coeffs**: Coefficients for added constraints; either a list of coefficients or a single coefficient.

The two arguments must have the same size.

**constrs**: Constraints to add to column; either a list of constraints or a single constraint.

The two arguments must have the same size.

#### Example usage:

```
col.addTerms(1.0, x)  
col.addTerms([2.0, 3.0], [y, z])
```

### Column.clear()

```
| clear ( )
```

Remove all terms from a column.

**Example usage:**  
`col.clear()`

## Column.copy()

| `copy` ( )

Copy a column.

**Return value:**

Copy of input column.

**Example usage:**

```
col0 = Column(1.0, c0)
col1 = col0.copy()
```

## Column.getCoeff()

| `getCoeff` ( i )

Retrieve the coefficient from a single term in the column.

**Return value:**

Coefficient for the term at index `i` in the column.

**Example usage:**

```
col = Column([1.0, 2.0], [c0, c1])
print(col.getCoeff(1))
```

## Column.getConstr()

| `getConstr` ( i )

Retrieve the constraint object from a single term in the column.

**Return value:**

Constraint for the term at index `i` in the column.

**Example usage:**

```
col = Column([1.0, 2.0], [c0, c1])
print(col.getConstr(1))
```

## Column.remove()

| `remove` ( item )

Remove a term from a column.

**Arguments:**

**item:** If `item` is an integer, then the term stored at index `item` of the column is removed.  
If `item` is a `Constr`, then all terms that involve `item` are removed.

**Example usage:**

```
col = Column([1.0, 2.0], [c0, c1])
col.remove(c0)
```

## Column.size()

| `size` ( )

Retrieve the number of terms in the column.

**Return value:**

Number of terms in the column.

**Example usage:**

```
print(Column([1.0, 2.0], [c0, c1]).size())
```

## 6.12 Callbacks

Gurobi callback class. A callback is a user function that is called periodically by the Gurobi optimizer in order to allow the user to query or modify the state of the optimization. More precisely, if you pass a function that takes two arguments (`model` and `where`) as the argument to `Model.optimize`, your function will be called during the optimization. Your callback function can then call `Model.cbGet` to query the optimizer for details on the state of the optimization.

Gurobi callbacks can be used both to monitor the progress of the optimization and to modify the behavior of the Gurobi optimizer. A simple user callback function might call `Model.cbGet` to produce a custom display, or perhaps to terminate optimization early (using `Model.terminate`). More sophisticated MIP callbacks might use `Model.cbGetNodeRel` or `Model.cbGetSolution` to retrieve values from the solution to the current node, and then use `Model.cbCut` or `Model.cbLazy` to add a constraint to cut off that solution, or `Model.cbSetSolution` to import a heuristic solution built from that solution.

The Gurobi callback class provides a set of constants that are used within the user callback function. The first set of constants in this class list the options for the `where` argument to the user callback function. The `where` argument indicates from where in the optimization process the user callback is being called. Options are listed in the [Callback Codes](#) section of this document.

The other set of constants in this class list the options for the `what` argument to `Model.cbGet`. The `what` argument is used by the user callback to indicate what piece of status information it would like to retrieve. The full list of options can be found in the [Callback Codes](#) section. As with the `where` argument, you refer to a `what` constant through `GRB.Callback`. For example, the simplex objective value would be requested using `GRB.Callback.SPX_OBJVAL`.

If you would like to pass data to your callback function, you can do so through the `Model` object. For example, if your program includes the statement `model._value = 1` before the optimization begins, then your callback function can query the value of `model._value`. Note that the name of the user data field must begin with an underscore.

When solving a model using multiple threads, note that the user callback is only ever called from a single thread, so you don't need to worry about the thread-safety of your callback.

You can look at `callback.py` in the examples directory for details of how to use Gurobi callbacks.

## 6.13 GurobiError

Gurobi exception object. Upon catching an exception `e`, you can examine `e.errno` (an integer) or `e.message` (a string). A list of possible values for `errno` can be found in the [Error Code](#) section. `message` provides additional information on the source of the error.

## 6.14 Env

Gurobi environment object. Note that environments play a much smaller role in the Python interface than they do in other Gurobi language APIs, mainly because the Python interface has a default environment. Unless you explicitly pass your own environment to routines that require an environment, the default environment will be used.

The primary situations where you will want to use your own environment are:

- When you are using a Gurobi Compute Server and want to choose the server from within your program.
- When you need control over garbage collection of your environment. The Gurobi Python interface maintains a reference to the default environment, so by default it will never be garbage collected. By creating your own environment, you can control exactly when your program releases any licensing tokens or Compute Servers it is using.
- When you are using [concurrent environments](#) in one of the [concurrent optimizers](#).

Note that you can manually remove the reference to the default environment by calling `disposeDefaultEnv`. After calling this, and after all models built within the default environment are garbage collected, the default environment will be garbage collected as well. A new default environment will be created automatically if you call a routine that needs one.

### Env()

```
| Env ( logfile="" )
```

Env constructor. You will generally want to use the default environment in Gurobi Python programs. The exception is when you want explicit control over environment garbage collection. By creating your own environment object and always passing it to methods that take an environment as input ([read](#) or the [Model](#) constructor), you will avoid creating the default environment. Once every model created using an Env object is garbage collected, and once the Env object itself is no longer referenced, the garbage collector will reclaim the environment and release all associated resources.

#### Arguments:

**logfile:** Name of the log file for this environment. Pass an empty string if you don't want a log file.

#### Return value:

New environment object.

#### Example usage:

```
env = Env("gurobi.log")
m = read("misc07.mps", env)
m.optimize()
```

### Env.ClientEnv()

```
| Env.ClientEnv ( logfile="", computeServers="", port=GRB.DEFAULT_CS_PORT,
|                 password="", priority=0, timeout=-1 )
```

Compute Server Env constructor. Creates a client environment on a compute server. If all compute servers are at capacity, this command will cause a job to be placed in the compute server queue, and the command will return an environment once capacity is available.

Client environments have limited uses in the Python environment. You can use a client environment as an argument to the [Model constructor](#), to indicate that a model should be constructed on a Compute Server, or as an argument to the global [read](#) function, to indicate that the result of reading the file should be placed on a Compute Server.

**Arguments:**

**logfile**`name`: Name of the log file for this environment. Pass an empty string if you don't want a log file.

**computeServers**: Comma-separated list of compute servers. Servers can be identified by name or by IP address.

**port**: Port number on compute server. Use the default value unless your server administrator has informed you that a different value should be used.

**password**: User password on compute server. Obtain this from your Compute Server administrator.

**priority**: Job priority on the compute server. Higher priority jobs are pulled from the job queue before lower priority jobs. A special value of 100 indicates that the job should run immediately.

**timeout**: Job queue timeout. After the specified timeout (in seconds) has elapsed, this command will give up and return a Gurobi exception. Use a negative value to indicate that the call should never timeout.

**Return value:**

New environment object.

**Example usage:**

```
env = Env.ClientEnv("client.log", "server1.mycompany.com,server2.mycompany.com")
m = read("misc07.mps", env)
m.optimize()
```

## Env.CloudEnv()

`Env.CloudEnv` ( logfile="" , accessID , secretKey , pool="" )

Instant Cloud Env constructor. Creates a Gurobi environment on an Instant Cloud server. Uses an existing Instant Cloud machine if one is currently active within the specified machine pool, and launches a new one otherwise. Note that launching a machine can take a few minutes.

Once an Instant Cloud server is active (either because it was already active or because the launch of a new server completed), this command places a job in the server queue. If the server has sufficient capacity, the job will start immediately. Otherwise, it is placed in the server queue and this command returns once capacity becomes available.

You should visit the Gurobi Instant Cloud site to obtain your `accessID` and `secretKey`, configure your machine pools, and perform other cloud setup and maintenance tasks.

Note that you should keep your `secretKey` private. Sharing it with others will allow them to launch Instant Cloud instances in your account.

In addition to creating a new environment, this routine will also check the current working directory for a file named `gurobi.env`, and it will attempt to read parameter settings from this file if it exists. The file should be in [PRM](#) format (briefly, each line should contain a parameter name, followed by the desired value for that parameter).

In general, you should aim to create a single Gurobi environment in your program, even if you plan to work with multiple models. Reusing one environment is much more efficient than creating and destroying multiple environments.

Most methods in the Gurobi Python interface will use the default environment, so you'll need to take special action to use the cloud environment created by this method. You can use a cloud environment as an argument to the [Model constructor](#), to indicate that a model should be constructed on the given Instant Cloud server, or as an argument to the global [read](#) function, to indicate that the result of reading the file should be placed on the given Instant Cloud Server.

#### Arguments:

**logfile**: The name of the log file for this environment. May be `NULL` (or an empty string), in which case no log file is created.

**accessID**: The access ID for your Gurobi Instant Cloud license. This can be retrieved from the Gurobi Instant Cloud website. When used in combination with your **secretKey**, this allows you to launch Instant Cloud instances and submit jobs to them.

**secretKey**: The secret key for your Gurobi Instant Cloud license. This can be retrieved from the Gurobi Instant Cloud website. When used in combination with your **accessID**, this allows you to launch Instant Cloud instances and submit jobs to them. Note that you should keep your secret key private.

**pool**: The machine pool. Machine pools allow you to create fixed configurations on the Instant Cloud website (capturing things like type of machine, geographic region, etc.), and then launch and share machines from client programs without having to restate the configuration information each time you launch a machine. May be an empty string, in which case your job will be launched in the default pool associated with your cloud license.

#### Return value:

New environment object.

#### Example usage:

```
env = Env.CloudEnv("cloud.log",
                  "3d1ecef9-dfad-eff4-b3fa", "ae6L23a1Je3+fas");
m = read("misc07.mps", env)
m.optimize()
```

## Env.resetParams()

| **resetParams** ( )

Reset the values of all parameters to their default values.

#### Example usage:

```
env.resetParams()
```

## Env.setParam()

| **setParam** ( paramname, newvalue )

Set the value of a parameter to a new value.

**Arguments:**

**paramname:** String containing the name of parameter that you would like to modify. The name can include '\*' and '?' wildcards. If more than one parameter matches, the matching names are listed and none are modified. Note that case is ignored.

**newvalue:** Desired new value for parameter. Can be 'default', which indicates that the parameter should be reset to its default value.

**Example usage:**

```
env.setParam("Cuts", 2)
env.setParam("Heu*", 0.5)
env.setParam("*Interval", 10)
```

## Env.writeParams()

```
| writeParams ( filename )
```

Write all modified parameters to a file. The file is written in [PRM](#) format.

**Example usage:**

```
env.setParam("Heu*", 0.5)
env.writeParams("params.prm") # file will contain changed parameter
system("cat params.prm")
```

## 6.15 GRB

Class for Python constants. Classes `GRB.Attr` and `GRB.Param` are used to get or set Gurobi attributes and parameters, respectively.

### Constants

The following list contains a set of constants that are used by the Gurobi Python interface. You would refer to them using a `GRB.` prefix (e.g., `GRB.OPTIMAL`).

```
# Model status codes (after call to optimize())
```

```
LOADED          = 1
OPTIMAL         = 2
INFEASIBLE     = 3
INF_OR_UNBD    = 4
UNBOUNDED      = 5
CUTOFF         = 6
ITERATION_LIMIT = 7
NODE_LIMIT     = 8
TIME_LIMIT     = 9
SOLUTION_LIMIT = 10
INTERRUPTED    = 11
NUMERIC        = 12
SUBOPTIMAL     = 13
INPROGRESS     = 14
USER_OBJ_LIMIT = 15
```

```
# Basis status info
```

```
BASIC          = 0
NONBASIC_LOWER = -1
NONBASIC_UPPER = -2
SUPERBASIC     = -3
```

```
# Constraint senses
```

```
LESS_EQUAL    = '<'
GREATER_EQUAL = '>'
EQUAL         = '='
```

```
# Variable types
```

```
CONTINUOUS    = 'C'
BINARY        = 'B'
INTEGER       = 'I'
```

```

SEMICONT      = 'S'
SEMIINT       = 'N'

# Objective sense

MINIMIZE = 1
MAXIMIZE = -1

# SOS types

SOS_TYPE1     = 1
SOS_TYPE2     = 2

# General constraint types

GENCONSTR_MAX      = 0
GENCONSTR_MIN      = 1
GENCONSTR_ABS      = 2
GENCONSTR_AND      = 3
GENCONSTR_OR       = 4
GENCONSTR_INDICATOR = 5

# Numeric constants

INFINITY   = 1e100
UNDEFINED  = 1e101

# Other constants

DEFAULT_CS_PORT = 61000

# Errors

ERROR_OUT_OF_MEMORY      = 10001
ERROR_NULL_ARGUMENT      = 10002
ERROR_INVALID_ARGUMENT   = 10003
ERROR_UNKNOWN_ATTRIBUTE  = 10004
ERROR_DATA_NOT_AVAILABLE = 10005
ERROR_INDEX_OUT_OF_RANGE = 10006
ERROR_UNKNOWN_PARAMETER  = 10007
ERROR_VALUE_OUT_OF_RANGE = 10008
ERROR_NO_LICENSE         = 10009
ERROR_SIZE_LIMIT_EXCEEDED = 10010
ERROR_CALLBACK           = 10011
ERROR_FILE_READ          = 10012

```

ERROR_FILE_WRITE	= 10013
ERROR_NUMERIC	= 10014
ERROR_IIS_NOT_INFEASIBLE	= 10015
ERROR_NOT_FOR_MIP	= 10016
ERROR_OPTIMIZATION_IN_PROGRESS	= 10017
ERROR_DUPLICATES	= 10018
ERROR_NODEFILE	= 10019
ERROR_Q_NOT_PSD	= 10020
ERROR_QCP_EQUALITY_CONSTRAINT	= 10021
ERROR_NETWORK	= 10022
ERROR_JOB_REJECTED	= 10023
ERROR_NOT_SUPPORTED	= 10024
ERROR_EXCEED_2B_NONZEROS	= 10025
ERROR_INVALID_PIECEWISE_OBJ	= 10026
ERROR_UPDATEMODE_CHANGE	= 10027
ERROR_CLOUD	= 10028
ERROR_MODEL_MODIFICATION	= 10029
ERROR_NOT_IN_MODEL	= 20001
ERROR_FAILED_TO_CREATE_MODEL	= 20002
ERROR_INTERNAL	= 20003

## GRB.Attr

The constants defined in this class are used to get or set attributes (through [Model.getAttr](#) or [Model.setAttr](#), for example). Please refer to the [Attributes](#) section to see a list of all attributes and their functions. You refer to an attribute using a `GRB.Attr` prefix (e.g., `GRB.Attr.obj`). Note that these constants are simply strings, so wherever you might use this constant, you also have the option of using the string directly (e.g, 'obj' rather than `GRB.Attr.obj`).

## GRB.Param

The constants defined in this class are used to get or set parameters [Model.getParamInfo](#) or [Model.setParam](#). Please refer to the [Parameters](#) section to see a list of all parameters and their functions. You refer to a parameter using a `GRB.Param` prefix (e.g., `GRB.Param.displayInterval`). Note that these constants are simply strings, so wherever you might use this constant, you also have the option of using the string directly (e.g, 'displayInterval' rather than `GRB.Param.-displayInterval`).

## 6.16 tuplelist

Gurobi tuple list. This is a sub-class of the Python `list` class that is designed to efficiently support a usage pattern that is quite common when building optimization models. In particular, if a `tuplelist` is populated with a list of tuples, the `select` function on this class efficiently selects tuples whose values match specified values in specified tuple fields. To give an example, the statement `l.select(1, '*', 5)` would select all member tuples whose first field is equal to '1' and whose third field is equal to '5'. The '\*' character is used as a wildcard to indicate that any value is acceptable in that field.

You generally build `tuplelist` objects in the same way you would build standard Python lists. For example, you can use the `+=` operator to append a new list of items to an existing `tuplelist`, or the `+` operator to concatenate a pair of `tuplelist` objects. You can also call the `append`, `extend`, `insert`, `pop`, and `remove` functions.

To access the members of a `tuplelist`, you also use standard list functions. For example, `l[0]` returns the first member of a `tuplelist`, while `l[0:10]` returns a `tuplelist` containing the first ten members. You can also use `len(l)` to query the length of a list.

Note that `tuplelist` objects build and maintain a set of internal data structures to support efficient `select` operations. If you wish to reclaim the storage associated with these data structures, you can call the `clean` function.

A `tuplelist` is designed to store tuples containing scalar values (`int`, `float`, `string`, ...). It may produce unpredictable results with other Python objects, such as tuples of tuples. Thus, you can store `(1, 2.0, 'abc')` in a `tuplelist`, but you shouldn't store `((1, 2.0), 'abc')`.

### `tuplelist()`

| `tuplelist` ( `list` )

tuplelist constructor.

**Arguments:**

`list`: Initial list of member tuples.

**Return value:**

A tuplelist object.

**Example usage:**

```
l = tuplelist([(1,2), (1,3), (2,4)])
l = tuplelist([('A', 'B', 'C'), ('A', 'C', 'D')])
```

### `tuplelist.select()`

| `select` ( `pattern` )

Returns a `tuplelist` containing all member tuples that match the specified pattern. The pattern requires one argument for each field in the member tuple. A scalar argument must match the corresponding field exactly. A list argument matches if any list member matches the corresponding field. A '\*' argument matches any value in the corresponding field.

**Arguments:**

`pattern`: Pattern to match for a member tuple.

**Example usage:**

```
l.select(1, 3, '*', 6)
l.select([1, 2], 3, '*', 6)
l.select('A', '*', 'C')
```

**tuplelist.clean()**

| **clean** ( )

Discards internal data structure associated with a `tuplelist` object. Note that calling this routine won't affect the contents of the `tuplelist`. It only affects the memory used and the performance of later calls to `select`.

**Example usage:**

```
l.clean()
```

**tuplelist.\_\_contains\_\_()**

| **\_\_contains\_\_** ( val )

Provides efficient support for the Python `in` operator.

**Example usage:**

```
if (1,2) in l:
    print("Tuple (1,2) is in tuplelist l")
```

## 6.17 tupledict

Gurobi tuple dict. This is a sub-class of the Python `dict` class that is designed to efficiently support a usage pattern that is quite common when building optimization models. In particular, a `tupledict` is a Python `dict` where the keys are stored as a Gurobi `tuplelist`, and where the values are typically Gurobi `Var` objects. Objects of this class make it easier to build linear expressions on sets of Gurobi variables, using `tuplelist.select()` syntax and semantics.

You typically build a `tupledict` by calling `Model.addVars`. Once you've created a `tupledict` `d`, you can use `d.sum()` to create a [linear expression](#) that captures the sum of the variables in the `tupledict`. You can also use a command like `d.sum(1, '*', 5)` to create a sum over a subset of the variables in `d`. Assuming the keys for the `tupledict` are tuples containing three fields, this statement would create a linear expression that captures the sum over all variables in `d` whose keys contain a 1 in the first field of the tuple and a 5 in the third field (the `'*` character is a wildcard that indicates that any value is acceptable in that field). You can also use `d.prod(coeff)` to create a linear expression where the coefficients are pulled from the argument `dict`. For example, if `d(1,2,5)` contains variable `x` and `coeff(1,2,5)` is 2.0, then the resulting expression would include term `2.0 * x`.

To access the members of a `tupledict`, you can use standard dict indexing. For example, `d[1,2]` returns the value associated with tuple `(1,2)`.

Note that `tupledict` objects build and maintain a set of internal data structures to support efficient `select` operations. If you wish to reclaim the storage associated with these data structures, you can call the `clean` function.

### tupledict()

```
| tupledict ( args, kwargs )
```

`tupledict` constructor. Arguments are identical to those of a Python `dict` constructor. Note that you will typically use `Model.addVars` to build a `tupledict`.

#### Arguments:

**args:** Positional arguments.

**kwargs:** Named arguments.

#### Return value:

A `tupledict` object.

#### Example usage:

```
d = tupledict([((1,2), 'onetwo'), ((1,3), 'onethree'), ((2,3), 'twothree')])
print(d[1,2]) # prints 'onetwo'
```

### tupledict.select()

```
| select ( pattern )
```

Returns a `list` containing the values associated with keys that match the specified tuple pattern. The pattern should provide one value for each field in the key tuple. A `'*'` value indicates that any value is accepted in that field.

Without arguments, this method returns a list of all values in the `tupledict`.

**Arguments:**

**pattern:** Pattern to match for a key tuple.

**Example usage:**

```
d = tupledict([(1,2), 'onetwo'), ((1,3), 'onethree'), ((2,3), 'twothree')])
print(d.select())          # prints ['onetwo', 'onethree', 'twothree']
print(d.select(1, '*'))    # prints ['onetwo', 'onethree']
print(d.select('*', 3))    # prints ['onethree', 'twothree']
print(d.select(1, 3))      # prints ['onethree']
```

**tupledict.sum()**

| **sum** ( pattern )

Returns the sum of the values associated with keys that match the specified pattern. If the values are Gurobi Var objects, the result is a `LinExpr`. The pattern should provide one value for each field in the key tuple. A '\*' value indicates that any value is accepted in that field.

Without arguments, this method returns the sum of all values in the `tupledict`.

**Arguments:**

**pattern:** Pattern to match for a key tuple.

**Example usage:**

```
x = m.addVars([(1,2), (1,3), (2,3)])
expr = x.sum()          # LinExpr: x[1,2] + x[1,3] + x[2,3]
expr = x.sum(1, '*')    # LinExpr: x[1,2] + x[1,3]
expr = x.sum('*', 3)    # LinExpr: x[1,3] + x[2,3]
expr = x.sum(1, 3)      # LinExpr: x[1,3]
```

**tupledict.prod()**

| **prod** ( coeff, pattern )

Returns a linear expression that contains one term for each tuple that is present in both the `tupledict` and in the argument `dict`. For example, `x.prod(coeff)` would contain term  $2.0 * var$  if `x[1,2] = var` and `coeff[1,2] = 2.0`.

**Arguments:**

**coeff:** Python dict that maps tuples to coefficients.

**pattern:** Pattern to match for a key tuple.

**Example usage:**

```
x = m.addVars([(1,2), (1,3), (2,3)])
coeff = dict([(1,2), 2.0], ((1,3), 2.1), ((2,3), 3.3)])
expr = x.prod(coeff)      # LinExpr: 2.0 x[1,2] + 2.1 x[1,3] + 3.3 x[2,3]
expr = x.prod(coeff, '*', 3) # LinExpr: 2.1 x[1,3] + 3.3 x[2,3]
```

**tupledict.clean()**

| **clean** ( )

Discards internal data structure associated with a `tupledict` object. Note that calling this routine won't affect the contents of the `tupledict`. It only affects the memory used and the performance of later calls to [select](#).

**Example usage:**

```
d.clean()
```

The Gurobi MATLAB® interface allows you to build an optimization model, pass the model to Gurobi, and obtain the optimization result, all from within the MATLAB environment. For those of you who are not familiar with MATLAB, it is an environment for doing numerical computing. Please visit the [MATLAB web site](#) for more information.

A quick note for new users: the convention in math programming is that variables are non-negative unless specified otherwise. You'll need to explicitly set lower bounds if you want variables to be able to take negative values.

## **The Gurobi MATLAB API**

The Gurobi MATLAB interface is quite concise. It consists of just five MATLAB functions: [gurobi](#), [gurobi\\_read](#), [gurobi\\_write](#), [gurobi\\_iis](#), and [gurobi\\_setup](#).

## 7.1 Solving models with the Gurobi MATLAB interface

The Gurobi MATLAB interface can be used to solve optimization problems of the following form:

minimize	$x^T Q x + c^T x + \text{alpha}$	
subject to	$Ax = b$	(linear constraints)
	$\ell \leq x \leq u$	(bound constraints)
	some $x_j$ integral	(integrality constraints)
	some $x_k$ lie within second order cones	(cone constraints)
	$x^T Q c x + q^T x \leq \text{beta}$	(quadratic constraints)
	some $x_i$ in SOS	(special ordered set constraints)

Many of the model components listed here are optional. For example, integrality constraints may be omitted. We'll discuss the details of how models are represented shortly.

The function `gurobi`, described next, allows you to take a model represented using MATLAB matrices and solve it with the Gurobi Optimizer.

### `gurobi()`

```
| gurobi ( model, params )
```

The two arguments are MATLAB `struct` variables, each consisting of multiple fields. The first argument contains the optimization model to be solved. The second contains an optional set of Gurobi parameters to be modified during the solution process. The return value of this function is a `struct`, also consisting of multiple fields. It contains the result of performing the optimization on the specified model. We'll now discuss the details of each of these data structures.

#### The optimization model

As we've mentioned, the `model` argument to the `gurobi` function is a `struct` variable, containing multiple `fields` that represent the various parts of the optimization model. Several of these fields are optional. Note that you refer to a field of a MATLAB `struct` variable by adding a period to the end of the variable name, followed by the name of the field. For example, `model.A` refers to field `A` of variable `model`.

The following is an enumeration of all of the fields of the `model` argument that Gurobi will take into account when optimizing the model:

**A:** The linear constraint matrix. This must be a sparse matrix.

**obj:** The linear objective vector ( $c$  in the [problem statement](#)). You must specify one value for each column of `A`. This must be a dense vector.

**sense:** The senses of the linear constraints. Allowed values are `'='`, `'<'`, or `'>'`. You must specify one value for each row of `A`, or a single value to specify that all constraints have the same sense. This must be a char array.

**rhs:** The right-hand side vector for the linear constraints ( $b$  in the [problem statement](#)). You must specify one value for each row of `A`. This must be a dense vector.

**lb (optional):** The lower bound vector. When present, you must specify one value for each column of `A`. This must be a dense vector. When absent, each variable has a lower bound of 0.

**ub** (optional): The upper bound vector. When present, you must specify one value for each column of **A**. This must be a dense vector. When absent, the variables have infinite upper bounds.

**vtype** (optional): The variable types. This char array is used to capture variable integrality constraints. Allowed values are 'C' (continuous), 'B' (binary), 'I' (integer), 'S' (semi-continuous), or 'N' (semi-integer). Binary variables must be either 0 or 1. Integer variables can take any integer value between the specified lower and upper bounds. Semi-continuous variables can take any value between the specified lower and upper bounds, or a value of zero. Semi-integer variables can take any integer value between the specified lower and upper bounds, or a value of zero. When present, you must specify one value for each column of **A**, or a single value to specify that all variables have the same type. When absent, each variable is treated as being continuous. Refer to [this section](#) for more information on variable types.

**modelsense** (optional): The optimization sense. Allowed values are 'min' (minimize) or 'max' (maximize). When absent, the default optimization sense is minimization.

**modelname** (optional): The name of the model. The name appears in the Gurobi log, and when writing a model to a file.

**objcon** (optional): The constant offset in the objective function (alpha in the [problem statement](#)).

**vbasis** (optional): The variable basis status vector. Used to provide an advanced starting point for the simplex algorithm. You would generally never concern yourself with the contents of this array, but would instead simply pass it from the result of a previous optimization run to the input of a subsequent run. When present, you must specify one value for each column of **A**. This must be a dense vector.

**cbasis** (optional): The constraint basis status vector. Used to provide an advanced starting point for the simplex algorithm. Consult the **vbasis** description for details. When present, you must specify one value for each row of **A**. This must be a dense vector.

**Q** (optional): The quadratic objective matrix. When present, **Q** must be a square matrix whose row and column counts are equal to the number of columns in **A**. **Q** must be a sparse matrix.

**cones** (optional): Second-order cone constraints. A struct array. Each element in the array defines a single cone constraint:  $x(k)^2 \geq \sum(x(idx).^2)$ ,  $x(k) \geq 0$ . The constraint is defined via `model.cones.index = [k idx]`, with the first entry in `index` corresponding to the index of the variable on the left-hand side of the constraint, and the remaining entries corresponding to the indices of the variables on the right-hand side of the constraint. `model.cones.index` must be a dense vector.

**quadcon** (optional): The quadratic constraints. A struct array. When present, each element in the array defines a single quadratic constraint:  $x^T Qc x + q^T x \leq \text{beta}$ . The **Qc** matrix must be a square matrix whose row and column counts are equal to the number of columns of **A**. **Qc** must be a sparse matrix. It is stored in `model.quadcon.Qc`. The **q** vector defines the linear terms in the constraint. You must specify a value for **q** for each column of **A**. This must be a

dense vector. It is stored in `model.quadcon.q`. The scalar beta defines the right-hand side of the constraint. It is stored in `model.quadcon.rhs`.

**sos** (optional): The Special Ordered Set (SOS) constraints. A struct array. When present, each element in the array defines a single SOS constraint. A SOS constraint can be of type 1 or 2. This is specified via `model.sos.type`. A type 1 SOS constraint is a set of variables for which at most one variable in the set may take a value other than zero. A type 2 SOS constraint is an ordered set of variables where at most two variables in the set may take non-zero values. If two take non-zero values, they must be contiguous in the ordered set. The members of an SOS constraint are specified by placing their indices in `model.sos.index`. Optional weights associated with SOS members may be defined in `model.sos.weight`. Please refer to [this section](#) for details on SOS constraints.

**pwlobj** (optional): The piecewise-linear objective functions. A struct array. When present, each element in the array defines a piecewise-linear objective function of a single variable. The index of the variable whose objective function is being defined is stored in `model.pwlobj.var`. The  $x$  values for the points that define the piecewise-linear function are stored in `model.pwlobj.x`. The values in the  $x$  vector must be in non-decreasing order. The  $y$  values for the points that define the piecewise-linear function are stored in `model.pwlobj.y`.

**start** (optional): The MIP start vector. The MIP solver will attempt to build an initial solution from this vector. When present, you must specify a start value for each variable. This must be a dense vector. Note that you can leave the start value for a variable undefined—the MIP solver will attempt to fill in values for the undefined start values. This may be done by setting the start value for that variable to `nan`.

**varnames** (optional): The variable names. A cell array of strings. When present, each element of the array defines the name of a variable. You must specify a name for each column of A.

**constrnames** (optional): The constraint names. A cell array of strings. When present, each element of the array defines the name of a constraint. You must specify a name for each row of A.

If any of the mandatory fields listed above are missing, the `gurobi` function will return an error.

Below is an example that demonstrates the construction of a simple optimization model:

```
model.A      = sparse([1 2 3; 1 1 0]);
model.obj    = [1 1 2];
model.modelsense = 'max';
model.rhs    = [4; 1];
model.sense  = '<>'
```

## Parameters

The optional `params` argument to the `gurobi` function is also a `struct`, potentially containing multiple fields. The name of each field must be the name of a Gurobi parameter, and the associated value should be the desired value of that parameter. Gurobi parameters allow users to modify the default behavior of the Gurobi optimization algorithms. You can find a complete list of the available Gurobi parameters [here](#).

To create a struct that would set the Gurobi [method](#) parameter to 2 you would do the following:

```
params.method = 2;
```

## The optimization result

The `gurobi` function returns a `struct`, with the various results of the optimization stored in its fields. The specific results that are available depend on the type of model that was solved, and the status of the optimization. The following is a list of fields that might be available in the returned result. We'll discuss the circumstances under which each will be available after presenting the list.

**status:** The status of the optimization, returned as a string. The desired result is 'OPTIMAL', which indicates that an optimal solution to the model was found. Other status are possible, for example if the model has no feasible solution or if you set a Gurobi parameter that leads to early solver termination. See the [Status Code](#) section for further information on the Gurobi status codes.

**objval:** The objective value of the computed solution.

**runtime:** The elapsed wall-clock time (in seconds) for the optimization.

**x:** The computed solution. This array contains one entry for each column of **A**.

**slack:** The constraint slack for the computed solution. This array contains one entry for each row of **A**.

**qcslack:** The quadratic constraint slack in the current solution. This array contains one entry for second-order cone constraint and one entry for each quadratic constraint. The slacks for the second-order cone constraints appear before the slacks for the quadratic constraints.

**pi:** Dual values for the computed solution (also known as *shadow prices*). This array contains one entry for each row of **A**.

**qcpi:** The dual values associated with the quadratic constraints. This array contains one entry for each second-order cone constraint and one entry for each quadratic constraint. The dual values for the second-order cone constraints appear before the dual values for the quadratic constraints.

**rc:** Variable reduced costs for the computed solution. This array contains one entry for each column of **A**.

**vbasis:** Variable basis status values for the computed optimal basis. You generally should not concern yourself with the contents of this array. If you wish to use an advanced start later, you would simply copy the **vbasis** and **cbasis** arrays into the corresponding fields for the next model. This array contains one entry for each column of **A**.

**cbasis:** Constraint basis status values for the computed optimal basis. This array contains one entry for each row of **A**.

**unbdray:** Unbounded ray. Provides a vector that, when added to any feasible solution, yields a new solution that is also feasible but improves the objective.

**farkasdual**: Farkas infeasibility proof. This is a dual unbounded vector. Adding this vector to any feasible solution of the dual model yields a new solution that is also feasible but improves the dual objective.

**farkasproof**: Magnitude of infeasibility violation in Farkas infeasibility proof. A Farkas infeasibility proof identifies a new constraint, obtained by taking a linear combination of the constraints in the model, that can never be satisfied. (the linear combination is available in the **farkasdual** field). This attribute indicates the magnitude of the violation of this aggregated constraint.

**objbound**: Best available bound on solution (lower bound for minimization, upper bound for maximization).

**itercount**: Number of simplex iterations performed.

**baritercount**: Number of barrier iterations performed.

**nodecount**: Number of branch-and-cut nodes explored.

The **Status** field will be present in all cases. It indicates whether Gurobi was able to find a proven optimal solution to the model. In cases where a solution to the model was found, optimal or otherwise, the **objval** and **x** fields will be present. For linear and quadratic programs, if a solution is available, then the **pi** and **rc** fields will also be present. For models with quadratic constraints, if the parameter **qcpdual** is set to 1, the field **qcpi** will be present. If the final solution is a *basic* solution (computed by simplex), then **vbasis** and **cbasis** will be present. If the model is an unbounded linear program and the **infunbdinfo** parameter is set to 1, the field **unbdray** will be present. Finally, if the model is an infeasible linear program and the **infunbdinfo** parameter is set to 1, the fields **farkasdual** and **farkasproof** will be set.

The following is an example of how the results of the **gurobi** call might be extracted and output:

```
result = gurobi(model, params)
if strcmp(result.status, 'OPTIMAL')
    fprintf('Optimal objective: %e\n', result.objval);
    disp(result.x)
else
    fprintf('Optimization returned status: %s\n', result.status);
end
```

Please consult [this section](#) for a discussion of some of the practical issues associated with solving a precisely defined mathematical model using finite-precision floating-point arithmetic.

## 7.2 Reading and writing models with the Gurobi MATLAB interface

The MATLAB interface contains functions to read and write model files.

### `gurobi_read()`

`gurobi_read` ( filename )

Reads a model from a file.

#### Arguments:

**filename:** Name of the file to read. Note that the type of the file is encoded in the file name suffix. The filename suffix should be one of `.mps`, `.rew`, `.lp`, `.rlp`, `.ilp`, or `.opb` (see the [file formats](#) section for details on Gurobi file formats). The files can be compressed, so additional suffixes of `.gz`, `.bz2`, `.zip`, or `.7z` are accepted. The file name may contain `*` or `?` wildcards. No file is read when no wildcard match is found. If more than one match is found, this routine will attempt to read the first matching file.

#### Return value:

A model struct containing multiple named fields. See the [gurobi](#) function for a description of these fields and their contents.

#### Example usage:

```
model = gurobi_read('etamacro.mps');
result = gurobi(model)
```

### `gurobi_write()`

`gurobi_write` ( model, filename )

Writes a model to a file.

#### Arguments:

**model:** The model struct must contain a valid Gurobi model. See the [gurobi](#) function for a description of model's required fields and values.

**filename:** Name of the file to write. Note that the type of the file is encoded in the file name suffix. The filename suffix should be one of `.mps`, `.rew`, `.lp`, `.rlp`, or `.ilp`, to indicate the desired file format (see the [file formats](#) section for details on Gurobi file formats). The files can be compressed, so additional suffixes of `.gz`, `.bz2`, `.zip`, or `.7z` are accepted.

#### Example usage:

```
model.A          = sparse([1 2 3; 1 1 0]);
model.obj        = [1 1 2];
model.modelsense = 'max';
model.rhs        = [4; 1];
model.sense      = '<>';

gurobi_write(model, 'mymodel.mps');
gurobi_write(model, 'mymodel.lp');
gurobi_write(model, 'mymodel.mps.bz2');
```

## 7.3 Computing an IIS with the Gurobi MATLAB interface

The MATLAB interface contains a function to compute an IIS.

### **gurobi\_iis()**

**gurobi\_iis** ( model, params )

Computes an IIS

#### **Arguments:**

**model:** The model struct must contain a valid Gurobi model. See the [gurobi](#) function for a description of model's required fields and values.

**params:** The params struct may contain Gurobi parameters. See the [gurobi](#) function for a description of the param's fields and values.

#### **Example usage:**

```
clear model params
model = gurobi_read('examples/data/klein1.mps')
params.resultfile = 'myiis.ilp';
iis = gurobi_iis(model, params);\
```

#### **The IIS result**

The `gurobi_iis` function returns a struct `iis`, with various results stored in its named components. The specific results that are available depend on the type of model.

The `iis` struct will always contain the following fields

**minimal:** A logical scalar that indicates whether the computed IIS is minimal. It will normally be true, but it may be false if the IIS computation was stopped early (e.g due to a time limit or a user interrupt).

**constrs:** A logical vector that indicates whether a linear constraint appears in the computed IIS.

**lb:** A logical vector that indicates whether a lower bound in the computed IIS.

**ub:** A logical vector that indicates whether an upper bound appears in the computed IIS.

If your model contains SOS constraints the IIS struct will contain the following field:

**sos:** A logical vector that indicates whether an sos constraint appears in the computed IIS

If your model contains cones or quadratic constraints the IIS struct will contain the following field:

**qconstrs:** A logical vector that indicates whether the cone or quadratic constraint appears in the computed IIS. Note that any cones in the model will appear first in this vector, followed by the quadratic constraints.

## 7.4 Setting up the Gurobi MATLAB interface

In order to use our MATLAB interface, you'll need to use the MATLAB function `gurobi_setup` to tell MATLAB where to find the Gurobi `mex` file. This file is stored in the `<installdir>/matlab` directory of your Gurobi installation. For example, if you installed the 64-bit Windows version of Gurobi 7.0 in the default location, you should run

```
>> cd c:/Users/jones/gurobi700/win64/matlab
>> gurobi_setup
```

The `gurobi_setup` function adjusts your MATLAB path to include the `<installdir>/matlab` directory. If you want to avoid typing this command every time you start MATLAB, follow the instructions issued by `gurobi_setup` to permanently adjust your path.

The MATLAB examples provided with the Gurobi distribution are included in the `<installdir>/examples/matlab` directory. To run these examples you need to change to this directory. For example, if you are running the 64-bit Windows version of Gurobi, you would say:

```
>> cd c:/Users/jones/gurobi700/win64/examples/matlab
>> mip1
```

If the Gurobi package was successfully installed, you should see the following output:

```
status: 'OPTIMAL'
versioninfo: [1x1 struct]
objval: 3
runtime: 0.0386
x: [3x1 double]
slack: [2x1 double]
objbound: 3
itercount: 0
baritercount: 0
nodecount: 0

x 1
y 0
z 1
Obj: 3.000000e+00
```

The Gurobi R interface allows you to build an optimization model, pass the model to Gurobi, and obtain the optimization result, all from within the R environment. For those of you who are not familiar with R, it is a free language for statistical computing. Please visit the [R Project web site](#) for more information.

A quick note for new users: the convention in math programming is that variables are non-negative unless specified otherwise. You'll need to explicitly set lower bounds if you want variables to be able to take negative values.

## **The Gurobi R API**

The Gurobi R interface is quite concise. It consists of a pair of R functions: [gurobi](#) and [gurobi\\_write](#).

## 8.1 Solving models with the Gurobi R interface

The Gurobi R interface can be used to solve optimization problems of the following form:

minimize	$x^T Q x + c^T x + \text{alpha}$	
subject to	$Ax = b$	(linear constraints)
	$\ell \leq x \leq u$	(bound constraints)
	some $x_j$ integral	(integrality constraints)
	some $x_k$ lie within second order cones	(cone constraints)
	$x^T Q c x + q^T x \leq \text{beta}$	(quadratic constraints)
	some $x_i$ in SOS	(special ordered set constraints)

Many of the model components listed here are optional. For example, integrality constraints may be omitted. We'll discuss the details of how models are represented shortly.

The following function allows you to take a model represented using R data structures and solve it with the Gurobi Optimizer:

```
| gurobi ( model, params=NULL )
```

The two arguments to this function are R `list` variables, each consisting of multiple *named components*. The first argument contains the optimization model to be solved. The second contains an optional list of Gurobi parameters to be modified during the solution process. The return value of this function is a list, also consisting of multiple named components. It contains the result of performing the optimization on the specified model. We'll now discuss the details of each of these lists.

### The optimization model

As we've mentioned, the `model` argument to the `gurobi()` function is a `list` variable, containing multiple *named components* that represent the various parts of the optimization model. Several of these components are optional. Note that you refer to a named component of an R list variable by appending a dollar sign followed by the component name to the list variable name. For example, `model$A` refers to component `A` of list variable `model`.

The following is an enumeration of all of the named components of the `model` argument that Gurobi will take into account when optimizing the model:

- A:** The linear constraint matrix. This can be dense or sparse. Sparse matrices should be built using either `sparseMatrix` from the `Matrix` package, or `simple_triplet_matrix` from the `slam` package.
- obj:** The linear objective vector (the `c` vector in the problem statement above). You must specify one value for each column of `A`.
- sense:** The senses of the linear constraints. Allowed values are `'='`, `'<='`, or `'>='`. You must specify one value for each row of `A`.
- rhs:** The right-hand side vector for the linear constraints (the `b` vector in the problem statement above). You must specify one value for each row of `A`.
- lb (optional):** The lower bound vector. When present, you must specify one value for each column of `A`. When absent, each variable has a lower bound of 0.

**ub (optional):** The upper bound vector. When present, you must specify one value for each column of **A**. When absent, the variables have infinite upper bounds.

**vtype (optional):** The variable type vector. This vector is used to capture variable integrality constraints. Allowed values are 'C' (continuous), 'B' (binary), 'I' (integer), 'S' (semi-continuous), or 'N' (semi-integer). Binary variables must be either 0 or 1. Integer variables can take any integer value between the specified lower and upper bounds. Semi-continuous variables can take any value between the specified lower and upper bounds, or a value of zero. Semi-integer variables can take any integer value between the specified lower and upper bounds, or a value of zero. When present, you must specify one value for each column of **A**. When absent, each variable is treated as being continuous. Refer to [this section](#) for more information on variable types.

**modelsense (optional):** The optimization sense. Allowed values are 'min' (minimize) or 'max' (maximize). When absent, the default optimization sense is minimization.

**modelname (optional):** The name of the model. The name appears in the Gurobi log, and when writing a model to a file.

**objcon (optional):** The constant offset in the objective function (alpha in the problem statement above).

**vbasis (optional):** The variable basis status vector. Used to provide an advanced starting point for the simplex algorithm. You would generally never concern yourself with the contents of this array, but would instead simply pass it from the result of a previous optimization run to the input of a subsequent run. When present, you must specify one value for each column of **A**.

**cbasis (optional):** The constraint basis status vector. Used to provide an advanced starting point for the simplex algorithm. Consult the **vbasis** description for details. When present, you must specify one value for each row of **A**.

**Q (optional):** The quadratic objective matrix. When present, **Q** must be a square matrix whose row and column counts are equal to the number of columns in **A**. The **Q** matrix can be dense or sparse. Sparse matrices should be built using either `sparseMatrix` from the **Matrix** package, or `simple_triplet_matrix` from the **slam** package.

**cones (optional):** Second-order cone constraints. A list of lists. Each member list defines a single cone constraint:  $\sum x_i^2 \leq y^2$ . The first integer in the list gives the column index for variable  $y$ , and the remainder give the column indices for the  $x$  variables.

**quadcon (optional):** The quadratic constraints. A list of lists. When present, each entry in the list defines a single quadratic constraint:  $x^T Q_c x + q^T x \leq \text{beta}$ . The **Qc** matrix must be a square matrix whose row and column counts are equal to the number of columns of **A**. The matrix associated with quadratic constraint  $i$  should be stored in `model$quadcon[[i]]$Qc`. The optional **q** vector defines the linear terms in the constraint. If present, you must specify one value for **q** for each column of **A**. It is stored in `model$quadcon[[i]]$q`. The scalar **beta** defines the right-hand side of the constraint. It is stored in `model$quadcon[[i]]$rhs`.

**sos** (optional): The Special Ordered Set (SOS) constraints. A list of lists. When present, each entry in the list defines a single SOS constraint. A SOS constraint can be of type 1 or 2. The type of SOS constraint  $i$  is specified via `model$sos[[i]]$type`. A type 1 SOS constraint is a set of variables for which at most one variable in the set may take a value other than zero. A type 2 SOS constraint is an ordered set of variables where at most two variables in the set may take non-zero values. If two take non-zero values, they must be contiguous in the ordered set. The members of an SOS constraint are specified by placing their indices in vector `model$sos[[i]]$index`. Weights associated with SOS members are provided in vector `model$sos[[i]]$weight`. Please refer to [this section](#) for details on SOS constraints.

**pwlobj** (optional): The piecewise-linear objective functions. A list of lists. When present, each entry in the list defines a piecewise-linear objective function of a single variable. The index of the variable whose objective function is being defined is stored in `model$pwlobj[[i]]$var`. The  $x$  values for the points that define the piecewise-linear function are stored in `model$pwlobj[[i]]$x`. The values in the  $x$  vector must be in non-decreasing order. The  $y$  values for the points that define the piecewise-linear function are stored in `model$pwlobj[[i]]$y`.

**start** (optional): The MIP start vector. The MIP solver will attempt to build an initial solution from this vector. When present, you must specify a start value for each variable. Note that you can set the start value for a variable to `NA`, which instructs the MIP solver to try to fill in a value for that variable.

If any of the mandatory components listed above are missing, the `gurobi()` function will return an error.

Below is an example that demonstrates the construction of a simple optimization model:

```
model <- list()

model$A      <- matrix(c(1,1,0,0,1,1), nrow=2, byrow=T)
model$obj    <- c(1,1,2)
model$model sense <- "max"
model$rhs    <- c(1,1)
model$sense  <- c('<=', '<=')
```

You can also build `A` as a sparse matrix, using either `sparseMatrix` or `simple_triplet_matrix`:

```
model$A <- spMatrix(2, 3, c(1, 1, 2, 2), c(1, 2, 2, 3), c(1, 1, 1, 1))
model$A <- simple_triplet_matrix(c(1, 1, 2, 2), c(1, 2, 2, 3), c(1, 1, 1, 1))
```

Note that the Gurobi interface allows you to specify a scalar value for any of the array-valued components. The specified value will be expanded to an array of the appropriate size, with each component of the array equal to the scalar (e.g., `model$rhs <- 1` would be equivalent to `model$rhs <- c(1,1)` in the example).

### The parameter list

The optional `params` argument to the `gurobi()` function is also a list of named components. For each component, the name should be the name of a Gurobi parameter, and the associated value should be the desired value of that parameter. Gurobi parameters allow users to modify the default

behavior of the Gurobi optimization algorithms. You can find a complete list of the available Gurobi parameters [here](#).

To create a list that would set the Gurobi [Method](#) parameter to 2 and the [ResultFile](#) parameter to `model.mps`, you would do the following:

```
params <- list(Method=2, ResultFile='model.mps')
```

We should say a bit more about the `ResultFile` parameter. If this parameter is set, the optimization model that is eventually passed to Gurobi will also be output to the specified file. The filename suffix should be one of `.mps`, `.lp`, `.rew`, or `.rlp`, to indicate the desired file format (see the [file formats](#) section for details on Gurobi file formats).

### The optimization result

The `gurobi()` function returns a list, with the various results of the optimization stored in its named components. The specific results that are available depend on the type of model that was solved, and the status of the optimization. The following is a list of components that might be available in the result list. We'll discuss the circumstances under which each will be available after presenting the list.

**status:** The status of the optimization, returned as a string. The desired result is "OPTIMAL", which indicates that an optimal solution to the model was found. Other status are possible, for example if the model has no feasible solution or if you set a Gurobi parameter that leads to early solver termination. See the [Status Code](#) section for further information on the Gurobi status codes.

**objval:** The objective value of the computed solution.

**runtime:** The elapsed wall-clock time (in seconds) for the optimization.

**x:** The computed solution. This array contains one entry for each column of **A**.

**slack:** Constraint slacks for the computed solution. This array contains one entry for each row of **A**.

**pi:** Dual values for the computed solution (also known as *shadow prices*). This array contains one entry for each row of **A**.

**rc:** Variable reduced costs for the computed solution. This array contains one entry for each column of **A**.

**vbasis:** Variable basis status values for the computed optimal basis. You generally should not concern yourself with the contents of this array. If you wish to use an advanced start later, you would simply copy the `vbasis` and `cbasis` arrays into the corresponding components for the next model. This array contains one entry for each column of **A**.

**cbasis:** Constraint basis status values for the computed optimal basis. This array contains one entry for each row of **A**.

**objbound:** Best available bound on solution (lower bound for minimization, upper bound for maximization).

**itercount**: Number of simplex iterations performed.

**baritercount**: Number of barrier iterations performed.

**nodecount**: Number of branch-and-cut nodes explored.

The **status** component will be present in all cases. It indicates whether Gurobi was able to find a proven optimal solution to the model. In cases where a solution to the model was found, optimal or otherwise, the **objval**, **x**, and **slack** components will be present. For linear and quadratic programs, if a solution is available, then the **pi** and **rc** components will also be present. Finally, if the final solution is a *basic* solution (computed by simplex), then **vbasis** and **cbasis** will be present.

The following is an example of how the results of the **gurobi()** call might be extracted and output:

```
result <- gurobi(model, params)
print(result$objval)
print(result$x)
```

Please consult [this section](#) for a discussion of some of the practical issues associated with solving a precisely defined mathematical model using finite-precision floating-point arithmetic.

## 8.2 Writing models with the Gurobi R interface

The Gurobi R interface also contains a routine that allows you to write an optimization model to a file:

```
gurobi_write ( model, filename )
```

### Arguments:

**model:** The model argument contains a valid Gurobi model. See the [gurobi](#) function for a description of model's required and optional components.

**filename:** Name of the file to write. Note that the type of the file is encoded in the file name suffix. The filename suffix should be one of `.mps`, `.rew`, `.lp`, `.rlp`, or `.ilp`, to indicate the desired file format (see the [file formats](#) section for details on Gurobi file formats). The files can be compressed, so additional suffixes of `.gz`, `.bz2`, `.zip`, or `.7z` are accepted.

Below is an example that demonstrates how a model can be written to a file:

```
model <- list()

model$A      <- matrix(c(1,1,0,0,1,1), nrow=2, byrow=T)
model$obj    <- c(1,1,2)
model$model_sense <- "max"
model$rhs    <- c(1,1)
model$sense  <- c('<=', '<=')

gurobi_write(model, "mymodel.mps");
gurobi_write(model, "mymodel.lp");
gurobi_write(model, "mymodel.mps.bz2");
```

## 8.3 Installing the R package

To use our R interface, you'll need to install the Gurobi package in your local R installation. The R command for doing this is:

```
install.packages('<R-package-file>', repos=NULL)
```

The Gurobi R package file can be found in the `<installdir>/R` directory of your Gurobi installation (the default `<installdir>` for Gurobi 7.0.2 is `/opt/gurobi702/linux64` for Linux, `c:\gurobi702` for Windows, and `/Library/gurobi702` for Mac). You should browse the `<installdir>/R` directory to find the exact name of the file for your platform (the Linux package is in file `gurobi_7.0-2_R_x86_64-pc-li`, the Windows package is in file `gurobi_7.0-2.zip`, and the Mac package is in file `gurobi_7.0-2.tgz`).

You will need to be careful to make sure that the R binary and the Gurobi package you install both use the same instruction set. For example, if you are using the 64-bit version of R, you'll need to install the 64-bit version of Gurobi, and the 64-bit Gurobi R package. This is particularly important on Windows systems, where the error messages that result from instruction set mismatches can be quite cryptic.

To run one of the R examples provided with the Gurobi distribution, you can use the `source` command in R. For example, if you are running R from the Gurobi R examples directory, you can say:

```
> source('mip.R')
```

If the Gurobi package was successfully installed, you should see the following output:

```
[1] "Solution:"  
[1] 3  
[1] 1 0 1
```

The lowest-level building blocks for Gurobi models are variables and constraints. While each has a clean mathematical definition, linear and integer programming aren't performed in exact arithmetic, so computed results can sometimes deviate from these clean definitions. This section discusses the use of and restrictions on these basic building blocks.

## 9.1 Variables

Decision variables capture the results of the optimization. In a feasible solution, the computed values for the decision variables satisfy all of the model constraints. Some of these constraints are associated with individual variables (e.g., variable bounds), while others capture relationships between variables. We'll first consider the different types of decision variables that can be added to a Gurobi model, and the implicit and explicit constraints associated with these variable types.

Before starting, we should point out one important thing about the variables in a mathematical programming model: their computed solution values will only satisfy bounds *to tolerances*, meaning that a variable may violate its stated bounds. Mathematical programming is fundamentally built on top of linear algebra and in particular on the numerical solution of systems of linear equations. These linear systems are solved using finite-precision arithmetic, which means that small errors are unavoidable. For some models, large errors are unavoidable too; we'll return to that topic later in this section.

The available variables types are [continuous](#), [general integer](#), [binary](#), [semi-continuous](#), and [semi-integer](#).

### Continuous Variables

The simplest and least constrained of the available variable types is the continuous variable. This variable can take any value between its lower and upper bound. In mathematical programming, the convention is that variables are non-negative unless stated otherwise, so if you don't explicitly provide bounds for a variable, you should assume that the lower bound is 0 and the upper bound is infinite.

The Gurobi APIs provides a symbolic constant to allow you to indicate that a bound is infinite (`GRB_INFINITY` in C and C++, `GRB.INFINITY` in C#, Java, and Python). A variable can have an infinite upper bound, an infinite lower bound (negative infinity), or both. A variable with infinite upper and lower bounds is referred to as a *free variable*. Any bound larger than  $1e30$  is treated as infinite.

As noted earlier, variables may violate their bounds by tolerances. In the case of variable bounds, the relevant tolerance value is the [FeasibilityTol](#). You can reduce the value of this tolerance parameter, but due to numerical errors it may not be possible to achieve your desired accuracy.

### General Integer Variables

General integer variables are more constrained than continuous variables. In addition to respecting the specified lower and upper bounds, integer variables also take integral values.

Due to the limitations of finite-precision arithmetic, integer variables will often take values that aren't exactly integral. The magnitude of the allowed integrality violation is controlled by the [IntFeasTol](#) parameter. You can tighten this parameter to reduce the magnitude of these integrality violations, but the cost of solving the optimization problem may increase significantly as a result.

The fact that modern computers represent integer values using 32-bit values places some restrictions on the range of an integral variable. Specifically, the largest and smallest bounds that can be placed on an integer variable are +/- 2,000,000,000. Furthermore, integer variables with infinite bounds actually have these values as their implicit bounds. A solution is not considered feasible unless all integer variables take values that satisfy these bounds.

### Binary Variables

Binary variables are the most constrained variable type that can be added to your model. A binary variable takes a value of either 0 or 1.

Again, due to the limitations of finite-precision arithmetic, binary variables will often take values that aren't exactly integral. The magnitude of the allowed integrality violation is controlled by the [IntFeasTol](#) parameter.

### Semi-Continuous and Semi-Integer Variables

You can also add semi-continuous or semi-integer variables to your model. A semi-continuous variable has the property that it takes a value of 0, or a value between the specified lower and upper bounds. A semi-integer variable adds the additional restriction that the variable also take an integral value.

Again, these variables may violate these restrictions up to tolerances. In this case, the relevant tolerance is [IntFeasTol](#) (even for semi-continuous variables).

## 9.2 Constraints

A constraint in Gurobi captures a restriction on the values that a set of variables may take. The simplest example is a linear constraint, which states that a linear expression on a set of variables take a value that is either less-than-or-equal, greater-than-or-equal, or equal another linear expression. Recall that Gurobi works in finite-precision arithmetic, so constraints are only satisfied *to tolerances*. Tolerances can be tightened to reduce such violations, but there are limits to how small the violations can be - errors are inherent in floating-point arithmetic.

The available constraint types are [linear](#), [SOS](#), [quadratic](#), and [general](#).

### Linear Constraints

A linear constraint allows you to restrict the value of a linear expression. For example, you may require that any feasible solution satisfy the constraint  $3x + 4y \leq 5z$ . Note that the matrix-oriented Gurobi API's (C, MATLAB, and R) require the right-hand side of a linear constraint to be a constant, while the object-oriented APIs (C++, Java, .NET, and Python) allow arbitrary linear expressions on both sides of the comparator.

The computed solution should satisfy the stated constraint to within [FeasibilityTol](#) (although it may not in cases of numerical ill-conditioning - we'll discuss this shortly).

Gurobi supports a limited set of comparators. Specifically, you can constrain an expression to be less-than-or-equal, greater-than-or-equal, or equal another. We do not support strict less-than, strict greater-than, or not-equal comparators. While these other comparators may seem appropriate for mathematical programming, we exclude them to avoid potential confusion related to numerical

tolerances. Consider a simple example of a strict inequality constraint on a pair of continuous variables:  $x > y$ . How large would  $x - y$  need to be in order to satisfy the constraint? Rather than trying to embed a subtle and potentially confusing strategy for handling such constraints into the solver, we've chosen not to support them instead.

## SOS Constraints

An Special-Ordered Set, or SOS constraint, is a highly specialized constraint that places restrictions on the values that variables in a given list can take. There are two types of SOS constraints. In an SOS constraint of type 1 (an SOS1 constraint), at most one variable in the specified list is allowed to take a non-zero value. In an SOS constraint of type 2 (an SOS2 constraint), at most two variables in the specified, ordered list are allowed to take a non-zero value, and those non-zero variables must be contiguous in the list. The variables in an SOS constraint can be continuous, integer, or binary.

Again, tolerances play an important role in SOS constraints. Specifically, variables that take values less than `IntFeasTol` (in absolute value) are considered to be zero for the purposes of determining whether an SOS constraint is satisfied.

An SOS constraint is described using a list of variables and a list of corresponding weights. While the weights have historically had intuitive meanings associated with them, we simply use them to order the list of variables. The weights should be unique. This is especially important for an SOS2 constraint, which relies on the notion of *contiguous* variables. Since the variables in the SOS are ordered by weight, contiguity becomes ambiguous when multiple variables have the same weight.

It is often more efficient to capture SOS structure using linear constraints rather than SOS constraints. The optimizer will often perform this conversion automatically. This is controlled with two parameters: `PreSOS1BigM` and `PreSOS2BigM`. The conversion is done by adding constraints of the form  $x \leq Mb$ , where  $x$  is the variable that participates in the SOS constraint,  $b$  is a binary variable, and  $M$  is an upper bound on the value of variable  $x$ . Large values of  $M$  can lead to numerical issues, so these parameters control the maximum value of  $M$  that can be introduced by this conversion. SOS constraints that would require a larger value aren't converted.

## Quadratic Constraints

A quadratic constraint allows you to restrict the value of a quadratic expression. For example, you may require that any feasible solution satisfy the constraint  $3x^2 + 4y^2 + 5z \leq 10$ . Note that the matrix-oriented Gurobi API's (C, MATLAB, and R) require the right-hand side of a quadratic constraint to be a constant, while the object-oriented APIs (C++, Java, .NET, and Python) allow arbitrary quadratic expressions on both sides of the comparator.

The computed solution should satisfy the stated constraint to within `FeasibilityTol`. Quadratic constraints are often much more challenging to satisfy than linear constraints, so tightening the parameter may increase runtimes dramatically.

The algorithms that Gurobi uses to solve quadratically constrained problems can only handle certain types of quadratic constraints. Constraints of the following forms are always accepted:

- $x^T Q x + q^T x \leq b$ , where  $Q$  is Positive Semi-Definite (PSD)
- $x^T x \leq y^2$ , where  $x$  is a vector of variables, and  $y$  is a non-negative variable (a Second-Order Cone)

- $x^T x \leq yz$ , where  $x$  is a vector of variables, and  $y$  and  $z$  are non-negative variables (a rotated Second-Order Cone)

If you add a constraint that isn't in one of these forms (and Gurobi presolve is unable to transform the constraint into one of these forms), you'll get an error when you try to solve the model. Constraints where the quadratic terms only involve binary variables will always be transformed into one of these forms.

## General Constraints

The previously-described constraints are typically handled directly by the underlying optimization algorithms (although not always). Gurobi also includes an additional set of constraints, which we collectively refer to as *general constraints*. General constraints are a convenience feature, designed to allow you to capture certain relationships between variables without having to immerse yourself in the often esoteric details of how to model these relationships in terms of the more fundamental constraints of MIP. Capturing a single one of these general constraints can often require a large set of linear and SOS constraints, plus a number of auxiliary decision variables. By supporting them directly in the Gurobi API, we simplify the modeling process by performing the transformation to a corresponding MIP formulation automatically and transparently during the solution process.

Gurobi supports a number of different types of general constraints, each having its own syntax and semantics:

- **MAX constraint:** The constraint  $r = \max\{x_1, \dots, x_k, c\}$  states that the *resultant variable*  $r$  should be equal to the maximum of the *operand variables*  $x_1, \dots, x_k$  and the *constant*  $c$ . For example, a solution ( $r = 3, x_1 = 2, x_2 = 3, x_3 = 0$ ) would be feasible for the constraint  $r = \max\{x_1, x_2, x_3, 1.7\}$  because 3 is indeed the maximum of 2, 3, 0, and 1.7.
- **MIN constraint:** Similar to a MAX constraint, the constraint  $r = \min\{x_1, \dots, x_k, c\}$  states that the *resultant variable*  $r$  should be equal to the minimum of the *operand variables*  $x_1, \dots, x_k$  and the *constant*  $c$ .
- **ABS constraint:** The constraint  $r = \text{abs}\{x\}$  states that the *resultant variable*  $r$  should be equal to the absolute value of the *operand variable*  $x$ . For example, a solution ( $r = 3, x = -3$ ) would be feasible for the constraint  $r = \text{abs}\{x\}$ .
- **AND constraint:** The constraint  $r = \text{and}\{x_1, \dots, x_k\}$  states that the binary *resultant variable*  $r$  should be equal 1 if and only if all of the binary *operand variables*  $x_1, \dots, x_k$  are equal to 1. For example, a solution ( $r = 1, x_1 = 1, x_2 = 1, x_3 = 1$ ) would be feasible for the constraint  $r = \text{and}\{x_1, x_2, x_3\}$ . Note that declaring an AND constraint implicitly declares all involved variables to be of binary type.
- **OR constraint:** Similar to an AND constraint, the constraint  $r = \text{or}\{x_1, \dots, x_k\}$  states that the binary *resultant variable*  $r$  should be 1 if and only if at least one of the binary *operand variables*  $x_1, \dots, x_k$  is equal to 1. Note that declaring an OR constraint implicitly declares all involved variables to be of binary type.
- **INDICATOR constraints:** An indicator constraint  $y = f \rightarrow a^T x \leq b$  states that if the binary *indicator variable*  $y$  has the value  $f \in \{0, 1\}$  in a given solution, then the linear constraint  $a^T x \leq b$  has to be satisfied. On the other hand, if  $y \neq f$  (i.e.,  $y = 1 - f$ ) then the

linear constraint may be violated. Note that the sense of the linear constraint can also be  $=$  or  $\geq$ ; refer to [this earlier section](#) for a more detailed description of linear constraints. Note also that declaring an INDICATOR constraint implicitly declares the indicator variable to be of binary type.

As stated above, each general constraint has an equivalent MIP formulation that consists of linear and SOS constraints, and possibly auxiliary variables. Thus, you could always model such constraints yourself without using a Gurobi general constraint. For example, the MAX constraint  $r = \max\{x_1, \dots, x_k, c\}$  can be modeled as follows:

$$\begin{aligned}
 r &= x_j + s_j && \text{for all } j = 1, \dots, k \\
 r &= c + s_{k+1} \\
 z_1 + \dots + z_{k+1} &= 1 \\
 \text{SOS1}(s_j, z_j) &&& \text{for all } j = 1, \dots, k + 1 \\
 s_j &\geq 0 && \text{for all } j = 1, \dots, k + 1 \\
 z_j &\in \{0, 1\} && \text{for all } j = 1, \dots, k + 1
 \end{aligned}$$

The first two constraints state that  $r \geq \max\{x_1, \dots, x_k, c\}$ , i.e., that the resultant variable  $r$  has to be at least as large as each of the operand variables  $x_j$  and the constant  $c$ . This can be modeled using inequalities, but we turned them into equations by introducing explicit continuous slack variables  $s_j \geq 0$ , which we will reuse below.

Those slack variables and the remaining constraints model  $r \leq \max\{x_1, \dots, x_k, c\}$ , which is more complicated. In addition to the explicit slacks, this requires the introduction of binary auxiliary variables  $z_j \in \{0, 1\}$ . The SOS1 constraints state that at most one of the two variables  $s_j$  and  $z_j$  can be non-zero, which models the implication  $z_j = 1 \rightarrow s_j = 0$ . Due to the third constraint, one  $z_j$  will be equal to 1 and thus at least one  $s_j$  will be zero. Hence,  $r = x_j$  for at least one  $j$  due to the first constraint, or  $r = c$  due to the second constraint.

Tolerances play a role in general constraints, although as you might expect, the exact role depends on the constraint type. Generally, violations in the resultant will be smaller than the [feasibility tolerance](#), and integrality violations in integer resultants will also satisfy the [integrality tolerance](#).

If a model contains general constraints, then Gurobi adds the respective MIP formulations for those constraints during the solution process. In this respect, general constraints are just a means of concisely capturing these relationships between variables while removing the burden of creating an equivalent MIP formulation. However, general constraints have another potential advantage: Gurobi might be able to simplify parts of the MIP formulation if it can prove during presolve that the simplified version suffices for the correctness of the model. For this reason, Gurobi might be able to produce a smaller or tighter representation of the general constraint than you would get from the most general formulation. For example, it might be the case that  $r \leq \max\{x_1, \dots, x_k, c\}$  is already implied by the other constraints in the model, so that a simple set of inequalities

$$\begin{aligned}
 r &\geq x_j && \text{for all } j = 1, \dots, k \\
 r &\geq c
 \end{aligned}$$

to describe  $r \geq \max\{x_1, \dots, x_k, c\}$  suffices to model the relevant part of the MAX constraint.

### 9.3 Tolerances and Ill Conditioning - A Caveat

As noted at several places in this section, finite-precision arithmetic limits the precision of the solutions Gurobi computes. This limitation is managed through numerical tolerances in most cases; we treat a solution as satisfying a constraint if the violation is smaller than the corresponding tolerance. The default tolerances are chosen to be sufficiently large so that numerical errors aren't an issue for most models.

Unfortunately, some models suffer from severe *ill conditioning*, which can greatly complicate the search for a solution. This can show itself in a few ways. Ill conditioning can severely hurt performance, and it can lead to solutions whose constraint violations are larger than the tolerances.

Ill conditioning is a measure of the amount of error that can result when solving linear systems of equations. As noted earlier, linear and mixed-integer programming are built on top of linear solves, so errors in solving linear systems directly lead to errors in LP and MIP solutions. Serious problems arise when the error in solving a linear system is comparable to the desired tolerance. If you want to solve a linear programming problem to the default feasibility tolerance of  $1e - 6$ , for example, and if your linear system solves produce errors that are also roughly  $1e - 6$ , then you have no way of knowing whether your current solution is truly feasible. This can lead to oscillations, as your solution bounces between feasible and infeasible due to nothing more than numerical error, which can make it extremely difficult to achieve forward progress towards an optimal solution.

When solving linear and quadratic programming problems, we recommend that you check final primal and dual constraint violations. Duality theory states that, if your solution is primal feasible, dual feasible, and complementary, then you have an optimal solution. Complementarity is automatically enforced by the simplex method, so achieving primal and dual feasibility (to tolerances) assures that the solution is optimal (to tolerances).

When solving a MIP model, there is unfortunately no simple method available to check the optimality of the result. While we work hard to identify and manage the negative effects of ill conditioning, we are unable to provide a mathematical proof that the solution returned is truly optimal.

The primary mechanism for querying and modifying properties of a Gurobi model is through the attribute interface. A variety of different attributes are available. Some are only populated at certain times (e.g., those related to the solution of a model), while others are available at all times (e.g., the number of variables in the model). Attributes can be associated with variables (e.g., lower bounds), constraints (e.g., the right-hand side), SOSs (e.g., IIS membership), or with the model as a whole (e.g., the objective value for the current solution).

The following tables list the full set of Gurobi attributes. The attributes have been grouped by type: model attributes take scalar values, while variable, linear constraint, SOS constraint, quadratic constraint, and general constraint attributes contain one entry per variable or constraint in the model. The APIs provide methods to query attribute values for individual constraints or variables, or to query their values for arrays of constraints or variables (refer to our [Attribute Examples](#) section for examples). Array queries are generally more efficient.

Note that the attributes that provide solution quality information have been split off into a separate table at the end of this section. These attributes are also associated with the model as a whole.

Some solution attributes require information that is only computed by certain Gurobi algorithms. Such cases are noted in the detailed attribute descriptions that follow. For example, the `VBasis` and `CBasis` attributes can only be queried when a simplex basis is available (a basis is available when a continuous model has been solved using primal simplex, dual simplex, or barrier with crossover). Sensitivity information (`SAObjLow`, `SAObjUp`, etc.) is also only available for basic solutions.

**Model attributes:**

These attributes provide information about the overall model (as opposed to information about individual variables or constraints in the model).

<b>Attribute name</b>	<b>Description</b>
NumVars	Number of variables
NumConstrs	Number of linear constraints
NumSOS	Number of SOS constraints
NumQConstrs	Number of quadratic constraints
NumGenConstrs	Number of general constraints
NumNZs	Number of non-zero coefficients in the constraint matrix
DNumNZs	Number of non-zero coefficients in the constraint matrix (in double format)
NumQNZs	Number of non-zero quadratic objective terms
NumQCNZs	Number of non-zero terms in quadratic constraints
NumIntVars	Number of integer variables
NumBinVars	Number of binary variables
NumPWLObjVars	Number of variables with piecewise-linear objective functions.
ModelName	Model name
ModelSense	Model sense (minimization or maximization)
ObjCon	Constant offset for objective function
ObjVal	Objective value for current solution
ObjBound	Best available objective bound (lower bound for minimization, upper bound for maximization)
ObjBoundC	Best available objective bound, without rounding (lower bound for minimization, upper bound for maximization)
PoolObjBound	Bound on best objective for solutions not in pool (lower bound for minimization, upper bound for maximization)
PoolObjVal	Objective value of alternatives solutions stored during the optimization process
MIPGap	Current relative MIP optimality gap
Runtime	Runtime for most recent optimization
Status	Current optimization status
SolCount	Number of solutions found
IterCount	Number of simplex iterations performed in most recent optimization
BarIterCount	Number of barrier iterations performed in most recent optimization
NodeCount	Number of branch-and-cut nodes explored in most recent optimization
IsMIP	Indicates whether the model is a MIP
IsQP	Indicates whether the model is a QP/MIQP
IsQCP	Indicates whether the model is a QCP/MIQCP
IISMinimal	Indicates whether the current IIS is minimal
MaxCoeff	Maximum constraint matrix coefficient (in absolute value)
MinCoeff	Minimum (non-zero) constraint matrix coefficient (in absolute value)
MaxBound	Maximum finite variable bound
MinBound	Minimum finite variable bound
MaxObjCoeff	Maximum linear objective coefficient (in absolute value)
MinObjCoeff	Minimum (non-zero) linear objective coefficient (in absolute value)

MaxRHS	Maximum constraint right-hand side (in absolute value)
MinRHS	Minimum (non-zero) constraint right-hand side (in absolute value)
MaxQCCoeff	Maximum quadratic constraint matrix coefficient (in absolute value)
MinQCCoeff	Minimum (non-zero) quadratic constraint matrix coefficient (in absolute value)
MaxQObjCoeff	Maximum quadratic objective coefficient (in absolute value)
MinQObjCoeff	Minimum (non-zero) quadratic objective coefficient (in absolute value)
Kappa	Estimated basis condition number
KappaExact	Exact basis condition number
FarkasProof	Magnitude of infeasibility violation in Farkas infeasibility proof
TuneResultCount	Number of improved parameter sets found by tuning tool

### Variable attributes:

These attributes provide information that is associated with specific variables.

<b>Attribute name</b>	<b>Description</b>
LB	Lower bound
UB	Upper bound
Obj	Linear objective coefficient
VType	Variable type (continuous, binary, integer, etc.)
VarName	Variable name
X	Value in the current solution
Xn	Value in a sub-optimal MIP solution
RC	Reduced cost
BarX	Value in the best barrier iterate (before crossover)
Start	MIP start value (for constructing an initial MIP solution)
VarHintVal	MIP hint value
VarHintPri	MIP hint priority
BranchPriority	Branching priority
VBasis	Basis status
PStart	Simplex start vector
IISLB	Indicates whether the lower bound participate in the IIS
IISUB	Indicates whether the upper bound participate in the IIS
PWLObjCvx	Indicates whether the variable has a convex piecewise-linear objective
SAObjLow	Objective coefficient sensitivity information
SAObjUp	Objective coefficient sensitivity information
SALBLow	Lower bound sensitivity information
SALBUp	Lower bound sensitivity information
SAUBLow	Upper bound sensitivity information
SAUBUp	Upper bound sensitivity information
UnbdRay	Unbounded ray

**Linear constraint attributes:**

These attributes provide information that is associated with specific linear constraints.

<b>Attribute name</b>	<b>Description</b>
Sense	Constraint sense ('<', '>', or '=')
RHS	Right-hand side value
ConstrName	Constraint name
Pi	Dual value (also known as the <i>shadow price</i> )
Slack	Slack in the current solution
CBasis	Basis status
DStart	Simplex start vector
Lazy	Determines whether a constraint is treated as a lazy constraint
IISConstr	Indicates whether the constraint participates in the IIS
SARHSLow	Right-hand-side sensitivity information
SARHSUp	Right-hand-side sensitivity information
FarkasDual	Farkas infeasibility proof

**SOS attributes:**

These attributes provide information that is associated with specific Special-Ordered Set (SOS) constraints.

<b>Attribute name</b>	<b>Description</b>
<a href="#">IISOS</a>	Indicates whether the SOS constraint participates in the IIS

**Quadratic constraint attributes:**

These attributes provide information that is associated with specific quadratic constraints.

<b>Attribute name</b>	<b>Description</b>
QCSense	Constraint sense ('<', '>', or '=')
QCRHS	Right-hand side
QCName	Quadratic constraint name
QCPI	Dual value
QCSlack	Slack in the current solution
IISQConstr	Indicates whether the quadratic constraint participates in the IIS

**General constraint attributes:**

These attributes provide information that is associated with specific general constraints.

<b>Attribute name</b>	<b>Description</b>
<a href="#">GenConstrType</a>	Type of general constraint
<a href="#">GenConstrName</a>	General constraint name
<a href="#">IISGenConstr</a>	Indicates whether the general constraint participates in the IIS

## Solution quality attributes:

<b>Attribute name</b>	<b>Description</b>
<a href="#">BoundVio</a>	Maximum (unscaled) bound violation
<a href="#">BoundSVio</a>	Maximum (scaled) bound violation
<a href="#">BoundVioIndex</a>	Index of variable with the largest (unscaled) bound violation
<a href="#">BoundSVioIndex</a>	Index of variable with the largest (scaled) bound violation
<a href="#">BoundVioSum</a>	Sum of (unscaled) bound violations
<a href="#">BoundSVioSum</a>	Sum of (scaled) bound violations
<a href="#">ConstrVio</a>	Maximum (unscaled) constraint violation
<a href="#">ConstrSVio</a>	Maximum (scaled) constraint violation
<a href="#">ConstrVioIndex</a>	Index of constraint with the largest (unscaled) violation
<a href="#">ConstrSVioIndex</a>	Index of constraint with the largest (scaled) violation
<a href="#">ConstrVioSum</a>	Sum of (unscaled) constraint violations
<a href="#">ConstrSVioSum</a>	Sum of (scaled) constraint violations
<a href="#">ConstrResidual</a>	Maximum (unscaled) primal constraint error
<a href="#">ConstrSResidual</a>	Maximum (scaled) primal constraint error
<a href="#">ConstrResidualIndex</a>	Index of constraint with the largest (unscaled) primal constraint error
<a href="#">ConstrSResidualIndex</a>	Index of constraint with the largest (scaled) primal constraint error
<a href="#">ConstrResidualSum</a>	Sum of (unscaled) primal constraint errors
<a href="#">ConstrSResidualSum</a>	Sum of (scaled) primal constraint errors
<a href="#">DualVio</a>	Maximum (unscaled) reduced cost violation
<a href="#">DualSVio</a>	Maximum (scaled) reduced cost violation
<a href="#">DualVioIndex</a>	Index of variable with the largest (unscaled) reduced cost violation
<a href="#">DualSVioIndex</a>	Index of variable with the largest (scaled) reduced cost violation
<a href="#">DualVioSum</a>	Sum of (unscaled) reduced cost violations
<a href="#">DualSVioSum</a>	Sum of (scaled) reduced cost violations
<a href="#">DualResidual</a>	Maximum (unscaled) dual constraint error
<a href="#">DualSResidual</a>	Maximum (scaled) dual constraint error
<a href="#">DualResidualIndex</a>	Index of variable with the largest (unscaled) dual constraint error
<a href="#">DualSResidualIndex</a>	Index of variable with the largest (scaled) dual constraint error
<a href="#">DualResidualSum</a>	Sum of (unscaled) dual constraint errors
<a href="#">DualSResidualSum</a>	Sum of (scaled) dual constraint errors
<a href="#">ComplVio</a>	Maximum complementarity violation
<a href="#">ComplVioIndex</a>	Index of variable with the largest complementarity violation
<a href="#">ComplVioSum</a>	Sum of complementarity violations
<a href="#">IntVio</a>	Maximum integrality violation
<a href="#">IntVioIndex</a>	Index of variable with the largest integrality violation
<a href="#">IntVioSum</a>	Sum of integrality violations

## Multi-objective attributes:

Attribute name	Description
<a href="#">ObjN</a>	Objectives of multi-objectives
<a href="#">ObjNCon</a>	Constant terms of multi-objectives
<a href="#">ObjNPriority</a>	Priorities of multi-objectives
<a href="#">ObjNWeight</a>	Weights of multi-objectives
<a href="#">ObjNRelTol</a>	Relative tolerances of multi-objectives
<a href="#">ObjNAbsTol</a>	Absolute tolerances of multi-objectives
<a href="#">ObjNVal</a>	Objective value of multi-objectives solutions
<a href="#">ObjNName</a>	Names of multi-objectives
<a href="#">NumObj</a>	Number of multi-objectives

## 10.1 Model Attributes

These are model attributes, meaning that they are associated with the overall model (as opposed to being associated with a particular variable or constraint of the model). You should use one of the various `get` routines to retrieve the value of an attribute. These are described at the beginning of [this section](#)). For the object-oriented interfaces, model attributes are retrieved by invoking the `get` method on the model object itself. For attributes that can be modified directly by the user, you can use one of the various `set` methods.

Attempting to query an attribute that is not available will produce an error. In C, the attribute query routine will return a `GRB_ERROR_DATA_NOT_AVAILABLE` error code. The object-oriented interfaces will throw an exception.

### NumConstrs

**Type:** int

**Modifiable:** No

The number of linear constraints in the model.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

### NumVars

**Type:** int

**Modifiable:** No

The number of decision variables in the model.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

### NumSOS

**Type:** int

**Modifiable:** No

The number of Special-Ordered Set (SOS) constraints in the model.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## NumQConstrs

**Type:** int

**Modifiable:** No

The number of quadratic constraints in the model.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## NumGenConstrs

**Type:** int

**Modifiable:** No

The number of general constraints in the model.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## NumNZs

**Type:** int

**Modifiable:** No

The number of non-zero coefficients in the linear constraints of the model. For models with more than 2 billion non-zero coefficients use [DNumNZs](#).

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DNumNZs

**Type:** double

**Modifiable:** No

The number of non-zero coefficients in the linear constraints of the model. This attribute is provided in double precision format to accurately count the number of non-zeros in models that contain more than 2 billion non-zero coefficients.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## NumQNZs

**Type:** int

**Modifiable:** No

The number of terms in the lower triangle of the Q matrix in the quadratic objective.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## NumQCNZs

**Type:** int

**Modifiable:** No

The number of non-zero coefficients in the quadratic constraints.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## NumIntVars

**Type:** int

**Modifiable:** No

The number of integer variables in the model. This includes both binary variables and general integer variables.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## NumBinVars

**Type:** int

**Modifiable:** No

The number of binary variables in the model.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## NumPWLObjVars

**Type:** int

**Modifiable:** No

The number of variables in the model with piecewise-linear objective functions. You can query the function for a specific variable using the appropriate `getPWLObj` method for your language (in [C](#), [C++](#), [C#](#), [Java](#), and [Python](#)).

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ModelName

**Type:** string

**Modifiable:** Yes

The name of the model. The name has no effect on Gurobi algorithms. It is output in the Gurobi log file when a model is solved, and when a model is written to a file.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ModelSense

**Type:** int

**Modifiable:** Yes

Optimization sense. The default +1.0 value indicates that the objective is to minimize the objective. Setting this attribute to -1 changes the sense to maximization.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ObjCon

**Type:** double

**Modifiable:** Yes

A constant value that is added into the model objective. The default value is 0.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ObjVal

**Type:** double

**Modifiable:** No

The objective value for the current solution. If the model was solved to optimality, then this attribute gives the optimal objective value.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ObjBound

**Type:** double

**Modifiable:** No

The best known bound on the optimal objective. When solving a MIP model, the algorithm maintains both a lower bound and an upper bound on the optimal objective value. For a minimization model, the upper bound is the objective of the best known feasible solution, while the lower bound gives a bound on the best possible objective.

In contrast to [ObjBoundC](#), this attribute takes advantage of objective integrality information to round to a tighter bound. For example, if the objective is known to take an integral value and the current best bound is 1.5, [ObjBound](#) will return 2.0 while [ObjBoundC](#) will return 1.5.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ObjBoundC

**Type:** double

**Modifiable:** No

The best known bound on the optimal objective. When solving a MIP model, the algorithm maintains both a lower bound and an upper bound on the optimal objective value. For a minimization model, the upper bound is the objective of the best known feasible solution, while the lower bound gives a bound on the best possible objective.

In contrast to [ObjBound](#), this attribute does not take advantage of objective integrality information to round to a tighter bound. For example, if the objective is known to take an integral value and the current best bound is 1.5, [ObjBound](#) will return 2.0 while [ObjBoundC](#) will return 1.5.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## PoolObjBound

**Type:** double

**Modifiable:** No

Bound on the objective of undiscovered MIP solutions. The MIP solver stores solutions that it finds during the MIP search, but it only provides quality guarantees for those whose objective is at least as good as [PoolObjBound](#). Specifically, further exploration of the MIP search tree will not find solutions whose objective is better than [PoolObjBound](#).

The difference between [PoolObjBound](#) and [ObjBound](#) is that the former gives an objective bound for undiscovered solutions, while the latter gives a bound for any solution.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## PoolObjVal

**Type:** double

**Modifiable:** No

This attribute is used to query the objective value of the  $k$ -th solution stored in the pool of feasible solutions found so far for the problem. You set  $k$  using the [SolutionNumber](#) parameter.

The number of stored solutions can be queried using the [SolCount](#) attribute.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MIPGap

**Type:** double

**Modifiable:** No

Current relative MIP optimality gap; computed as  $(\text{ObjBound} - \text{ObjVal}) / |\text{ObjVal}|$  (where ObjBound and ObjVal are the MIP objective bound and incumbent solution objective, respectively). Returns GRB\_INFINITY when an incumbent solution has not yet been found, when no objective bound is available, or when the current incumbent objective is 0.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## Runtime

**Type:** double

**Modifiable:** No

Runtime for the most recent optimization (in seconds). Note that all times reported by the Gurobi Optimizer are wall-clock times.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## Status

**Type:** int

**Modifiable:** No

Current optimization status for the model. Status values are described in the [Status Code](#) section.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## SolCount

**Type:** int

**Modifiable:** No

Number of solutions found during the most recent optimization.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IterCount

**Type:** double

**Modifiable:** No

Number of simplex iterations performed during the most recent optimization.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## BarIterCount

**Type:** int

**Modifiable:** No

Number of barrier iterations performed during the most recent optimization.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## NodeCount

**Type:** double

**Modifiable:** No

Number of branch-and-cut nodes explored in the most recent optimization.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IsMIP

**Type:** int

**Modifiable:** No

Indicates whether the model is a MIP. Note that any discrete elements make the model a MIP. Discrete elements include binary, integer, semi-continuous, semi-integer variables, SOS constraints, and general constraints. In addition, models having [multiple objectives](#) are considered as MIP models, even when all variables are continuous and all constraints are linear.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IsQP

**Type:** int

**Modifiable:** No

Indicates whether the model is a quadratic programming problem. Note that a model with both a quadratic objective and quadratic constraints is classified as a QCP, not a QP.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IsQCP

**Type:** int

**Modifiable:** No

Indicates whether the model has quadratic constraints.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IISMinimal

**Type:** int

**Modifiable:** No

Indicates whether the current Irreducible Inconsistent Subsystem (IIS) is minimal. This attribute is only available after you have computed an IIS on an infeasible model. It will normally take value 1, but it may take value 0 if the IIS computation was stopped early (e.g., due to a time limit or user interrupt).

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MaxCoeff

**Type:** double

**Modifiable:** No

Maximum matrix coefficient (in absolute value) in the linear constraint matrix.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MinCoeff

**Type:** double

**Modifiable:** No

Minimum non-zero matrix coefficient (in absolute value) in the linear constraint matrix.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MaxBound

**Type:** double

**Modifiable:** No

Maximum (finite) variable bound.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MinBound

**Type:** double

**Modifiable:** No

Minimum (non-zero) variable bound.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MaxObjCoeff

**Type:** double

**Modifiable:** No

Maximum linear objective coefficient (in absolute value).

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MinObjCoeff

**Type:** double

**Modifiable:** No

Minimum (non-zero) linear objective coefficient (in absolute value).

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MaxRHS

**Type:** double

**Modifiable:** No

Maximum (finite) linear constraint right-hand side value (in absolute value).

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MinRHS

**Type:** double

**Modifiable:** No

Minimum (non-zero) linear constraint right-hand side value (in absolute value).

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MaxQCCoeff

**Type:** double

**Modifiable:** No

Maximum coefficient in all quadratic constraint matrices (in absolute value).

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MinQCCoeff

**Type:** double

**Modifiable:** No

Minimum (non-zero) coefficient in all quadratic constraint matrices (in absolute value).

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MaxQObjCoeff

**Type:** double

**Modifiable:** No

Maximum coefficient of the quadratic terms in the objective (in absolute value).

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## MinQObjCoeff

**Type:** double

**Modifiable:** No

Minimum (non-zero) coefficient of the quadratic terms in the objective (in absolute value).

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## Kappa

**Type:** double

**Modifiable:** No

Estimated condition number for the current LP basis matrix. Only available for basic solutions.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## KappaExact

**Type:** double

**Modifiable:** No

Exact condition number for the current LP basis matrix. Only available for basic solutions. The exact condition number is much more expensive to compute than the estimate that you get from the [Kappa](#) attribute. Only available for basic solutions.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## FarkasProof

**Type:** double

**Modifiable:** No

Magnitude of infeasibility violation in Farkas infeasibility proof (for infeasible linear models only). A Farkas infeasibility proof identifies a new constraint, obtained by taking a linear combination of the constraints in the model, that can never be satisfied (the linear combination is available in the [FarkasDual](#) attribute). This attribute indicates the magnitude of the violation of this aggregated constraint. Only available when parameter [InfUnbdInfo](#) is set to 1.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## TuneResultCount

**Type:** int

**Modifiable:** No

After the tuning tools has been run, this attribute reports the number of parameter sets that were stored. This value will be zero if no improving parameter sets were found, and its upper bound is determined by the [TuneResults](#) parameter.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## 10.2 Variable Attributes

These are variable attributes, meaning that they are associated with specific variables in the model. You should use one of the various `get` routines to retrieve the value of an attribute. These are described at the beginning of [this section](#)). For the object-oriented interfaces, variable attributes are retrieved by invoking the `get` method on a variable object. For attributes that can be modified directly by the user, you can use one of the various `set` methods.

Attempting to query an attribute that is not available will produce an error. In C, the attribute query routine will return a `GRB_ERROR_DATA_NOT_AVAILABLE` error code. The object-oriented interfaces will throw an exception.

### LB

**Type:** double

**Modifiable:** Yes

Variable lower bound. Note that any value less than  $-1e20$  is treated as negative infinity.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

### UB

**Type:** double

**Modifiable:** Yes

Variable upper bound. Note that any value greater than  $1e20$  is treated as infinite.  
For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## Obj

**Type:** double

**Modifiable:** Yes

Linear objective coefficient. In our object-oriented interfaces, you typically use the `setObjective` method to set the objective, but this attribute provides an alternative for setting or modifying linear objective terms.

Note that this attribute interacts with our piecewise-linear objective feature. If you set a piecewise-linear objective function for a variable, that will automatically set the `Obj` attribute to zero. Similarly, if you set the `Obj` attribute for a variable, that will automatically delete any previously specified piecewise-linear objective.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## VType

**Type:** char

**Modifiable:** Yes

Variable type ('C' for continuous, 'B' for binary, 'I' for integer, 'S' for semi-continuous, or 'N' for semi-integer). Binary variables must be either 0 or 1. Integer variables can take any integer value between the specified lower and upper bounds. Semi-continuous variables can take any value between the specified lower and upper bounds, or a value of zero. Semi-integer variables can take any integer value between the specified lower and upper bounds, or a value of zero.

Refer to [this section](#) for more information on variable types.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## VarName

**Type:** string

**Modifiable:** Yes

Variable name.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## X

**Type:** double

**Modifiable:** No

Variable value in the current solution.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## Xn

**Type:** double

**Modifiable:** No

The variable value in a sub-optimal MIP solution. Use parameter [SolutionNumber](#) to indicate which alternate solution to retrieve. Solutions are sorted in order of worsening objective value. Thus, when [SolutionNumber](#) is 1, `Xn` returns the second-best solution found. When [SolutionNumber](#) is equal to its default value of 0, querying attribute `Xn` is equivalent to querying attribute `X`.

The number of sub-optimal solutions found during the MIP search will depend on the values of a few parameters. The most important of these are [PoolSolutions](#), [PoolSearchMode](#), and [PoolGap](#). Please consult the section on [Solution Pools](#) for a more detailed discussion of this topic.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## RC

**Type:** double

**Modifiable:** No

The reduced cost in the current solution. Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## BarX

**Type:** double

**Modifiable:** No

The variable value in the best barrier iterate (before crossover). Only available when the barrier algorithm was selected.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## Start

**Type:** double

**Modifiable:** Yes

The current MIP start vector. The MIP solver will attempt to build an initial solution from this vector when it is available. Note that the start can be partially populated — the MIP solver will attempt to fill in values for missing start values. If you wish to leave the start value for a variable undefined, you can either avoid setting the `Start` attribute for that variable, or you can set it to a special `undefined` value (`GRB_UNDEFINED` in C and C++, or `GRB.UNDEFINED` in Java, .NET, and Python).

If the Gurobi MIP solver log indicates that your MIP start didn't produce a new incumbent solution, note that there can be multiple explanations. One possibility is that your MIP start is infeasible. Another, more common possibility is that one of the Gurobi heuristics found a solution that is as good as the solution produced by the MIP start, so the MIP start solution was cut off. Finally, if you specified a partial MIP start, it is possible that the limited MIP exploration done on this partial start was insufficient to find a new incumbent solution. You can try setting the [SubMIPNodes](#) parameter to a larger value if you want Gurobi to work harder to try to complete the partial start.

If you solve a sequence of models, where one is built by modifying the previous one, and if you don't provide a MIP start, then Gurobi will try to construct one automatically from the solution of the previous model. If you don't want it to try this, you should reset the model before starting

the subsequent solve. If you provided a MIP start but would prefer to use the previous solution as the start instead, you should clear your start (by setting the `Start` attribute to `undefined` for all variables).

If you want to diagnose an infeasible MIP start, you can try fixing the variables in the model to their values in your MIP start (by setting their lower and upper bound attributes). If the resulting MIP model is infeasible, you can then compute an IIS on this model to get additional information that should help to identify the cause of the infeasibility.

Note that deleting variables from your model will cause several attributes to be discarded (MIP starts, variables hints, and branch priorities). If you'd like them to persist, your program will need to repopulate them after deleting the variables and making a subsequent model update call.

Only affects MIP models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## VarHintVal

**Type:** double

**Modifiable:** Yes

A set of user hints. If you know that a variable is likely to take a particular value in high quality solutions of a MIP model, you can provide that value as a hint. You can also (optionally) provide information about your level of confidence in a hint with the [VarHintPri](#) attribute.

The Gurobi MIP solver will use these variable hints in a number of different ways. Hints will affect the heuristics that Gurobi uses to find feasible solutions, and the branching decisions that Gurobi makes to explore the MIP search tree. In general, high quality hints should produce high quality MIP solutions faster. In contrast, low quality hints will lead to some wasted effort, but shouldn't lead to dramatic performance degradations.

Variables hints and [MIP starts](#) are similar in concept, but they behave in very different ways. If you specify a MIP start, the Gurobi MIP solver will try to build a single feasible solution from the provided set of variable values. If you know a solution, you should use a MIP start to provide it to the solver. In contrast, variable hints provide guidance to the MIP solver that affects the entire solution process. If you have a general sense of the likely values for variables, you should provide them through variable hints.

If you wish to leave the hint value for a variable undefined, you can either avoid setting the `VarHintVal` attribute for that variable, or you can set it to a special `undefined` value (`GRB_UNDEFINED` in C and C++, or `GRB.UNDEFINED` in Java, .NET, and Python).

Note that deleting variables from your model will cause several attributes to be discarded (MIP starts, variables hints, and branch priorities). If you'd like them to persist, your program will need to repopulate them after deleting the variables and making a subsequent model update call.

Only affects MIP models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## VarHintPri

**Type:** int

**Modifiable:** Yes

Priorities on user hints. After providing variable hints through the [VarHintVal](#) attribute, you can optionally also provide hint priorities to give an indication of your level of confidence in your

hints.

Hint priorities are relative. If you are more confident in the hint value for one variable than for another, you simply need to set a larger priority value for the more solid hint. The default hint priority for a variable is 0.

Please refer to the [VarHintVal](#) discussion for more details on the role of variable hints.

Only affects MIP models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## BranchPriority

**Type:** int

**Modifiable:** Yes

Variable branching priority. The value of this attribute is used as the primary criteria for selecting a fractional variable for branching during the MIP search. Variables with larger values always take priority over those with smaller values. Ties are broken using the standard branch variable selection criteria. The default variable branch priority value is zero.

Note that deleting variables from your model will cause several attributes to be discarded (MIP starts, variables hints, and branch priorities). If you'd like them to persist, your program will need to repopulate them after deleting the variables and making a subsequent model update call.

Only affects MIP models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## VBasis

**Type:** int

**Modifiable:** Yes

The status of a given variable in the current basis. Possible values are 0 (basic), -1 (non-basic at lower bound), -2 (non-basic at upper bound), and -3 (super-basic). Note that, if you wish to specify an advanced starting basis, you must set basis status information for all constraints and variables in the model. Only available for basic solutions.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## PStart

**Type:** double

**Modifiable:** Yes

The current simplex start vector. If you set **PStart** values for every variable in the model and **DStart** values for every constraint, then simplex will use those values to compute a warm start basis. If you'd like to retract a previously specified start, set any **PStart** value to **GRB\_UNDEFINED**.

Note that any model modifications made after setting **PStart** (adding variables or constraints, changing coefficients, etc.) will discard the start. You should only set this attribute after you are done modifying your model.

Note also that you'll get much better performance if you warm start your linear program using a simplex basis (using [VBasis](#) and [CBasis](#)). The **PStart** attribute should only be used in situations where you don't have a basis.

If you'd like to provide a feasible starting solution for a MIP model, you should input it using the [Start](#) attribute.

Only affects LP models; it will be ignored for QP, QCP, or MIP models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IISLB

**Type:** int

**Modifiable:** No

For an infeasible model, indicates whether the lower bound participates in the computed Irreducible Inconsistent Subsystem (IIS). Only available after you have computed an IIS.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IISUB

**Type:** int

**Modifiable:** No

For an infeasible model, indicates whether the upper bound participates in the computed Irreducible Inconsistent Subsystem (IIS). Only available after you have computed an IIS.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## PWLObjCvx

**Type:** int

**Modifiable:** No

Indicates whether a variable has a convex piecewise-linear objective. Returns 0 if the piecewise-linear objective function on the variable is non-convex. Returns 1 if the function is convex, or if the objective function on the variable is linear.

This attribute is useful for isolating the particular variable that caused a continuous model with a piecewise-linear objective function to become a MIP.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## SAObjLow

**Type:** double

**Modifiable:** No

Objective coefficient sensitivity information: smallest objective value at which the current optimal basis would remain optimal. Only available for basic solutions.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## SAObjUp

**Type:** double

**Modifiable:** No

Objective coefficient sensitivity information: largest objective value at which the current optimal basis would remain optimal. Only available for basic solutions.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## SALBLow

**Type:** double

**Modifiable:** No

Lower bound sensitivity information: smallest lower bound value at which the current optimal basis would remain optimal. Only available for basic solutions.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## SALBUp

**Type:** double

**Modifiable:** No

Lower bound sensitivity information: largest lower bound value at which the current optimal basis would remain optimal. Only available for basic solutions.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## SAUBLow

**Type:** double

**Modifiable:** No

Upper bound sensitivity information: smallest upper bound value at which the current optimal basis would remain optimal. Only available for basic solutions.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## SAUBUp

**Type:** double

**Modifiable:** No

Upper bound sensitivity information: largest upper bound value at which the current optimal basis would remain optimal. Only available for basic solutions.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## UnbdRay

**Type:** double

**Modifiable:** No

Unbounded ray (for unbounded linear models only). Provides a vector that, when added to any feasible solution, yields a new solution that is also feasible but improves the objective. Only available when parameter [InfUnbdInfo](#) is set to 1.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## 10.3 Linear Constraint Attributes

These are linear constraint attributes, meaning that they are associated with specific linear constraints in the model. You should use one of the various `get` routines to retrieve the value of an attribute. These are described at the beginning of [this section](#)). For the object-oriented interfaces,

linear constraint attributes are retrieved by invoking the `get` method on a constraint object. For attributes that can be modified directly by the user, you can use one of the various `set` methods.

Attempting to query an attribute that is not available will produce an error. In C, the attribute query routine will return a `GRB_ERROR_DATA_NOT_AVAILABLE` error code. The object-oriented interfaces will throw an exception.

## Sense

**Type:** char

**Modifiable:** Yes

Constraint sense ('<', '>', or '=').

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## RHS

**Type:** double

**Modifiable:** Yes

Constraint right-hand side.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ConstrName

**Type:** string

**Modifiable:** Yes

Constraint name.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## Pi

**Type:** double

**Modifiable:** No

The constraint dual value in the current solution (also known as the *shadow price*).

Given a linear programming problem

$$\begin{array}{ll} \text{minimize} & c'x \\ \text{subject to} & Ax \geq b \\ & x \geq 0 \end{array}$$

and a corresponding dual problem

$$\begin{array}{ll} \text{maximize} & b'y \\ \text{subject to} & A'y \leq c \\ & y \geq 0 \end{array}$$

the `Pi` attribute returns  $y$ .

Of course, not all models fit this canonical form. In general, dual values have the following properties:

- Dual values for  $\geq$  constraints are  $\geq 0$ .
- Dual values for  $\leq$  constraints are  $\leq 0$ .
- Dual values for  $=$  constraints are unconstrained.

For models with a maximization sense, the senses of the dual values are reversed: the dual is  $\geq 0$  for a  $\leq$  constraint and  $\leq 0$  for a  $\geq$  constraint.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## Slack

**Type:** double

**Modifiable:** No

The constraint slack in the current solution.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## CBasis

**Type:** int

**Modifiable:** Yes

The status of a given linear constraint in the current basis. Possible values are 0 (basic) or -1 (non-basic). A constraint is basic when its slack variable is in the simplex basis. Note that, if you wish to specify an advanced starting basis, you must set basis status information for all constraints and variables in the model. Only available for basic solutions.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DStart

**Type:** double

**Modifiable:** Yes

The current simplex start vector. If you set **DStart** values for every linear constraint in the model and **PStart** values for every variable, then simplex will use those values to compute a warm start basis. If you'd like to retract a previously specified start, set any **DStart** value to `GRB_UNDEFINED`.

Note that any model modifications made after setting **DStart** (adding variables or constraints, changing coefficients, etc.) will discard the start. You should only set this attribute after you are done modifying your model.

Note also that you'll get much better performance if you warm start your linear program from a simplex basis (using **VBasis** and **CBasis**). The **DStart** attribute should only be used in situations where you don't have a basis.

If you'd like to provide a feasible starting solution for a MIP model, you should input it using the **Start** attribute.

Only affects LP models; it will be ignored for QP, QCP, or MIP models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## Lazy

**Type:** int

**Modifiable:** Yes

Determines whether a linear constraint is treated as a *lazy constraint*. At the beginning of the MIP solution process, any constraint whose **Lazy** attribute is set to 1, 2, or 3 (the default value is 0) is removed from the model and placed in the lazy constraint pool. Lazy constraints remain inactive until a feasible solution is found, at which point the solution is checked against the lazy constraint pool. If the solution violates any lazy constraints, the solution is discarded and one or more of the violated lazy constraints are pulled into the active model.

Larger values for this attribute cause the constraint to be pulled into the model more aggressively. With a value of 1, the constraint can be used to cut off a feasible solution, but it won't necessarily be pulled in if another lazy constraint also cuts off the solution. With a value of 2, all lazy constraints that are violated by a feasible solution will be pulled into the model. With a value of 3, lazy constraints that cut off the relaxation solution at the root node are also pulled in.

Note that deleting constraints from your model will cause this attribute to be discarded. If you'd like it to persist, your program will need to repopulate it after deleting the constraints and making a subsequent model update call.

Only affects MIP models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IISConstr

**Type:** int

**Modifiable:** No

For an infeasible model, indicates whether the linear constraint participates in the computed Irreducible Inconsistent Subsystem (IIS). Only available after you have computed an IIS.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## SARHSLow

**Type:** double

**Modifiable:** No

Right-hand-side sensitivity information: smallest right-hand-side value at which the current optimal basis would remain optimal. Only available for basic solutions.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## SARHSUp

**Type:** double

**Modifiable:** No

Right-hand-side sensitivity information: largest right-hand-side value at which the current optimal basis would remain optimal. Only available for basic solutions.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## FarkasDual

**Type:** double

**Modifiable:** No

Farkas infeasibility proof (for infeasible linear models only). Provides a dual unbounded vector. Adding this vector into any feasible solution to the dual model yields a new solution that is also feasible but improves the dual objective. Only available when parameter [InfUnbdInfo](#) is set to 1.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## 10.4 SOS Attributes

These are SOS attributes, meaning that they are associated with specific special-ordered set constraints in the model. You should use one of the various `get` routines to retrieve the value of an attribute. These are described at the beginning of [this section](#)). For the object-oriented interfaces, SOS attributes are retrieved by invoking the `get` method on an SOS object. For attributes that can be modified directly by the user, you can use one of the various `set` methods.

Attempting to query an attribute that is not available will produce an error. In C, the attribute query routine will return a `GRB_ERROR_DATA_NOT_AVAILABLE` error code. The object-oriented interfaces will throw an exception.

## IISOS

**Type:** int

**Modifiable:** No

For an infeasible model, indicates whether the SOS constraint participates in the computed Irreducible Inconsistent Subsystem (IIS). Only available after you have computed an IIS.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## 10.5 Quadratic Constraint Attributes

These are quadratic constraint attributes, meaning that they are associated with specific quadratic constraints in the model. You should use one of the various `get` routines to retrieve the value of an attribute. These are described at the beginning of [this section](#)). For the object-oriented interfaces, quadratic constraint attributes are retrieved by invoking the `get` method on a constraint object. For attributes that can be modified directly by the user, you can use one of the various `set` methods.

Attempting to query an attribute that is not available will produce an error. In C, the attribute query routine will return a `GRB_ERROR_DATA_NOT_AVAILABLE` error code. The object-oriented interfaces will throw an exception.

## QCSense

**Type:** char

**Modifiable:** Yes

Quadratic constraint sense ('<', '>', or '=').

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## QCRHS

**Type:** double

**Modifiable:** Yes

Quadratic constraint right-hand side.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## QCName

**Type:** string

**Modifiable:** Yes

Quadratic constraint name.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## QCPi

**Type:** double

**Modifiable:** No

The constraint dual value in the current solution. Note that quadratic constraint dual values are only available when the [QCPDual](#) parameter is set to 1.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## QCSlack

**Type:** double

**Modifiable:** No

The constraint slack in the current solution.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IISQConstr

**Type:** int

**Modifiable:** No

For an infeasible model, indicates whether the quadratic constraint participates in the computed Irreducible Inconsistent Subsystem (IIS). Only available after you have computed an IIS.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## 10.6 General Constraint Attributes

These are general constraint attributes, meaning that they are associated with specific general constraints in the model. You should use one of the various `get` routines to retrieve the value of an attribute. These are described at the beginning of [this section](#)). For the object-oriented interfaces, general constraint attributes are retrieved by invoking the `get` method on a constraint object. For attributes that can be modified directly by the user, you can use one of the various `set` methods.

Attempting to query an attribute that is not available will produce an error. In C, the attribute query routine will return a `GRB_ERROR_DATA_NOT_AVAILABLE` error code. The object-oriented interfaces will throw an exception.

## GenConstrType

**Type:** int

**Modifiable:** No

General constraint type.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## GenConstrName

**Type:** string

**Modifiable:** Yes

General constraint name.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IISGenConstr

**Type:** int

**Modifiable:** No

For an infeasible model, indicates whether the general constraint participates in the computed Irreducible Inconsistent Subsystem (IIS). Only available after you have computed an IIS.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## 10.7 Quality Attributes

These are solution quality attributes. They are associated with the overall model. You should use one of the various `get` routines to retrieve the value of an attribute. These are described at the beginning of [this section](#)). For the object-oriented interfaces, quality attributes are retrieved by invoking the `get` method on a constraint object. For attributes that can be modified directly by the user, you can use one of the various `set` methods.

Attempting to query an attribute that is not available will produce an error. In C, the attribute query routine will return a `GRB_ERROR_DATA_NOT_AVAILABLE` error code. The object-oriented interfaces will throw an exception.

## BoundVio

**Type:** double

**Modifiable:** No

Maximum (unscaled) bound violation.

Available for all model types.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## BoundSVio

**Type:** double

**Modifiable:** No

Maximum (scaled) bound violation.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

### BoundViolIndex

**Type:** int

**Modifiable:** No

Index of variable with the largest (unscaled) bound violation.

Available for all model types.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

### BoundSViolIndex

**Type:** int

**Modifiable:** No

Index of variable with the largest (scaled) bound violation.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

### BoundVioSum

**Type:** double

**Modifiable:** No

Sum of (unscaled) bound violations.

Available for all model types.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

### BoundSVioSum

**Type:** double

**Modifiable:** No

Sum of (scaled) bound violations.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

### ConstrVio

**Type:** double

**Modifiable:** No

Reporting constraint violations for the simplex solver is actually more complex than it may appear, due to the treatment of slacks on linear inequality constraints. The simplex solver introduces explicit non-negative slack variables inside the algorithm. Thus, for example,  $a^T x \leq b$  becomes  $a^T x + s = b$ . In this formulation, constraint errors can show up in two places: (i) as bound violations on the computed slack variable values, and (ii) as differences between  $a^T x + s$  and  $b$ . We report the former as `ConstrVio` and the latter as `ConstrResidual`.

For MIP models, constraint violations are reported in `ConstrVio`.

Available for all model types.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ConstrSVio

**Type:** double

**Modifiable:** No

Maximum (scaled) slack bound violation.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ConstrViolIndex

**Type:** int

**Modifiable:** No

Index of linear constraint with the largest (unscaled) slack bound violation.

Available for all model types.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ConstrSViolIndex

**Type:** int

**Modifiable:** No

Index of linear constraint with the largest (scaled) slack bound violation.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ConstrVioSum

**Type:** double

**Modifiable:** No

Sum of (unscaled) slack bound violations.

Available for all model types.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ConstrSVioSum

**Type:** double

**Modifiable:** No

Sum of (scaled) slack bound violations.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ConstrResidual

**Type:** double

**Modifiable:** No

Reporting constraint violations for the simplex solver is actually more complex than it may appear, due to the treatment of slacks on linear inequality constraints. The simplex solver introduces explicit non-negative slack variables inside the algorithm. Thus, for example,  $a^T x \leq b$  becomes

$a^T x + s = b$ . In this formulation, constraint errors can show up in two places: (i) as bound violations on the computed slack variable values, and (ii) as differences between  $a^T x + s$  and  $b$ . We report the former as **ConstrVio** and the latter as **ConstrResidual**.

Only available for continuous models. For MIP models, constraint violations are reported in **ConstrVio**.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ConstrSResidual

**Type:** double

**Modifiable:** No

Maximum (scaled) primal constraint error.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ConstrResidualIndex

**Type:** int

**Modifiable:** No

Index of linear constraint with the largest (unscaled) constraint error.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ConstrSResidualIndex

**Type:** int

**Modifiable:** No

Index of linear constraint with the largest (scaled) constraint error.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ConstrResidualSum

**Type:** double

**Modifiable:** No

Sum of (unscaled) linear constraint violations.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ConstrSResidualSum

**Type:** double

**Modifiable:** No

Sum of (scaled) linear constraint violations.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DualVio

**Type:** double

**Modifiable:** No

Reporting dual constraint violations for the simplex solver is actually more complex than it may appear, due to the treatment of reduced costs for bounded variables. The simplex solver introduces explicit non-negative reduced-cost variables inside the algorithm. Thus,  $a^T y \geq c$  becomes  $a^T y - z = c$  (where  $y$  is the dual vector and  $z$  is the reduced cost). In this formulation, errors can show up in two places: (i) as bound violations on the computed reduced-cost variable values, and (ii) as differences between  $a^T y - z$  and  $c$ . We report the former as `DualVio` and the latter as `DualResidual`.

`DualVio` reports the maximum (unscaled) reduced-cost bound violation.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DualSVio

**Type:** double

**Modifiable:** No

Maximum (scaled) reduced cost violation.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DualVioIndex

**Type:** int

**Modifiable:** No

Index of variable with the largest (unscaled) reduced cost violation. Note that the result may be larger than the number of variables in the model, which indicates that a constraint slack is the variable with the largest violation. Subtract the variable count from the result to get the index of the corresponding constraint.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DualSVioIndex

**Type:** int

**Modifiable:** No

Index of variable with the largest (scaled) reduced cost violation. Note that the result may be larger than the number of variables in the model, which indicates that a constraint slack is the variable with the largest violation. Subtract the variable count from the result to get the index of the corresponding constraint.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DualVioSum

**Type:** double

**Modifiable:** No

Sum of (unscaled) reduced cost violations.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DualSVioSum

**Type:** double

**Modifiable:** No

Sum of (scaled) reduced cost violations.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DualResidual

**Type:** double

**Modifiable:** No

Reporting dual constraint violations for the simplex solver is actually more complex than it may appear, due to the treatment of reduced costs for bounded variables. The simplex solver introduces explicit non-negative reduced-cost variables inside the algorithm. Thus,  $a^T y \geq c$  becomes  $a^T y - z = c$  (where  $y$  is the dual vector and  $z$  is the reduced cost). In this formulation, errors can show up in two places: (i) as bound violations on the computed reduced-cost variable values, and (ii) as differences between  $a^T y - z$  and  $c$ . We report the former as `DualVio` and the latter as `DualResidual`.

`DualResidual` reports the maximum (unscaled) dual constraint error.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DualSResidual

**Type:** double

**Modifiable:** No

Maximum (scaled) dual constraint error.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DualResidualIndex

**Type:** int

**Modifiable:** No

Index of variable with the largest (unscaled) dual constraint error.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DualSResidualIndex

**Type:** int

**Modifiable:** No

Index of variable with the largest (scaled) dual constraint error.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DualResidualSum

**Type:** double

**Modifiable:** No

Sum of (unscaled) dual constraint errors.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## DualSResidualSum

**Type:** double

**Modifiable:** No

Sum of (scaled) dual constraint errors.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ComplVio

**Type:** double

**Modifiable:** No

Maximum complementarity violation. In an optimal solution, the product of the value of a variable and its reduced cost must be zero. This isn't always strictly true for interior point solutions. This attribute returns the maximum complementarity violation for any variable.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ComplVioIndex

**Type:** int

**Modifiable:** No

Index of variable with the largest complementarity violation.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ComplVioSum

**Type:** double

**Modifiable:** No

Sum of complementarity violation.

Only available for continuous models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IntVio

**Type:** double

**Modifiable:** No

A MIP solver won't always assign strictly integral values to integer variables. This attribute returns the largest distance between the computed value of any integer variable and the nearest integer.

Only available for MIP models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IntViolIndex

**Type:** int

**Modifiable:** No

Index of variable with the largest integrality violation.

Only available for MIP models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## IntVioSum

**Type:** double

**Modifiable:** No

Sum of integrality violations.

Only available for MIP models.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## 10.8 Multi-objective Attributes

These are the attributes for setting and querying multiple objectives (refer to [this section](#) for additional information on multi-objective optimization).

### ObjN

**Type:** double

**Modifiable:** Yes

When the model has multiple objectives, this attribute is used to query or modify objective coefficients for objective  $n$ . You set  $n$  using the [ObjNumber](#) parameter. Note that when [ObjNumber](#) is equal to 0, [ObjN](#) is equivalent to [Obj](#).

The number of objectives in the model can be queried (or modified) using the [NumObj](#) attribute.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ObjNCon

**Type:** double

**Modifiable:** Yes

When the model has multiple objectives, this attribute is used to query or modify the constant term for objective  $n$ . You set  $n$  using the [ObjNumber](#) parameter. Note that when `ObjNumber` is equal to 0, `ObjNCon` is equivalent to `ObjCon`.

The number of objectives in the model can be queried (or modified) using the `NumObj` attribute.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ObjNPriority

**Type:** int

**Modifiable:** Yes

This attribute is used to query or modify the priority of objective  $n$  when doing hierarchical multi-objective optimization. You set  $n$  using the [ObjNumber](#) parameter.

The default priority for an objective is 0.

The number of objectives in the model can be queried (or modified) using the `NumObj` attribute.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ObjNWeight

**Type:** double

**Modifiable:** Yes

This attribute is used to query or modify the weight of objective  $n$  when doing blended multi-objective optimization. You set  $n$  using the [ObjNumber](#) parameter.

The default weight for an objective is 1.0.

The number of objectives in the model can be queried (or modified) using the `NumObj` attribute.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ObjNRelTol

**Type:** double

**Modifiable:** Yes

This attribute is used to set the allowable degradation for objective  $n$  when doing hierarchical multi-objective optimization. You set  $n$  using the [ObjNumber](#) parameter.

Hierarchical multi-objective optimization will optimize for the different objectives in the model one at a time, in priority order. If it achieves objective value  $z$  when it optimizes for this objective, then subsequent steps are allowed to degrade this value by at most  $\text{ObjNRelTol}^{|z|}$ .

The number of objectives in the model can be queried (or modified) using the `NumObj` attribute.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ObjNAbsTol

**Type:** double

**Modifiable:** Yes

This attribute is used to set the allowable degradation for objective  $n$  when doing hierarchical multi-objective optimization. You set  $n$  using the [ObjNumber](#) parameter.

Hierarchical multi-objective optimization will optimize for the different objectives in the model one at a time, in priority order. If it achieves objective value  $z$  when it optimizes for this objective, then subsequent steps are allowed to degrade this value by at most `ObjNAbsTol`.

The number of objectives in the model can be queried (or modified) using the [NumObj](#) attribute.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ObjNVal

**Type:** double

**Modifiable:** No

This attribute is used to query the objective value obtained for objective  $n$  by the  $k$ -th solution stored in the pool of feasible solutions found so far for the problem. You set  $n$  using the [ObjNumber](#) parameter, while you set  $k$  using the [SolutionNumber](#) parameter.

The number of objectives in the model can be queried (or modified) using the [NumObj](#) attribute; while the number of stored solutions can be queried using the [SolCount](#) attribute.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## ObjNName

**Type:** string

**Modifiable:** No

When the model has multiple objectives, this attribute is used to query or modify the name for objective  $n$ . You set  $n$  using the [ObjNumber](#) parameter.

The number of objectives in the model can be queried (or modified) using the [NumObj](#) attribute.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## NumObj

**Type:** int

**Modifiable:** Yes

Number of objectives in the model. If you modify this attribute, it will change the number of objectives in the model. Decreasing it will discard existing objectives. Increasing it will create new objectives (initialized to 0). Setting it to 0 will create a model with no objective (i.e., a feasibility model).

You can use the [ObjNumber](#) parameter, in conjunction with multi-objective attributes ([ObjN](#), [ObjNName](#), etc.), to query or modify attributes for different objectives. The value of `ObjNumber` should always be less than `NumObj`.

For examples of how to query or modify attributes, refer to our [Attribute Examples](#).

## 10.9 Attribute Examples

The same attributes exist in all of the Gurobi APIs, but the approaches used to query and modify them, and the means by which you refer to them vary. Consider the `LB` attribute, which captures the lower bound on a variable. You would refer to this attribute as follows in the different Gurobi

APIs:

Language	Attribute
C	GRB_DBL_ATTR_LB
C++	GRB_DoubleAttr_LB
Java	GRB.DoubleAttr.LB
.NET	GRB.DoubleAttr.LB, or just <code>var.LB</code>
Python	GRB.Attr.lb, or just <code>var.lb</code>

To query the value of this attribute for an individual variable in the different API's, you would do the following:

Language	Attribute Query Example
C	<code>GRBgetdblattrlement(model, GRB_DBL_ATTR_LB, var_index, &amp;value);</code>
C++	<code>var.get(GRB_DoubleAttr_LB)</code>
Java	<code>var.get(GRB.DoubleAttr.LB)</code>
.NET	<code>var.Get(GRB.DoubleAttr.LB)</code> , or just <code>var.LB</code>
Python	<code>var.getAttr(GRB.Attr.lb)</code> , or just <code>var.lb</code>

Our APIs also include routines for querying attribute values for multiple variables or constraints at once, which is more efficient.

Attributes are referred to using a set of `enum` types in C++, Java, and .NET (one `enum` for double-valued attributes, one for int-valued attributes, etc.). In C and Python, the names listed above are simply constants that take string values. For example, `GRB_DBL_ATTR_LB` is defined in the C layer as:

```
#define GRB_DBL_ATTR_LB "LB"
```

In C and Python, you have the option of using the strings directly when calling attribute methods. If you wish to do so, note that character case and underscores are ignored. Thus, `MIN_COEFF` and `MinCoeff` are equivalent.

One important point to note about attributes modification is that it is done in a *lazy* fashion. Modifications don't actually affect the model until the next request to either update or optimize the model (`GRBupdatemodel` or `GRBoptimize` in C).

Refer to the following sections for more detailed examples of how to query or modify attributes from our various API's:

- [C](#)
- [C++](#)
- [C#](#)
- [Java](#)
- [Python](#)
- [Visual Basic](#)

You can also also browse our [Examples](#) to get a better sense of how to use our attribute interface.

## C Attribute Examples

Consider the case where you have a Gurobi model  $m$ . You can retrieve the number of variables in the model by querying the `NumVars` model attribute. This is an integer-valued, scalar attribute, so you use `GRBgetintattr`:

```
int cols;
error = GRBgetintattr(m, GRB_INT_ATTR_NUMVARS, &cols);
```

You can also use the name of the attribute directly:

```
int cols;
error = GRBgetintattr(m, "NumVars", &cols);
```

(Note that attribute capitalization doesn't matter in the C interface, so you could also use `"numVars"` or `"numvars"`).

If you've performed optimization on the model, the optimal objective value can be obtained by querying the `ObjVal` model attribute. This is a double-valued, scalar attribute, so you use `GRBgetdblattr`:

```
double objval;
error = GRBgetdblattr(m, GRB_DBL_ATTR_OBJVAL, &objval);
```

If you'd like to query the value that a variable takes in the computed solution, you can query the `X` variable attribute. This is a double-valued, vector attribute, so you have a few options for querying the associated values. You can retrieve the value for a single variable using `GRBgetdblattrelement`:

```
double x0;
error = GRBgetdblattrelement(m, GRB_DBL_ATTR_X, 0, &x0);
```

(we query the solution value for variable 0 in this example). You can also query attribute values for multiple variables using `GRBgetdblattrarray` or `GRBgetdblattrlist`:

```
double x[];
error = GRBgetdblattrarray(m, GRB_DBL_ATTR_X, 0, cols, x);
```

The former routine retrieves a contiguous set of values ( $cols$  values, starting from index 0 in our example). The latter allows you to provide a list of indices, and it returns the values for the corresponding entries.

For each attribute query routine, there's an analogous *set* routine. To set the upper bound of a variable, for example, you would use `GRBsetdblattrelement`:

```
error = GRBsetdblattrelement(m, GRB_DBL_ATTR_UB, 0, 0.0);
```

(In this example, we've set the upper bound for variable 0 to 0). You can set attribute values for multiple variables in a single call using `GRBsetdblattrarray` or `GRBsetdblattrlist`.

## C++ Attribute Examples

Consider the case where you have a Gurobi model  $m$ . You can retrieve the number of variables in the model by querying the `NumVars` model attribute using the `get` method:

```
cols = m.get(GRB_IntAttr_NumVars);
```

If you've performed optimization on the model, the optimal objective value can be obtained by querying the `ObjVal` model attribute:

```
obj = m.get(GRB_DoubleAttr_ObjVal);
```

If you'd like to query the value that a variable takes in the computed solution, you can query the `X` attribute for the corresponding variable object:

```
vars = m.getVars()
for (int j = 0; j < cols; j++)
    xj = vars[j].get(GRB_DoubleAttr_X)
```

You can also query the value of  $X$  for multiple variables in a single `get` call on the model  $m$ :

```
double xvals[] = m.get(GRB_DoubleAttr_X, m.GetVars())
```

For each attribute query method, there's an analogous `set` routine. To set the upper bound of a variable, for example:

```
v = m.getVars()[0]
v.set(GRB_DoubleAttr_UB, 0)
```

(In this example, we've set the upper bound for the first variable in the model to 0).

## C# Attribute Examples

Consider the case where you have a Gurobi model  $m$ . You can retrieve the number of variables in the model by querying the `NumVars` model attribute (which is implemented as a .NET *property*):

```
cols = m.NumVars;
```

If you've performed optimization on the model, the optimal objective value can be obtained by querying the `ObjVal` model attribute:

```
obj = m.ObjVal;
```

If you'd like to query the value that a variable takes in the computed solution, you can query the `X` attribute for the corresponding variable object:

```
vars = m.GetVars()
for (int j = 0; j < cols; j++)
    xj = vars[j].X
```

You can also query the value of  $X$  for multiple variables in a single call using the `Get` method on the model  $m$ :

```
double[] xvals = m.Get(GRB.DoubleAttr.X, m.GetVars()))
```

For each attribute query method, there's an analogous *Set* routine. To set the upper bound of a variable, for example:

```
v = m.GetVars()[0]
v.UB = 0
```

(In this example, we've set the upper bound for the first variable in the model to 0).

## Java Attribute Examples

Consider the case where you have a Gurobi model *m*. You can retrieve the number of variables in the model by querying the `NumVars` model attribute using the `get` method:

```
cols = m.get(GRB.IntAttr.NumVars);
```

If you've performed optimization on the model, the optimal objective value can be obtained by querying the `ObjVal` model attribute:

```
obj = m.get(GRB.DoubleAttr.ObjVal);
```

If you'd like to query the value that a variable takes in the computed solution, you can query the `X` attribute for the corresponding variable object:

```
vars = m.getVars()
for (int j = 0; j < cols; j++)
    xj = vars[j].get(GRB.DoubleAttr.X)
```

You can also query the value of *X* for multiple variables in a single `get` call on the model *m*:

```
double[] xvals = m.get(GRB.DoubleAttr.X, m.getVars()))
```

For each attribute query method, there's an analogous *set* routine. To set the upper bound of a variable, for example:

```
v = m.getVars()[0]
v.set(GRB.DoubleAttr.UB, 0)
```

(In this example, we've set the upper bound for the first variable in the model to 0).

## Python Attribute Examples

Consider the case where you have a Gurobi model *m*. You can retrieve the number of variables in the model by querying the `NumVars` model attribute:

```
print(m.numVars)
```

(Note that attribute capitalization doesn't matter in the Python interface, so you could also query `m.NumVars` or `m.numvars`).

If you've performed optimization on the model, the optimal objective value can be obtained by querying the `ObjVal` model attribute:

```
print(m.ObjVal)
```

If you'd like to query the value that a variable takes in the computed solution, you can query the [X](#) attribute for the corresponding variable object:

```
for v in m.getVars():  
    print(v.x)
```

You can also query the value of  $X$  for multiple variables in a single [getAttr](#) call on the model  $m$ :

```
print(m.getAttr(GRB.Attr.x, m.getVars()))
```

For each attribute query method, there's an analogous *set* routine. To set the upper bound of a variable, for example:

```
v = m.getVars()[0]  
v.ub = 0
```

(In this example, we've set the upper bound for the first variable in the model to 0).

## Visual Basic Attribute Examples

Consider the case where you have a Gurobi model  $m$ . You can retrieve the number of variables in the model by querying the [NumVars](#) model attribute (which is implemented as a .NET *property*):

```
cols = m.NumVars;
```

If you've performed optimization on the model, the optimal objective value can be obtained by querying the [ObjVal](#) model attribute:

```
obj = m.ObjVal;
```

If you'd like to query the value that a variable takes in the computed solution, you can query the [X](#) attribute for the corresponding variable object:

```
vars = m.GetVars()  
For j As Integer = 0 To cols - 1  
    xj = vars[j].X
```

You can also query the value of  $X$  for multiple variables in a single call using the [Get](#) method on the model  $m$ :

```
xvals = m.Get(GRB.DoubleAttr.X, m.GetVars()))
```

For each attribute query method, there's an analogous *Set* routine. To set the upper bound of a variable, for example:

```
v = m.GetVars()[0]  
v.UB = 0
```

(In this example, we've set the upper bound for the first variable in the model to 0).

Parameters control the operation of the Gurobi solvers. They must be modified before the optimization begins. While you should feel free to experiment with different parameter settings, we recommend that you leave parameters at their default settings unless you find a compelling reason not to. For a discussion of when you might want to change parameter values, refer to our [Parameter Guidelines](#).

The various Gurobi APIs all provide routines for querying and modifying parameter values. Refer to our [Parameter Examples](#) for additional information.

### Available Gurobi Parameters

**Termination:** These parameters affect the termination of the algorithms. If the algorithm exceeds any of these limits, it will terminate and report a non-optimal termination status (see the [Status Code](#) section for further details). Note that the algorithm won't necessarily stop the moment it hits the specified limit. The termination check may occur well after the limit has been exceeded.

Parameter name	Purpose
<a href="#">BarIterLimit</a>	Barrier iteration limit
<a href="#">Cutoff</a>	Objective cutoff
<a href="#">IterationLimit</a>	Simplex iteration limit
<a href="#">NodeLimit</a>	MIP node limit
<a href="#">SolutionLimit</a>	MIP feasible solution limit
<a href="#">TimeLimit</a>	Time limit
<a href="#">BestObjStop</a>	Best objective value to stop
<a href="#">BestBdStop</a>	Best objective bound to stop

**Tolerances:** These parameters control the allowable feasibility or optimality violations.

Parameter name	Purpose
<a href="#">BarConvTol</a>	Barrier convergence tolerance
<a href="#">BarQCPCConvTol</a>	Barrier QCP convergence tolerance
<a href="#">FeasibilityTol</a>	Primal feasibility tolerance
<a href="#">IntFeasTol</a>	Integer feasibility tolerance
<a href="#">MarkowitzTol</a>	Threshold pivoting tolerance
<a href="#">MIPGap</a>	Relative MIP optimality gap
<a href="#">MIPGapAbs</a>	Absolute MIP optimality gap
<a href="#">OptimalityTol</a>	Dual feasibility tolerance
<a href="#">PSDTol</a>	Positive semi-definite tolerance

**Simplex:** These parameters control the operation of the simplex algorithms.

Parameter name	Purpose
InfUnbdInfo	Generate additional info for infeasible/unbounded models
NormAdjust	Simplex pricing norm
ObjScale	Objective scaling
PerturbValue	Simplex perturbation magnitude
Quad	Quad precision computation in simplex
ScaleFlag	Model scaling
Sifting	Sifting within dual simplex
SiftMethod	LP method used to solve sifting sub-problems
SimplexPricing	Simplex variable pricing strategy

**Barrier:** These parameters control the operation of the barrier solver.

Parameter name	Purpose
BarCorrectors	Central correction limit
BarHomogeneous	Barrier homogeneous algorithm
BarOrder	Barrier ordering algorithm
Crossover	Barrier crossover strategy
CrossoverBasis	Crossover initial basis construction strategy
QCPDual	Compute dual variables for QCP models

**MIP:** These parameters control the operation of the MIP algorithms.

Parameter name	Purpose
BranchDir	Branch direction preference
DegenMoves	Degenerate simplex moves
ConcurrentJobs	Enables distributed concurrent solver
ConcurrentMIP	Enables concurrent MIP solver
ConcurrentSettings	Comma-separated list of .prm files - used to create concurrent environments
Disconnected	Disconnected component strategy
DistributedMIPJobs	Enables the distributed MIP solver
Heuristics	Turn MIP heuristics up or down
ImproveStartGap	Trigger solution improvement
ImproveStartNodes	Trigger solution improvement
ImproveStartTime	Trigger solution improvement
MinRelNodes	Minimum relaxation heuristic control
MIPFocus	Set the focus of the MIP solver
MIQCPMethod	Method used to solve MIQCP models
NodefileDir	Directory for MIP node files
NodefileStart	Memory threshold for writing MIP tree nodes to disk
NodeMethod	Method used to solve MIP node relaxations
PumpPasses	Feasibility pump heuristic control
RINS	RINS heuristic
SolutionNumber	Sub-optimal MIP solution retrieval
SubMIPNodes	Nodes explored by sub-MIP heuristics
Symmetry	MIP symmetry detection
VarBranch	Branch variable selection strategy
ZeroObjNodes	Zero objective heuristic control

**Tuning:** These parameters control the operation of the parameter tuning tool.

Parameter name	Purpose
<a href="#">TuneCriterion</a>	Specify tuning criterion
<a href="#">TuneJobs</a>	Enables distributed tuning
<a href="#">TuneOutput</a>	Tuning output level
<a href="#">TuneResults</a>	Number of improved parameter sets returned
<a href="#">TuneTimeLimit</a>	Time limit for tuning
<a href="#">TuneTrials</a>	Perform multiple runs on each parameter set to limit the effect of random noise

**Multiple Solutions:** These parameters allow you to modify the behavior of the MIP search in order to find more than one solution to a MIP model.

Parameter name	Purpose
<a href="#">PoolSearchMode</a>	Choose the approach used to find additional solutions
<a href="#">PoolGap</a>	Gap for solutions in pool
<a href="#">PoolSolutions</a>	Number of solutions to keep in pool

**MIP Cuts:** These parameters affect the generation of MIP cutting planes. In all cases, a value of -1 corresponds to an automatic setting, which allows the solver to determine the appropriate level of aggressiveness in the cut generation. Unless otherwise noted, settings of 0, 1, and 2 correspond to no cut generation, conservative cut generation, or aggressive cut generation, respectively. The **Cuts** parameter provides global cut control, affecting the generation of all cuts. This parameter also has a setting of 3, which corresponds to very aggressive cut generation. The other parameters override the global **Cuts** parameter (so setting **Cuts** to 2 and **CliqueCuts** to 0 would generate all cut types aggressively, except clique cuts which would not be generated at all).

Parameter name	Purpose
<a href="#">Cuts</a>	Global cut generation control
<a href="#">CliqueCuts</a>	Clique cut generation
<a href="#">CoverCuts</a>	Cover cut generation
<a href="#">FlowCoverCuts</a>	Flow cover cut generation
<a href="#">FlowPathCuts</a>	Flow path cut generation
<a href="#">GUBCoverCuts</a>	GUB cover cut generation
<a href="#">ImpliedCuts</a>	Implied bound cut generation
<a href="#">MIPSepCuts</a>	MIP separation cut generation
<a href="#">MIRCuts</a>	MIR cut generation
<a href="#">StrongCGCuts</a>	Strong-CG cut generation
<a href="#">ModKCuts</a>	Mod-k cut generation
<a href="#">NetworkCuts</a>	Network cut generation
<a href="#">ProjImpliedCuts</a>	Projected implied bound cut generation
<a href="#">SubMIPCuts</a>	Sub-MIP cut generation
<a href="#">ZeroHalfCuts</a>	Zero-half cut generation
<a href="#">InfProofCuts</a>	Infeasibility proof cut generation
<a href="#">CutAggPasses</a>	Constraint aggregation passes performed during cut generation
<a href="#">CutPasses</a>	Root cutting plane pass limit
<a href="#">GomoryPasses</a>	Root Gomory cut pass limit

**Distributed algorithms:** Parameters that are used to control our distributed parallel algorithms

(distributed MIP, distributed concurrent, and distributed tuning).

<b>Parameter name</b>	<b>Purpose</b>
<a href="#">WorkerPassword</a>	Password for distributed workers
<a href="#">WorkerPool</a>	List of available distributed workers
<a href="#">WorkerPort</a>	Non-default port number for distributed workers

**Other:** Other parameters.

<b>Parameter name</b>	<b>Purpose</b>
AggFill	Allowed fill during presolve aggregation
Aggregate	Presolve aggregation control
DisplayInterval	Frequency at which log lines are printed
DualReductions	Disables dual reductions in presolve
FeasRelaxBigM	Big-M value for feasibility relaxations
IISMethod	IIS method
InputFile	File to be read before optimization commences
LazyConstraints	Programs that add lazy constraints must set this parameter
LogFile	Log file name
LogToConsole	Console logging
Method	Algorithm used to solve continuous models
MultiObjMethod	Warm-start method to solve for subsequent objectives
MultiObjPre	Initial presolve on multi-objective models
NumericFocus	Set the numerical focus
ObjNumber	Set index of multi-objectives
OutputFlag	Solver output control
PreCrush	Allows presolve to translate constraints on the original model to equivalent constraints on the presolved model
PreDepRow	Presolve dependent row reduction
PreDual	Presolve dualization
PreMIQCPForm	Format of presolved MIQCP model
PrePasses	Presolve pass limit
PreQLinearize	Presolve Q matrix linearization
Presolve	Presolve level
PreSOS1BigM	Controls SOS1 conversion to binary form
PreSOS2BigM	Controls SOS2 conversion to binary form
PreSparsify	Presolve sparsify reduction
Record	Enable API call recording
ResultFile	Result file written upon completion of optimization
Seed	Modify the random number seed
Threads	Number of parallel threads to use
UpdateMode	Change the behavior of lazy updates

## 11.1 Parameter Guidelines

This section provides a brief discussion of the roles of the various Gurobi parameters when solving continuous or MIP models, with some indication of their relative importance.

Note that you also have the option of using the [Parameter Tuning Tool](#) to tune parameters. We recommend that you browse this section, though, even if you use the tuning tool, so that you can get an understanding of the roles of the various parameters.

### Continuous Models

If you wish to use Gurobi parameters to tune performance on continuous models, we offer the following guidelines.

#### Choosing the method for LP or QP

The most important parameter when solving an LP or QP is `Method`. The default setting (-1) uses the [concurrent optimizer](#) for an LP, and the parallel barrier solver for a QP. While the default is usually a good choice, you may want to choose a different method in a few situations.

If memory is tight, you should consider using the dual simplex method (`Method=1`) instead of the default. The default will invoke the barrier method, which can take a lot more memory than dual. In addition, the default for LP will try multiple algorithms simultaneously, and each requires a copy of the original model. By selecting dual simplex, you will only use one copy of the model.

Another scenario where you should change the default is when you must get the same optimal basis each time you run your program. For LP models, the default concurrent solver invokes multiple algorithms simultaneously on multi-core systems, returning the optimal basis from the one that finishes first. In rare cases, one algorithm may complete first in one run, while another completes first in another. This can potentially lead to different alternate optimal solutions. Selecting any other method, including the deterministic concurrent solver, will avoid this possibility. Note, however, that the deterministic concurrent solver can be significantly slower than the default concurrent solver.

Finally, if you are confronted with a difficult LP model, you should experiment with the different method options. While the default is rarely significantly slower than the best choice, you may find that one option is consistently faster or more robust for your models. There are no simple rules for predicting which method will work best for a particular family of models.

If you are solving QCP or SOCP models, note that the barrier algorithm is your only option.

#### Parallel solution

Among the remaining parameters that affect continuous models, the only one that you would typically want to adjust is `Threads`, which controls the number of threads used for the concurrent and parallel barrier algorithms. By default, concurrent and barrier will use all available cores in your machine. Note that the simplex solvers can only use one thread, so this parameter has no effect on them.

If you would like to experiment with different strategies than the default ones when solving an LP model using the concurrent optimizer, we provide methods in [C](#), [C++](#), [Java](#), [.NET](#), and [Python](#) that allow you to create and configure concurrent environments.

## Infeasible or unbounded models

If you are confronted with an infeasible or unbounded LP, additional details can be obtained when you set the `InfUnbdInfo` parameter. For an unbounded model, setting this parameter allows you to retrieve an unbounded ray (using the `UnbdRay` attribute). For an infeasible model, setting this parameter allows you to retrieve a Farkas infeasibility proof (using the `FarkasDual` and `FarkasProof` attributes).

For the barrier algorithm, you should set the `BarHomogeneous` parameter to 1 whenever you have a model that you suspect is infeasible or unbounded. This algorithm is better at diagnosing infeasibility or unboundedness.

## Special structure

If you wish to solve an LP model that has many more variables than constraints, you may want to try the sifting algorithm. Sifting is actually implemented within our dual simplex solver, so to select sifting, set the `Method` parameter to 1 (to select dual), and then set the `Sifting` parameter to a positive value. You can use the `SiftMethod` parameter to choose the algorithm that is used to solve the sub-problems that arise within the sifting algorithm. In general, sifting is only effective when the ratio between variables and constraints is extremely large (100 to 1 or more). Note that the default `Sifting` setting allows the Gurobi Optimizer to select sifting automatically when a problem has the appropriate structure, so you won't typically need to select it manually.

## Additional parameters

The `ScaleFlag` parameter can be used to modify the scaling performed on the model. The default scaling value (1) is usually the most effective choice, but turning off scaling entirely (0) can sometimes reduce constraint violations on the original model, and applying more aggressive scaling (2) can sometimes improve the numerical properties of the scaled model. The `ObjScale` parameter allows you to scale just the objective. Objective scaling can be useful when the objective contains extremely large values, but it can also lead to large dual violations, so it should be used sparingly.

The `SimplexPricing` parameter determines the method used to choose a simplex pivot. The default is usually the best choice. The `NormAdjust` parameter allows you to choose alternate simplex pricing norms. Again, the default is usually best. The `Quad` parameter allows you to force the simplex solver to use (or not use) quad precision. While quad precision can help for numerically difficult models, the default setting will typically recognize such cases automatically. The `PerturbValue` parameter allows you to adjust the magnitude of the simplex perturbation (used to overcome degeneracy). Again, the default value is typically effective.

Other Gurobi parameters control the details of the barrier solver. The `BarConvTol` and `BarQCPConvTol` parameters allow you to adjust barrier termination. While you can ask for more precision than the default, you will typically run into the limitations of double-precision arithmetic quite quickly. This parameter is typically used to indicate that you are willing to settle for a less accurate answer than the defaults would give. The `BarCorrectors` parameter allows you to adjust the number of central corrections applied in each barrier iteration. More corrections generally lead to more forward progress in each iteration, but at a cost of more expensive iterations. The `BarOrder` parameter allows you to choose the barrier ordering method. The default approach typically works well, but you can manually choose the less expensive Approximate Minimum Degree ordering option (`BarOrder=0`) if you find that ordering is taking too long.

## MIP Models

While default settings generally work well, MIP models will often benefit from parameter tuning. We offer the following guidelines, but we also encourage you to experiment.

### Most Important Parameters

The two most important Gurobi settings when solving a MIP model are probably the `Threads` and `MIPFocus` parameters. The `Threads` parameter controls the number of threads used by the parallel MIP solver to solve the model. The default is to use all cores in the machine. If you wish to leave some available for other activities, adjust this parameter accordingly.

The `MIPFocus` parameter allows you to modify your high-level solution strategy, depending on your goals. By default, the Gurobi MIP solver strikes a balance between finding new feasible solutions and proving that the current solution is optimal. If you are more interested in good quality feasible solutions, you can select `MIPFocus=1`. If you believe the solver is having no trouble finding the optimal solution, and wish to focus more attention on proving optimality, select `MIPFocus=2`. If the best objective bound is moving very slowly (or not at all), you may want to try `MIPFocus=3` to focus on the bound.

### Solution Improvement

The `ImproveStartTime` and `ImproveStartGap` parameters can also be used to modify your high-level solution strategy, but in a different way. These parameters allow you to give up on proving optimality at a certain point in the search, and instead focus all attention on finding better feasible solutions from that point onward. The `ImproveStartTime` parameter allows you to make this transition after the specified time has elapsed, while the `ImproveStartGap` parameter makes the transition when the specified optimality gap has been achieved.

### Termination

Another important set of Gurobi parameters affect solver termination. If the solver is unable to find a proven optimal solution within the desired time, you will need to indicate how to limit the search. The simplest option is to limit runtime using the `TimeLimit` parameter. Another common termination choice for MIP models is to set the `MIPGap` parameter. The `MIPGap` parameter allows you to indicate that optimization should stop when the relative gap between the best known solution and the best known bound on the solution objective is less than the specified value. You can terminate when the absolute gap is below a desired threshold using the `MIPGapAbs` parameter. Other termination options include `NodeLimit`, `IterationLimit`, `SolutionLimit`, and `Cutoff`. The first three indicate that optimization should terminate when the number of branch-and-bound nodes, the total number of simplex iterations, or the number of discovered feasible integer solutions exceeds the specified value, respectively. The `Cutoff` parameter indicates that the solver should only consider solutions whose objective values are better than the specified value, and should terminate if no such solutions are found.

### Reducing Memory Usage

If you find that the Gurobi optimizer exhausts memory when solving a MIP, you should modify the `NodefileStart` parameter. When the amount of memory used to store nodes (measured in GBytes) exceeds the specified parameter value, nodes are written to disk. We recommend a setting of 0.5, but you may wish to choose a different value, depending on the memory available in your machine.

By default, nodes are written to the current working directory. The `NodefileDir` parameter can be used to choose a different location.

If you still exhaust memory after setting the `NodefileStart` parameter to a small value, you should try limiting the thread count. Each thread in parallel MIP requires a copy of the model, as well as several other large data structures. Reducing the `Threads` parameter can sometimes significantly reduce memory usage.

### Speeding Up The Root Relaxation

The root relaxation in a MIP model can sometimes be quite expensive to solve. If you find that a lot of time is spent here, consider using the `Method` parameter to select a different continuous algorithm for the root. For example, `Method=2` would select the parallel barrier algorithm at the root, and `Method=3` would select the concurrent solver. Note that you can choose a different algorithm for the MIP node relaxations using the `NodeMethod` parameter, but it is rarely beneficial to change this from the default (dual simplex).

### Heuristics

A few Gurobi parameters control internal MIP strategies. The `Heuristics` parameter controls the fraction of runtime spent on feasibility heuristics. Increasing the parameter can lead to more and better feasible solutions, but it will also reduce the rate of progress in the best bound. The `SubMIPNodes` parameter controls the number of nodes explored in some of the more sophisticated local search heuristics inside the Gurobi solver. You can increase this if you are having trouble finding good feasible solutions. The `MinRelNodes`, `PumpPasses`, and `ZeroObjNodes` parameters control a set of expensive heuristics whose goal is to find a feasible solution. All are invoked at the end of the MIP root node, but only if no feasible solution has been found already. Try these if you are having trouble finding any feasible solutions.

### Cutting Planes

The Gurobi MIP solver employs a wide range of cutting plane strategies. The aggressiveness of these strategies can be controlled at a coarse level through the `Cuts` parameter, and at a finer grain through a further set of cuts parameters (e.g., `FlowCoverCuts`, `MIRCuts`, etc.). Each cut parameter can be set to Aggressive (2), Conservative (1), Automatic (-1), or None (0). The more specific parameters override the more general, so for example setting `MIRCuts` to None (0) while also setting `Cuts` to Aggressive (2) would aggressively generate all cut types, except MIR cuts which would not be generated. Very easy models can sometimes benefit from turning cuts off, while extremely difficult models can benefit from turning them to their Aggressive setting.

### Presolve

Presolve behavior can be modified with a set of parameters. The `Presolve` parameter sets the aggressiveness level of presolve. Options are Aggressive (2), Conservative (1), Automatic (-1), or None (0). More aggressive application of presolve takes more time, but can sometimes lead to a significantly tighter model. The `PrePasses` provides finer-grain control of presolve. It limits the number of passes presolve performs. Setting it to a small value (e.g., 3) can reduce presolve runtime. The `Aggregate` parameter controls whether presolve performs constraint aggregation. Aggregation typically leads to a smaller formulation, but in rare cases it can introduce numerical issues. The `AggFill` parameter controls aggregation at a finer grain. It controls how much fill is tolerated in the constraint matrix from a single variable aggregation. The `PreSparsify` parameter enables an

algorithm that can sometimes significantly reduce the number of nonzero values in the constraint matrix.

### Additional Parameters

The `Symmetry` parameter controls symmetry detection. The default value usually works well. The `VarBranch` parameter controls the branching variable selection strategy within the branch-and-bound process. Variable selection can have a significant impact on overall time to solution, but the default strategy is usually the best choice.

### Tolerances

The Gurobi solver includes a set of numerical tolerance parameters. These rarely require adjustment, and are included for advanced users who are having trouble with the numerical properties of their models. The `FeasibilityTol`, `IntFeasTol`, `MarkowitzTol`, and `OptimalityTol` parameters allow you to adjust the primal feasibility tolerance, the integer feasibility tolerance, the Markowitz tolerance for simplex basis factorization, and the dual feasibility tolerance, respectively.

## 11.2 Parameter Descriptions

### AggFill

	<b>Type:</b>	int
Presolve aggregation fill level	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	MAXINT

Controls the amount of fill allowed during presolve aggregation. Larger values generally lead to presolved models with fewer rows and columns, but with more constraint matrix non-zeros.

The default value chooses automatically, and usually works well.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

### Aggregate

	<b>Type:</b>	int
Presolve aggregation	<b>Default value:</b>	1
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	1

Enables or disables aggregation in presolve. In rare instances, aggregation can lead to an accumulation of numerical errors. Turning it off can sometimes improve solution accuracy.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

### BarConvTol

	<b>Type:</b>	double
Barrier convergence tolerance	<b>Default value:</b>	1e-8
	<b>Minimum value:</b>	0.0
	<b>Maximum value:</b>	1.0

The barrier solver terminates when the relative difference between the primal and dual objective values is less than the specified tolerance (with a `GRB_OPTIMAL` status). Tightening this tolerance often produces a more accurate solution, which can sometimes reduce the time spent in crossover. Loosening it causes the barrier algorithm to terminate with a less accurate solution, which can be useful when barrier is making very slow progress in later iterations.

**Note:** Barrier only

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## BarCorrectors

	<b>Type:</b>	int
Barrier central corrections	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	MAXINT

Limits the number of central corrections performed in each barrier iteration. The default value chooses automatically, depending on problem characteristics. The automatic strategy generally works well, although it is often possible to obtain higher performance on a specific model by selecting a value manually.

**Note:** Barrier only

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## BarHomogeneous

	<b>Type:</b>	int
Barrier homogeneous algorithm	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	1

Determines whether to use the homogeneous barrier algorithm. At the default setting (-1), it is only used when barrier solves a node relaxation for a MIP model. Setting the parameter to 0 turns it off, and setting it to 1 forces it on. The homogeneous algorithm is useful for recognizing infeasibility or unboundedness. It is a bit slower than the default algorithm.

**Note:** Barrier only

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## BarOrder

	<b>Type:</b>	int
Barrier ordering algorithm	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	1

Chooses the barrier sparse matrix fill-reducing algorithm. A value of 0 chooses Approximate Minimum Degree ordering, while a value of 1 chooses Nested Dissection ordering. The default value of -1 chooses automatically. You should only modify this parameter if you notice that the barrier ordering phase is consuming a significant fraction of the overall barrier runtime.

**Note:** Barrier only

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

### BarQCPConvTol

	<b>Type:</b>	double
	<b>Default value:</b>	1e-6
	<b>Minimum value:</b>	0.0
	<b>Maximum value:</b>	1.0

Barrier convergence tolerance for QCP models

When solving a QCP model, the barrier solver terminates when the relative difference between the primal and dual objective values is less than the specified tolerance (with a `GRB_OPTIMAL` status). Tightening this tolerance may lead to a more accurate solution, but it may also lead to a failure to converge.

**Note:** Barrier only

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

### BarIterLimit

	<b>Type:</b>	int
	<b>Default value:</b>	1000
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	MAXINT

Barrier iteration limit

Limits the number of barrier iterations performed. This parameter is rarely used. If you would like barrier to terminate early, it is almost always better to use the [BarConvTol](#) parameter instead.

Optimization returns with an `ITERATION_LIMIT` status if the limit is exceeded (see the [Status Code](#) section for further details).

**Note:** Barrier only

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

### BestBdStop

	<b>Type:</b>	double
	<b>Default value:</b>	Infinity
	<b>Minimum value:</b>	-Infinity
	<b>Maximum value:</b>	Infinity

Objective bound to stop optimization

Terminates as soon as the engine determines that the best bound on the objective value is at least as good as the specified value. Optimization returns with an `USER_OBJ_LIMIT` status in this case.

Note that you should always include a small tolerance in this value. Without this, a bound that satisfies the intended termination criterion may not actually lead to termination due to numerical round-off in the bound.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## BestObjStop

	<b>Type:</b>	double
Objective value to stop optimization	<b>Default value:</b>	-Infinity
	<b>Minimum value:</b>	-Infinity
	<b>Maximum value:</b>	Infinity

Terminate as soon as the engine finds a feasible solution whose objective value is at least as good as the specified value. Optimization returns with an `USER_OBJ_LIMIT` status in this case.

Note that you should always include a small tolerance in this value. Without this, a solution that satisfies the intended termination criterion may not actually lead to termination due to numerical round-off in the objective.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## BranchDir

	<b>Type:</b>	int
Preferred branch direction	<b>Default value:</b>	0
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	1

Determines which child node is explored first in the branch-and-cut search. The default value chooses automatically. A value of -1 will always explore the down branch first, while a value of 1 will always explore the up branch first.

Changing the value of this parameter rarely produces a significant benefit.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## DegenMoves

	<b>Type:</b>	int
Degenerate simplex moves	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	MAXINT

Limits degenerate simplex moves. These moves are performed to improve the integrality of the current relaxation solution. By default, the algorithm chooses the number of moves to perform automatically.

Changing the value of this parameter can help performance in cases where an excessive amount of time is spent after the initial root relaxation has been solved but before the cut generation process or the root heuristics have started.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## CliqueCuts

	<b>Type:</b>	int
Clique cut generation	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls clique cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value choose automatically. Overrides the [Cuts](#) parameter.

We have observed that setting this parameter to its aggressive setting can produce a significant benefit for some large set partitioning models.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ConcurrentJobs

	<b>Type:</b>	int
Distributed concurrent optimizer job count	<b>Default value:</b>	0
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	MAXINT

Enables distributed concurrent optimization, which can be used to solve LP or MIP models on multiple machines. A value of **n** causes the solver to create **n** independent models, using different parameter settings for each. Each of these models is sent to a distributed worker for processing. Optimization terminates when the first solve completes. Use the [WorkerPool](#) parameter to provide a list of available distributed workers.

By default, Gurobi chooses the parameter settings used for each independent solve automatically. You can create concurrent environments to choose your own parameter settings (refer to the

[concurrent optimization](#) section for details). The intent of concurrent MIP solving is to introduce additional diversity into the MIP search. By bringing the resources of multiple machines to bear on a single model, this approach can sometimes solve models much faster than a single machine.

The distributed concurrent solver produces a slightly different log from the standard solver, and provides different callbacks as well. Please refer to the [Distributed Algorithm](#) discussion for additional details.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ConcurrentMIP

	<b>Type:</b>	int
	<b>Default value:</b>	1
	<b>Minimum value:</b>	1
	<b>Maximum value:</b>	MAXINT

Enables the concurrent MIP solver

This parameter enables the concurrent MIP solver. When the parameter is set to value *n*, the MIP solver performs *n* independent MIP solves in parallel, with different parameter settings for each. Optimization terminates when the first solve completes.

By default, Gurobi chooses the parameter settings used for each independent solve automatically. You can create concurrent environments to choose your own parameter settings (refer to the [concurrent optimization](#) section for details). The intent of concurrent MIP solving is to introduce additional diversity into the MIP search. This approach can sometimes solve models much faster than applying all available threads to a single MIP solve, especially on very large parallel machines.

The concurrent MIP solver divides available threads evenly among the independent solves. For example, if you have 6 threads available and you set **ConcurrentMIP** to 2, the concurrent MIP solver will allocate 3 threads to each independent solve. Note that the number of independent solves launched will not exceed the number of available threads.

The concurrent MIP solver produces a slightly different log from the standard MIP solver, and provides different callbacks as well. Please refer to the [concurrent optimizer](#) discussion for additional details.

Concurrent MIP is not deterministic. If runtimes for different independent solves are very similar, and if the model has multiple optimal solutions, you may get slightly different results from multiple runs on the same model.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ConcurrentSettings

	<b>Type:</b>	string
	<b>Default value:</b>	""

Create concurrent environments from a set of .prm files

This command-line only parameter allows you to specify a comma-separated list of .prm files that are used to set parameters for the different instances in a concurrent MIP run.

To give an example, you could create two .prm files with the following contents...

s0.prm:

MIPFocus 0

s1.prm:

MIPFocus 1

Issuing the command `gurobi_cl ConcurrentSettings=s0.prm,s1.prm model.mps` would invoke the concurrent MIP solver, using parameter setting `MIPFocus=0` in one of the two concurrent solves and `MIPFocus=1` in the other.

Note that if you want to run concurrent MIP on multiple machines, you must also set the [ConcurrentJobs](#) parameter. The command for running distributed concurrent optimization using the two example parameter files on two machines would be

```
> gurobi_cl ConcurrentJobs=2 ConcurrentSettings=s0.prm,s1.prm model.mps
```

**Note:** Command-line only

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## CoverCuts

	<b>Type:</b>	int
Cover cut generation	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls cover cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the [Cuts](#) parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## Crossover

	<b>Type:</b>	int
Barrier crossover strategy	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	4

Determines the crossover strategy used to transform the interior solution produced by barrier into a basic solution (note that crossover is not available for QP or QCP models). Crossover consists of three phases: (i) a *primal push* phase, where primal variables are pushed to bounds, (ii) a *dual push* phase, where dual variables are pushed to bounds, and (iii) a *cleanup* phase, where simplex is used to remove any primal or dual infeasibilities that remain after the push phases are complete. The order of the first two phases and the algorithm used for the third phase are both controlled by the [Crossover](#) parameter:

Parameter value	First push	Second push	Cleanup
1	Dual	Primal	Primal
2	Dual	Primal	Dual
3	Primal	Dual	Primal
4	Primal	Dual	Dual

The default value of -1 chooses the strategy automatically. Use value 0 to disable crossover; this setting returns the interior solution computed by barrier.

**Note:** Barrier only

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## CrossoverBasis

	<b>Type:</b>	int
	<b>Default value:</b>	0
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	1

Determines the initial basis construction strategy for crossover. The default value (0) chooses an initial basis quickly. A value of 1 can take much longer, but often produces a more numerically stable start basis.

**Note:** Barrier only

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## Cutoff

	<b>Type:</b>	double
	<b>Default value:</b>	Infinity for minimization, -Infinity for maximization
	<b>Minimum value:</b>	-Infinity
	<b>Maximum value:</b>	Infinity

Indicates that you aren't interested in solutions whose objective values are worse than the specified value. If the objective value for the optimal solution is better than the specified cutoff, the solver will return the optimal solution. Otherwise, it will terminate with a **CUTOFF** status (see the [Status Code](#) section for further details).

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## CutAggPasses

	<b>Type:</b>	int
	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	MAXINT

A non-negative value indicates the maximum number of constraint aggregation passes performed during cut generation. Overrides the [Cuts](#) parameter.

Changing the value of this parameter rarely produces a significant benefit.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## CutPasses

	<b>Type:</b>	int
Cutting plane passes	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	MAXINT

A non-negative value indicates the maximum number of cutting plane passes performed during root cut generation. The default value chooses the number of cut passes automatically.

You should experiment with different values of this parameter if you notice the MIP solver spending significant time on root cut passes that have little impact on the objective bound.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## Cuts

	<b>Type:</b>	int
Global cut control	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	3

Global cut aggressiveness setting. Use value 0 to shut off cuts, 1 for moderate cut generation, 2 for aggressive cut generation, and 3 for very aggressive cut generation. This parameter is overridden by the parameters that control individual cut types (e.g., [CliqueCuts](#)).

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## Disconnected

	<b>Type:</b>	int
Disconnected component strategy	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

A MIP model can sometimes be made up of multiple, completely independent sub-models. This parameter controls how aggressively we try to exploit this structure. A value of 0 ignores this structure entirely, while larger values try more aggressive approaches. The default value of -1 chooses automatically.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## DisplayInterval

	<b>Type:</b>	int
	<b>Default value:</b>	5
Frequency of log lines	<b>Minimum value:</b>	1
	<b>Maximum value:</b>	MAXINT

Determines the frequency at which log lines are printed (in seconds).

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## DistributedMIPJobs

	<b>Type:</b>	int
	<b>Default value:</b>	0
Distributed MIP job count	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	MAXINT

Enables distributed MIP. A value of *n* causes the MIP solver to divide the work of solving a MIP model among *n* machines. Use the [WorkerPool](#) parameter to provide the list of available machines.

The distributed MIP solver produces a slightly different log from the standard MIP solver, and provides different callbacks as well. Please refer to the [Distributed Algorithm](#) discussion for additional details.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## DualReductions

	<b>Type:</b>	int
	<b>Default value:</b>	1
Controls dual reductions	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	1

Determines whether dual reductions are performed in presolve. You should disable these reductions if you received an optimization status of `INF_OR_UNBD` and would like a more definitive conclusion.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## FeasibilityTol

	<b>Type:</b>	double
Primal feasibility tolerance	<b>Default value:</b>	1e-6
	<b>Minimum value:</b>	1e-9
	<b>Maximum value:</b>	1e-2

All constraints must be satisfied to a tolerance of `FeasibilityTol`. Tightening this tolerance can produce smaller constraint violations, but for numerically challenging models it can sometimes lead to much larger iteration counts.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## FeasRelaxBigM

	<b>Type:</b>	double
Big-M value for feasibility relaxations	<b>Default value:</b>	1e6
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	Infinity

When relaxing a constraint in a feasibility relaxation, it is sometimes necessary to introduce a big-M value. This parameter determines the default magnitude of that value.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## FlowCoverCuts

	<b>Type:</b>	int
Flow cover cut generation	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls flow cover cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the `Cuts` parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## FlowPathCuts

	<b>Type:</b>	int
Flow path cut generation	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls flow path cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the `Cuts` parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## GomoryPasses

	<b>Type:</b>	int
	<b>Default value:</b>	-1
Gomory cut passes	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	MAXINT

A non-negative value indicates the maximum number of Gomory cut passes performed. Overrides the [Cuts](#) parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## GUBCoverCuts

	<b>Type:</b>	int
	<b>Default value:</b>	-1
GUB cover cut generation	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls GUB cover cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the [Cuts](#) parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## Heuristics

	<b>Type:</b>	double
	<b>Default value:</b>	0.05
Time spent in feasibility heuristics	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	1

Determines the amount of time spent in MIP heuristics. You can think of the value as the desired fraction of total MIP runtime devoted to heuristics (so by default, we aim to spend 5% of runtime on heuristics). Larger values produce more and better feasible solutions, at a cost of slower progress in the best bound.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## IISMethod

	<b>Type:</b>	int
Selects method used to compute IIS	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	3

Chooses the IIS method to use. Method 0 is often faster, while method 1 can produce a smaller IIS. Method 2 ignores the bound constraints. Method 3 will return the IIS for the LP relaxation of a MIP model if the relaxation is infeasible, even though the result may not be minimal when integrality constraints are included. The default value of -1 chooses automatically.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ImpliedCuts

	<b>Type:</b>	int
Implied bound cut generation	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls implied bound cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the [Cuts](#) parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ImproveStartGap

	<b>Type:</b>	double
Solution improvement strategy control	<b>Default value:</b>	0.0
	<b>Minimum value:</b>	0.0
	<b>Maximum value:</b>	Infinity

The MIP solver can change parameter settings in the middle of the search in order to adopt a strategy that gives up on moving the best bound and instead devotes all of its effort towards finding better feasible solutions. This parameter allows you to specify an optimality gap at which the MIP solver switches to a solution improvement strategy. For example, setting this parameter to 0.1 will cause the MIP solver to switch strategies once the relative optimality gap is smaller than 0.1.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ImproveStartNodes

	<b>Type:</b>	double
	<b>Default value:</b>	Infinity
Solution improvement strategy control	<b>Minimum value:</b>	0.0
	<b>Maximum value:</b>	Infinity

The MIP solver can change parameter settings in the middle of the search in order to adopt a strategy that gives up on moving the best bound and instead devotes all of its effort towards finding better feasible solutions. This parameter allows you to specify the node count at which the MIP solver switches to a solution improvement strategy. For example, setting this parameter to 10 will cause the MIP solver to switch strategies once the node count is larger than 10.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ImproveStartTime

	<b>Type:</b>	double
	<b>Default value:</b>	Infinity
Solution improvement strategy control	<b>Minimum value:</b>	0.0
	<b>Maximum value:</b>	Infinity

The MIP solver can change parameter settings in the middle of the search in order to adopt a strategy that gives up on moving the best bound and instead devotes all of its effort towards finding better feasible solutions. This parameter allows you to specify the time when the MIP solver switches to a solution improvement strategy. For example, setting this parameter to 10 will cause the MIP solver to switch strategies 10 seconds after starting the optimization.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## InfProofCuts

	<b>Type:</b>	int
	<b>Default value:</b>	-1
Infeasibility proof cut generation	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls infeasibility proof cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the [Cuts](#) parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## InfUnbdInfo

	<b>Type:</b>	int
Additional info for infeasible/unbounded models	<b>Default value:</b>	0
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	1

Determines whether simplex (and crossover) will compute additional information when a model is determined to be infeasible or unbounded. Set this parameter if you want to query the unbounded ray for unbounded models (through the [UnbdRay](#) attribute), or the infeasibility proof for infeasible models (through the [FarkasDual](#) and [FarkasProof](#) attributes).

Note that if a model is found to be either infeasible or unbounded, and you simply want to know which one it is, you should use the [DualReductions](#) parameter instead. It performs much less additional computation.

**Note:** LP only

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## InputFile

	<b>Type:</b>	string
Import data into a model before beginning optimization	<b>Default value:</b>	""

Specifies the name of a file that will be read before beginning a command-line optimization run. This parameter can be used to input a MIP start (a `.mst` or `.sol` file), MIP hints (a `.hnt` file), a simplex basis (a `.bas` file), or a set of parameter settings (a `.prm` file) from the Gurobi command line. The suffix may optionally be followed by `.zip`, `.gz`, `bz2`, or `.7z` if the input files are compressed.

**Note:** Command-line only

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## IntFeasTol

	<b>Type:</b>	double
Integer feasibility tolerance	<b>Default value:</b>	1e-5
	<b>Minimum value:</b>	1e-9
	<b>Maximum value:</b>	1e-1

An integrality restriction on a variable is considered satisfied when the variable's value is less than `IntFeasTol` from the nearest integer value. Tightening this tolerance can produce smaller integrality violations, but very tight tolerances may significantly increase runtime. Loosening this tolerance rarely reduces runtime.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## IterationLimit

	<b>Type:</b>	double
	<b>Default value:</b>	Infinity
Simplex iteration limit	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	Infinity

Limits the number of simplex iterations performed. The limit applies to MIP, barrier crossover, and simplex. Optimization returns with an `ITERATION_LIMIT` status if the limit is exceeded (see the [Status Code](#) section for further details).

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## LazyConstraints

	<b>Type:</b>	int
	<b>Default value:</b>	0
Programs that use lazy constraints must set this parameter	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	1

Programs that add lazy constraints through a callback must set this parameter to value 1. The parameter tells the Gurobi algorithms to avoid certain reductions and transformations that are incompatible with lazy constraints.

Note that if you use lazy constraints by setting the [Lazy](#) attribute (and not through a callback), there's no need to set this parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## LogFile

	<b>Type:</b>	string
Name for Gurobi log file	<b>Default value:</b>	""

Determines the name of the Gurobi log file. Modifying this parameter closes the current log file and opens the specified file. Use an empty string for no log file. Use [OutputFlag](#) to shut off all logging.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## LogToConsole

	<b>Type:</b>	int
	<b>Default value:</b>	1
Control console logging	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	1

Enables or disables console logging. Use [OutputFlag](#) to shut off all logging.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## MarkowitzTol

	<b>Type:</b>	double
	<b>Default value:</b>	0.0078125
Threshold pivoting tolerance	<b>Minimum value:</b>	1e-4
	<b>Maximum value:</b>	0.999

The Markowitz tolerance is used to limit numerical error in the simplex algorithm. Specifically, larger values reduce the error introduced in the simplex basis factorization. A larger value may avoid numerical problems in rare situations, but it will also harm performance.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## Method

	<b>Type:</b>	int
	<b>Default value:</b>	-1
Algorithm used to solve continuous models	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	4

Algorithm used to solve continuous models or the root node of a MIP model. Options are: -1=automatic, 0=primal simplex, 1=dual simplex, 2=barrier, 3=concurrent, 4=deterministic concurrent.

In the current release, the default Automatic (-1) setting will typically choose non-deterministic concurrent (Method=3) for an LP, barrier (Method=2) for a QP or QCP, and dual (Method=1) for the MIP root node. Only the simplex and barrier algorithms are available for continuous QP models. Only primal and dual simplex are available for solving the root of an MIQP model. Only barrier is available for continuous QCP models.

Concurrent optimizers run multiple solvers on multiple threads simultaneously, and choose the one that finishes first. Deterministic concurrent (Method=4) gives the exact same result each time, while Method=3 is often faster but can produce different optimal bases when run multiple times.

The default setting is rarely significantly slower than the best possible setting, so you generally won't see a big gain from changing this parameter. There are classes of models where one particular algorithm is consistently fastest, though, so you may want to experiment with different options when confronted with a particularly difficult model.

Note that if memory is tight on an LP model, you should consider using the dual simplex method (Method=1). The concurrent optimizer, which is typically chosen when using the default setting, consumes a lot more memory than dual simplex alone.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## MinRelNodes

	<b>Type:</b>	int
	<b>Default value:</b>	-1
Minimum relaxation heuristic	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	MAXINT

Number of nodes to explore in the minimum relaxation heuristic. Note that this heuristic is only applied at the end of the MIP root, and only when no other root heuristic finds a feasible solution.

This heuristic is quite expensive, and generally produces poor quality solutions. You should generally only use it if other means, including exploration of the tree with default settings, fail to produce a feasible solution.

The default value automatically chooses whether to apply the heuristic. It will only rarely choose to do so.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## MIPFocus

	<b>Type:</b>	int
MIP solver focus	<b>Default value:</b>	0
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	3

The `MIPFocus` parameter allows you to modify your high-level solution strategy, depending on your goals. By default, the Gurobi MIP solver strikes a balance between finding new feasible solutions and proving that the current solution is optimal. If you are more interested in finding feasible solutions quickly, you can select `MIPFocus=1`. If you believe the solver is having no trouble finding good quality solutions, and wish to focus more attention on proving optimality, select `MIPFocus=2`. If the best objective bound is moving very slowly (or not at all), you may want to try `MIPFocus=3` to focus on the bound.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## MIPGap

	<b>Type:</b>	double
Relative MIP optimality gap	<b>Default value:</b>	1e-4
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	Infinity

The MIP solver will terminate (with an optimal result) when the gap between the lower and upper objective bound is less than `MIPGap` times the absolute value of the upper bound.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## MIPGapAbs

	<b>Type:</b>	double
Absolute MIP optimality gap	<b>Default value:</b>	1e-10
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	Infinity

The MIP solver will terminate (with an optimal result) when the gap between the lower and upper objective bound is less than `MIPGapAbs`.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## MIPSepCuts

	<b>Type:</b>	int
MIP separation cut generation	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls MIP separation cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the `Cuts` parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## MIQCPMethod

	<b>Type:</b>	int
Method used to solve MIQCP models	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	1

Controls the method used to solve MIQCP models. Value 1 uses a linearized, outer-approximation approach, while value 0 solves continuous QCP relaxations at each node. The default setting (-1) chooses automatically.

**Note:** Only affects MIQCP models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## MIRCuts

	<b>Type:</b>	int
MIR cut generation	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls Mixed Integer Rounding (MIR) cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the [Cuts](#) parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ModKCuts

	<b>Type:</b>	int
Mod-k cut generation	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls mod-k cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the [Cuts](#) parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## MultiObjMethod

	<b>Type:</b>	int
Method used for multi-objective solves	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

When solving a continuous multi-objective model using a hierarchical approach, the model is solved once for each objective. The algorithm used to solve for the highest priority objective is controlled by the [Method](#) parameter. This parameter determines the algorithm used to solve for subsequent objectives. As with the [Method](#) parameters, values of 0 and 1 use primal and dual simplex, respectively. A value of 2 indicates that warm-start information from previous solves should be discarded, and the model should be solved from scratch (using the algorithm indicated by the [Method](#) parameter). The default setting of -1 usually chooses primal simplex.

**Note:** Only affects continuous multi-objective models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## MultiObjPre

	<b>Type:</b>	int
Initial presolve level on multi-objective models	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls the initial presolve level used for multi-objective models. Value 0 disables the initial presolve, value 1 applies presolve conservatively, and value 2 applies presolve aggressively. The default -1 value usually applies presolve conservatively. Aggressive presolve may increase the chance of the objective values being slightly different than those for other options.

**Note:** Only affects multi-objective models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## NetworkCuts

	<b>Type:</b>	int
Network cut generation	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls network cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the [Cuts](#) parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## NodefileDir

Directory for node files	<b>Type:</b>	string
	<b>Default value:</b>	."

Determines the directory into which nodes are written when node memory usage exceeds the specified [NodefileStart](#) value.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## NodefileStart

	<b>Type:</b>	double
Write MIP nodes to disk	<b>Default value:</b>	Infinity
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	Infinity

If you find that the Gurobi optimizer exhausts memory when solving a MIP, you should modify the [NodefileStart](#) parameter. When the amount of memory used to store nodes (measured in GBytes) exceeds the specified parameter value, nodes are compressed and written to disk. We recommend a setting of 0.5, but you may wish to choose a different value, depending on the memory available in your machine. By default, nodes are written to the current working directory. The [NodefileDir](#) parameter can be used to choose a different location.

If you still exhaust memory after setting the `NodefileStart` parameter to a small value, you should try limiting the thread count. Each thread in parallel MIP requires a copy of the model, as well as several other large data structures. Reducing the [Threads](#) parameter can sometimes significantly reduce memory usage.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## NodeLimit

	<b>Type:</b>	double
MIP node limit	<b>Default value:</b>	Infinity
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	Infinity

Limits the number of MIP nodes explored. Optimization returns with an `NODE_LIMIT` status if the limit is exceeded (see the [Status Code](#) section for further details).

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## NodeMethod

	<b>Type:</b>	int
Method used to solve MIP node relaxations	<b>Default value:</b>	1
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	2

Algorithm used for MIP node relaxations (0=primal simplex, 1=dual simplex, 2=barrier). Note that barrier is not an option for MIQP node relaxations.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## NormAdjust

	<b>Type:</b>	int
Choose simplex pricing norm.	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	3

Chooses from among multiple pricing norm variants. The details of how this parameter affects the simplex pricing algorithm are subtle and difficult to describe, so we've simply labeled the options 0 through 3. The default value of -1 chooses automatically.

Changing the value of this parameter rarely produces a significant benefit.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## NumericFocus

	<b>Type:</b>	int
Numerical focus	<b>Default value:</b>	0
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	3

The `NumericFocus` parameter controls the degree to which the code attempts to detect and manage numerical issues. The default setting (0) makes an automatic choice, with a slight preference for speed. Settings 1-3 increasingly shift the focus towards being more careful in numerical computations. With higher values, the code will spend more time checking the numerical accuracy of intermediate results, and it will employ more expensive techniques in order to avoid potential numerical issues.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ObjScale

	<b>Type:</b>	double
Objective scaling	<b>Default value:</b>	0.0
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	Infinity

Divides the model objective by the specified value to avoid numerical errors that may result from very large objective coefficients. The default value of 0 decides on the scaling automatically. A value less than zero uses the maximum coefficient to the specified power as the scaling (so `ObjScale=-0.5` would scale by the square root of the largest objective coefficient).

Objective scaling can be useful when the objective contains extremely large values, but it can also lead to large dual violations, so it should be used sparingly.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## OptimalityTol

	<b>Type:</b>	double
Dual feasibility tolerance	<b>Default value:</b>	1e-6
	<b>Minimum value:</b>	1e-9
	<b>Maximum value:</b>	1e-2

Reduced costs must all be smaller than `OptimalityTol` in the improving direction in order for a model to be declared optimal.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ObjNumber

	<b>Type:</b>	int
	<b>Default value:</b>	0
Selects objective index of multi-objectives	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	2000000000

When working with multiple objectives, this parameter selects the index of the objective you want to work with. When you modify an attribute associated with multiple objectives ([ObjN](#), [ObjNVal](#), etc.), the `ObjNumber` parameter will determine which objective is actually affected. The value of this parameter should be less than the value of the [NumObj](#) attribute (which captures the number of objectives in the model).

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## OutputFlag

	<b>Type:</b>	int
	<b>Default value:</b>	1
Controls Gurobi output	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	1

Enables or disables solver output. Use [LogFile](#) and [LogToConsole](#) for finer-grain control. Setting `OutputFlag` to 0 is equivalent to setting [LogFile](#) to "" and [LogToConsole](#) to 0.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## PerturbValue

	<b>Type:</b>	double
	<b>Default value:</b>	0.0002
Simplex perturbation	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	0.01

Magnitude of the simplex perturbation. Note that perturbation is only applied when progress has stalled, so the parameter will often have no effect.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## PoolGap

	<b>Type:</b>	double
	<b>Default value:</b>	Infinity
Maximum gap for stored solutions	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	Infinity

Determines how large a gap to tolerate in stored solutions. When this parameter is set to a non-default value, solutions whose objective values exceed that of the best known solution by more than the specified (relative) gap are discarded. For example, if the MIP solver has found a solution at objective 100, then a setting of `PoolGap=0.2` would discard solutions with objective worse than 120 (assuming a minimization objective).

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## PoolSearchMode

	<b>Type:</b>	int
	<b>Default value:</b>	0
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	2

Selects different modes for exploring the MIP search tree

Selects different modes for exploring the MIP search tree. With the default setting (`PoolSearchMode=0`), the MIP solver tries to find an optimal solution to the model. It keeps other solutions found along the way, but those are incidental. By setting this parameter to a non-default value, the MIP search will continue after the optimal solution has been found in order to find additional, high-quality solutions. With a setting of 2, it will find the `n` best solutions, where `n` is determined by the value of the `PoolSolutions` parameter. With a setting of 1, it will try to find additional solutions, but with no guarantees about the quality of those solutions. The cost of the solve will increase with increasing values of this parameter.

Once optimization is complete, the `PoolObjBound` attribute can be used to evaluate the quality of the solutions that were found. For example, a value of `PoolObjBound=100` indicates that there are no other solutions with objective better 100, and thus that any known solutions with objective better than 100 are better than any as-yet undiscovered solutions.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## PoolSolutions

	<b>Type:</b>	int
	<b>Default value:</b>	10
	<b>Minimum value:</b>	1
	<b>Maximum value:</b>	2000000000

Number of MIP solutions to store

Determines how many MIP solutions are stored. For the default value of `PoolSearchMode`, these are just the solutions that are found along the way in the process of exploring the MIP search tree. For other values of `PoolSearchMode`, this parameter sets a target for how many solutions to find, so larger values will impact performance.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## PreCrush

	<b>Type:</b>	int
Controls presolve reductions that affect user cuts	<b>Default value:</b>	0
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	1

Allows presolve to translate constraints on the original model to equivalent constraints on the presolved model. You must turn this parameter on when you are using callbacks to add your own cuts.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## PreDepRow

	<b>Type:</b>	int
Controls the presolve dependent row reduction	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	1

Controls the presolve dependent row reduction, which eliminates linearly dependent constraints from the constraint matrix. The default setting (-1) applies the reduction to continuous models but not to MIP models. Setting 0 turns the reduction off for all models. Setting 1 turns it on for all models.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## PreDual

	<b>Type:</b>	int
Controls presolve model dualization	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls whether presolve forms the dual of a continuous model. Depending on the structure of the model, solving the dual can reduce overall solution time. The default setting uses a heuristic to decide. Setting 0 forbids presolve from forming the dual, while setting 1 forces it to take the dual. Setting 2 employs a more expensive heuristic that forms both the presolved primal and dual models (on two threads), and heuristically chooses one of them.

**Note:** LP only

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## PreMIQCPForm

	<b>Type:</b>	int
Format of presolved MIQCP model	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Determines the format of the presolved version of an MIQCP model. Option 0 leaves the model in MIQCP form, so the branch-and-cut algorithm will operate on a model with arbitrary quadratic constraints. Option 1 always transforms the model into MISOCP form; quadratic constraints are transformed into second-order cone constraints. Option 2 always transforms the model into disaggregated MISOCP form; quadratic constraints are transformed into rotated cone constraints, where each rotated cone contains two terms and involves only three variables.

The default setting (-1) choose automatically. The automatic setting works well, but there are cases where forcing a different form can be beneficial.

**Note:** Only affects MIQCP models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

### PrePasses

	<b>Type:</b>	int
Presolve pass limit	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	MAXINT

Limits the number of passes performed by presolve. The default setting (-1) chooses the number of passes automatically. You should experiment with this parameter when you find that presolve is consuming a large fraction of total solve time.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

### PreQLinearize

	<b>Type:</b>	int
Presolve quadratic linearization	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	1

Controls presolve Q matrix linearization. Option 1 attempts to linearize quadratic constraints or a quadratic objective, potentially transforming an MIQP or MIQCP into an MILP. Option 0 shuts off the transformation. The default setting (-1) choose automatically. The automatic setting works well, but there are cases where forcing Q linearization can be beneficial.

**Note:** Only affects MIQP and MIQCP models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

### Presolve

	<b>Type:</b>	int
Controls the presolve level	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls the presolve level. A value of -1 corresponds to an automatic setting. Other options are off (0), conservative (1), or aggressive (2). More aggressive application of presolve takes more time, but can sometimes lead to a significantly tighter model.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## PreSOS1BigM

	<b>Type:</b>	double
	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	1e10
Threshold for SOS1-to-binary reformulation		

Controls the automatic reformulation of SOS1 constraints into binary form. SOS1 constraints are often handled more efficiently using a binary representation. The reformulation often requires **big-M** values to be introduced as coefficients. This parameter specifies the largest **big-M** that can be introduced by presolve when performing this reformulation. Larger values increase the chances that an SOS1 constraint will be reformulated, but very large values (e.g., 1e8) can lead to numerical issues.

The default value of -1 chooses a threshold automatically. You should set the parameter to 0 to shut off SOS1 reformulation entirely, or a large value to force reformulation.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

Please refer to [this section](#) for more information on SOS constraints.

## PreSOS2BigM

	<b>Type:</b>	double
	<b>Default value:</b>	0
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	1e10
Threshold for SOS2-to-binary reformulation		

Controls the automatic reformulation of SOS2 constraints into binary form. SOS2 constraints are often handled more efficiently using a binary representation. The reformulation often requires **big-M** values to be introduced as coefficients. This parameter specifies the largest **big-M** that can be introduced by presolve when performing this reformulation. Larger values increase the chances that an SOS2 constraint will be reformulated, but very large values (e.g., 1e8) can lead to numerical issues.

The default value of 0 disables the reformulation. You can set the parameter to -1 to choose an automatic approach, or a large value to force reformulation.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

Please refer to [this section](#) for more information on SOS constraints.

## PreSparsify

	<b>Type:</b>	int
Controls the presolve sparsify reduction	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	1

Controls the presolve sparsify reduction. This reduction can sometimes significantly reduce the number of nonzero values in the presolved model. Value 0 shuts off the reduction, while value 1 forces it on. The default value of -1 chooses automatically.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ProjImpliedCuts

	<b>Type:</b>	int
Projected implied bound cut generation	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls projected implied bound cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the [Cuts](#) parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## PSDTol

	<b>Type:</b>	double
Positive semi-definite tolerance	<b>Default value:</b>	1e-6
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	Infinity

Sets a limit on the amount of diagonal perturbation that the optimizer is allowed to perform on a Q matrix in order to correct minor PSD violations. If a larger perturbation is required, the optimizer will terminate with a GRB\_ERROR\_Q\_NOT\_PSD error.

**Note:** Only affects QP/QCP/MIQP/MIQCP models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## PumpPasses

	<b>Type:</b>	int
	<b>Default value:</b>	-1
Passes of the feasibility pump heuristic	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	MAXINT

Number of passes of the feasibility pump heuristic. Note that this heuristic is only applied at the end of the MIP root, and only when no other root heuristic finds a feasible solution.

This heuristic is quite expensive, and generally produces poor quality solutions. You should generally only use it if other means, including exploration of the tree with default settings, fail to produce a feasible solution.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## QCPDual

	<b>Type:</b>	int
	<b>Default value:</b>	0
Dual variables for QCP models	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	1

Determines whether dual variable values are computed for QCP models. Computing them can add significant time to the optimization, so you should only set this parameter to 1 if you need them.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## Quad

	<b>Type:</b>	int
	<b>Default value:</b>	-1
Controls quad precision in simplex	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	1

Enables or disables quad precision computation in simplex. The -1 default setting allows the algorithm to decide. Quad precision can sometimes help solve numerically challenging models, but it can also significantly increase runtime.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## Record

	<b>Type:</b>	int
	<b>Default value:</b>	0
Enables API call recording	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	1

Enables API call recording. When enabled, Gurobi will write one or more files (named `gurobi000.grbr` or similar) that capture the sequence of Gurobi commands that your program issued. This file can subsequently be replayed using the [Gurobi command-line tool](#). Replaying the file will repeat the exact same sequence of commands, and when completed will show the time spent in Gurobi API routines, the time spent in Gurobi algorithms, and will indicate whether any Gurobi environments or models were leaked by your program. Replay files are particularly useful in tech support situations. They provide an easy way to relay to Gurobi tech support the exact sequence of Gurobi commands that led to a question or issue.

This parameter must be set as soon as you create your Gurobi environment (or in a `gurobi.env` file). All Gurobi commands will be recorded until the environment is freed or the program ends. Changing the parameter value back to 0 has no effect.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ResultFile

Write a result file upon completion of optimization **Type:** string  
**Default value:** ""

Specifies the name of the result file to be written upon completion of optimization. The type of the result file is determined by the file suffix. The most commonly used suffixes are `.sol` (to capture the solution vector), `.bas` (to capture the simplex basis), and `.mst` (to capture the solution vector on the integer variables). You can also write a `.ilp` file (to capture the IIS for an infeasible model), or a `.mps`, `.rew`, `.lp`, or `.rlp` file (to capture the original model). The file suffix may optionally be followed by `.gz`, `.bz2`, or `.7z`, which produces a compressed result.

More information on the file formats can be found in the [File Format](#) section.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## RINS

Relaxation Induced Neighborhood Search (RINS) heuristic frequency **Type:** int  
**Default value:** -1  
**Minimum value:** -1  
**Maximum value:** MAXINT

Frequency of the RINS heuristic. Default value (-1) chooses automatically. A value of 0 shuts off RINS. A positive value `n` applies RINS at every `n-th` node of the MIP search tree.

Increasing the frequency of the RINS heuristic shifts the focus of the MIP search away from proving optimality, and towards finding good feasible solutions. We recommend that you try [MIPFocus](#), [ImproveStartGap](#), or [ImproveStartTime](#) before experimenting with this parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ScaleFlag

	<b>Type:</b>	int
Model scaling	<b>Default value:</b>	1
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	2

Controls model scaling. By default, the rows and columns of the model are scaled in order to improve the numerical properties of the constraint matrix. The scaling is removed before the final solution is returned. Scaling typically reduces solution times, but it may lead to larger constraint violations in the original, unscaled model. Turning off scaling (`ScaleFlag=0`) can sometimes produce smaller constraint violations. Choosing a more aggressive scaling option (`ScaleFlag=2`) can sometimes improve performance for particularly numerically difficult models.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## Seed

	<b>Type:</b>	int
Random number seed	<b>Default value:</b>	0
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	MAXINT

Modifies the random number seed. This acts as a small perturbation to the solver, and typically leads to different solution paths.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## Sifting

	<b>Type:</b>	int
Controls sifting within dual simplex	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Enables or disables sifting within dual simplex. Sifting can be useful for LP models where the number of variables is many times larger than the number of constraints (we typically only see significant benefits when the ratio is 100 or more). Options are Automatic (-1), Off (0), Moderate (1), and Aggressive (2). With a Moderate setting, sifting will be applied to LP models and to the root node for MIP models. With an Aggressive setting, sifting will be applied any time dual simplex is used, including at the nodes of a MIP. Note that this parameter has no effect if you aren't using dual simplex. Note also that Gurobi will ignore this parameter in cases where sifting is obviously a worse choice than dual simplex.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## SiftMethod

	<b>Type:</b>	int
LP method used to solve sifting sub-problems	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

LP method used to solve sifting sub-problems. Options are Automatic (-1), Primal Simplex (0), Dual Simplex (1), and Barrier (2). Note that this parameter only has an effect when you are using dual simplex and sifting has been selected (either automatically by dual simplex, or through the [Sifting](#) parameter).

Changing the value of this parameter rarely produces a significant benefit.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## SimplexPricing

	<b>Type:</b>	int
Simplex pricing strategy	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	3

Determines the simplex variable pricing strategy. Available options are Automatic (-1), Partial Pricing (0), Steepest Edge (1), Devex (2), and Quick-Start Steepest Edge (3).

Changing the value of this parameter rarely produces a significant benefit.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## SolutionLimit

	<b>Type:</b>	int
MIP solution limit	<b>Default value:</b>	MAXINT
	<b>Minimum value:</b>	1
	<b>Maximum value:</b>	MAXINT

Limits the number of feasible MIP solutions found. Optimization returns with a `SOLUTION_LIMIT` status once the limit has been reached (see the [Status Code](#) section for further details).

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## SolutionNumber

	<b>Type:</b>	int
Select a sub-optimal MIP solution	<b>Default value:</b>	0
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	MAXINT

When querying attribute [Xn](#), [ObjNVal](#), or [PoolObjVal](#) to retrieve an alternate MIP solution, this parameter determines which alternate solution is retrieved. The value of this parameter should be less than the value of the [SolCount](#) attribute.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## StrongCGCuts

	<b>Type:</b>	int
Strong-CG cut generation	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls Strong Chvátal-Gomory (Strong-CG) cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the [Cuts](#) parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## SubMIPCuts

	<b>Type:</b>	int
Sub-MIP cut generation	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls sub-MIP cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the [Cuts](#) parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## SubMIPNodes

	<b>Type:</b>	int
Nodes explored in sub-MIP heuristics	<b>Default value:</b>	500
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	MAXINT

Limits the number of nodes explored by the RINS heuristic. Exploring more nodes can produce better solutions, but it generally takes longer.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## Symmetry

	<b>Type:</b>	int
MIP symmetric detection	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	2

Controls MIP symmetry detection. A value of -1 corresponds to an automatic setting. Other options are off (0), conservative (1), or aggressive (2).

Changing the value of this parameter rarely produces a significant benefit.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## Threads

	<b>Type:</b>	int
Thread count	<b>Default value:</b>	0
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	NProc

Controls the number of threads to apply to parallel algorithms (concurrent LP, parallel barrier, parallel MIP, etc.). The default value of 0 is an automatic setting. It will generally use all of the cores in the machine, but it may choose to use fewer.

While you will generally get the best performance by using all available cores in your machine, there are a few exceptions. One is of course when you are sharing a machine with other jobs. In this case, you should select a thread count that doesn't oversubscribe the machine.

We have also found that certain classes of MIP models benefit from reducing the thread count, often all the way down to one thread. Starting multiple threads introduces contention for machine resources. For classes of models where the first solution found by the MIP solver is almost always optimal, and that solution isn't found at the root, it is often better to allow a single thread to explore the search tree uncontended.

Another situation where reducing the thread count can be helpful is when memory is tight. Each thread can consume a significant amount of memory.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## TimeLimit

	<b>Type:</b>	double
Time limit	<b>Default value:</b>	Infinity
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	Infinity

Limits the total time expended (in seconds). Optimization returns with a `TIME_LIMIT` status if the limit is exceeded (see the [Status Code](#) section for further details).

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## TuneCriterion

	<b>Type:</b>	int
	<b>Default value:</b>	-1
Tuning criterion	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	3

Modifies the tuning criterion for the tuning tool. The primary tuning criterion is always to minimize the runtime required to find a proven optimal solution. However, for MIP models that don't solve to optimality within the specified time limit, a secondary criterion is needed. Set this parameter to 1 to use the optimality gap as the secondary criterion. Choose a value of 2 to use the objective of the best feasible solution found. Choose a value of 3 to use the best objective bound. Choose 0 to ignore the secondary criterion and focus entirely on minimizing the time to find a proven optimal solution. The default value of -1 chooses automatically.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## TuneJobs

	<b>Type:</b>	int
	<b>Default value:</b>	0
Distributed tuning job count	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	MAXINT

Enables distributed parallel tuning, which can significantly increase the performance of the tuning tool. A value of `n` causes the tuning tool to distribute tuning work among `n` parallel jobs. These jobs are distributed among a set of machines. Use the [WorkerPool](#) parameter to provide a list of available distributed worker machines.

Note that distributed tuning is most effective when the worker machines have similar performance. Distributed tuning doesn't attempt to normalize performance by server, so it can incorrectly attribute a boost in performance to a parameter change when the associated setting is tried on a worker that is significantly faster than the others.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## TuneOutput

	<b>Type:</b>	int
	<b>Default value:</b>	2
Tuning output level	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	3

Controls the amount of output produced by the tuning tool. Level 0 produces no output; level 1 produces tuning summary output only when a new best parameter set is found; level 2 produces

tuning summary output for each parameter set that is tried; level 3 produces tuning summary output, plus detailed solver output, for each parameter set tried.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## TuneResults

	<b>Type:</b>	int
	<b>Default value:</b>	-1
	<b>Minimum value:</b>	1
	<b>Maximum value:</b>	MAXINT

Number of improved parameter sets returned

The tuning tool often finds multiple parameter sets that produce better results than the baseline settings. This parameter controls how many of these sets should be retained when tuning is complete. The default value retains the best results that were found for each count of changed parameters. In other words, it retains the best result for one changed parameter, for two changed parameter, etc. Results that aren't on the efficient frontier are discard.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## TuneTimeLimit

	<b>Type:</b>	double
	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	Infinity

Tuning tool time limit

Limits total tuning runtime (in seconds). The default setting (-1) chooses a time limit automatically.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## TuneTrials

	<b>Type:</b>	int
	<b>Default value:</b>	3
	<b>Minimum value:</b>	1
	<b>Maximum value:</b>	MAXINT

Perform multiple runs on each parameter set to limit the effect of random noise

Performance on a MIP model can sometimes experience significant variations due to random effects. As a result, the tuning tool may return parameter sets that improve on the baseline only due to randomness. This parameter allows you to perform multiple solves for each parameter set, using different [Seed](#) values for each, in order to reduce the influence of randomness on the results.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## UpdateMode

	<b>Type:</b>	int
Changes the behavior of lazy updates	<b>Default value:</b>	1
	<b>Minimum value:</b>	0
	<b>Maximum value:</b>	1

Determines how newly added variables and linear constraints are handled. The default setting (1) allows you to use new variables and constraints immediately for building or modifying the model. A setting of 0 requires you to call `update` before these can be used.

Since the vast majority of programs never query Gurobi for details about the optimization models they build, the default setting typically removes the need to call `update`, or even be aware of the details of our *lazy update* approach for handling model modifications. However, these details will show through when you try to query modified model information.

In the Gurobi interface, model modifications (bound changes, right-hand side changes, objective changes, etc.) are placed in a queue. These queued modifications are applied to the model at three times: when you call `update`, when you call `optimize`, or when you call `write` to write the model to disk. When you query information about the model, the result will depend on both *whether* that information was modified and *when* it was modified. In particular, if the modification is sitting in the queue, you'll get the result from before the modification. Note that this lazy update behavior is independent of the value of the `UpdateMode` parameter.

The only potential benefit to changing the parameter to 0 is that in unusual cases this setting may allow simplex make more aggressive use of warm-start information after a model modification.

If you want to change this parameter, you need to set it as soon as you create your Gurobi environment.

Note that you still need to call `update` to modify an attribute on an SOS constraint, quadratic constraint, or general constraint.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## VarBranch

	<b>Type:</b>	int
Branch variable selection strategy	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	3

Controls the branch variable selection strategy. The default -1 setting makes an automatic choice, depending on problem characteristics. Available alternatives are Pseudo Reduced Cost Branching (0), Pseudo Shadow Price Branching (1), Maximum Infeasibility Branching (2), and Strong Branching (3).

Changing the value of this parameter rarely produces a significant benefit.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## WorkerPassword

Distributed worker password      **Type:**                    string  
   **Default value:**    ""

When using a distributed algorithm (distributed MIP, distributed concurrent, or distributed tuning), this parameter allows you to specify the password for the distributed workers listed in the [WorkerPool](#) parameter.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## WorkerPool

Pool of machines to use for distributed algorithms      **Type:**                    string  
   **Default value:**    ""

When using a distributed algorithm (distributed MIP, distributed concurrent, or distributed tuning), this parameter allows you to specify a comma-separated list of machines that can be used as workers. These machines must be running Gurobi Remote Services. You can refer to these workers using their names or their IP addresses. You should specify the access password, if there is one, in the [WorkerPassword](#) parameter.

To give an example, if you have two machines named `server1.mydomain.com` and `server2.mydomain.com`, with IP addresses 192.168.1.100 and 192.168.1.101, you could set the `WorkerPool` to `"server1.mydomain.com,server2.mydomain.com"` or `"192.168.1.100,192.168.1.101"`.

As shown in the examples above, when specifying multiple machines, the next machine should immediately follow the comma separator. You should *not* include any spaces before, after, or between, machine names or IP addresses.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## WorkerPort

Non-default port number for distributed workers      **Type:**                    int  
   **Default value:**    -1  
   **Minimum value:**   -1  
   **Maximum value:**   65536

When using a distributed algorithm (distributed MIP, distributed concurrent, or distributed tuning), this parameter allows you to specify a non-default port number for the distributed worker machines. All workers should use the same port number. The list of distributed workers should be specified via the [WorkerPool](#) parameter.

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ZeroHalfCuts

Zero-half cut generation      **Type:**                    int  
   **Default value:**    -1  
   **Minimum value:**   -1  
   **Maximum value:**   2

Controls zero-half cut generation. Use 0 to disable these cuts, 1 for moderate cut generation, or 2 for aggressive cut generation. The default -1 value chooses automatically. Overrides the [Cuts](#) parameter.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## ZeroObjNodes

	<b>Type:</b>	int
Zero-objective heuristic	<b>Default value:</b>	-1
	<b>Minimum value:</b>	-1
	<b>Maximum value:</b>	MAXINT

Number of nodes to explore in the zero objective heuristic. Note that this heuristic is only applied at the end of the MIP root, and only when no other root heuristic finds a feasible solution.

This heuristic is quite expensive, and generally produces poor quality solutions. You should generally only use it if other means, including exploration of the tree with default settings, fail to produce a feasible solution.

**Note:** Only affects mixed integer programming (MIP) models

For examples of how to query or modify parameter values from our different APIs, refer to our [Parameter Examples](#).

## 11.3 Parameter Examples

While the meanings of the various Gurobi parameters remain constant between the different language API's, the methods used to query or modify them vary. Refer to the following sections for detailed examples of how to work with parameters from our various API's:

- [C](#)
- [C++](#)
- [C#](#)
- [Java](#)
- [MATLAB](#)
- [Python](#)
- [R](#)
- [Visual Basic](#)

You can also browse our [Examples](#) to get a better sense of how to use our parameter interface.

One important note about integer-valued parameters: while the maximum value that can be stored in a signed integer is  $2^{31} - 1$ , we use a `MAXINT` value of 2,000,000,000. Attempting to set an integer parameter to a value larger than this maximum will produce an error.

## C Parameter Examples

The C interface defines a symbolic constant for each parameter. The symbolic constant name is prefixed by `GRB_type_PAR_`, where `type` is either `INT`, `DBL`, or `STR`. This is followed by the capitalized parameter name. For example, the symbolic constant for the integer [Threads](#) parameter (found in C header file `gurobi_c.h`) is:

```
#define GRB_INT_PAR_THREADS "Threads"
```

The routine you use to modify a parameter value depends on the type of the parameter. For a double-valued parameter, you would use [GRBsetdblparam](#). Recall that models get their own environments once they are created, so you'll generally need to get the environment for a model before setting a parameter on that model.

To set the [TimeLimit](#) parameter for a model, you'd do:

```
modelenv = GRBgetenv(model);  
...  
error = GRBsetdblparam(modelenv, GRB_DBL_PAR_TIMELIMIT, 100.0);
```

If you'd prefer to use a string for the parameter name, you can also do:

```
error = GRBsetdblparam(modelenv, "TimeLimit", 100.0);
```

The case of the string is ignored, as are underscores. Thus, `TimeLimit` and `TIME_LIMIT` are equivalent.

Use [GRBgetdblparam](#) to query the current value of a parameter:

```
double currentvalue;  
error = GRBgetdblparam(modelenv, "TimeLimit", &currentvalue);
```

## C++ Parameter Examples

In the C++ interface, parameters are grouped by datatype into three `enums`: `GRB_DoubleParam`, `GRB_IntParam`, and `GRB_StringParam`. You refer to a specific parameter by appending the parameter name to the enum name. For example, the [Threads](#) parameter is `GRB_IntParam_Threads`.

To modify a parameter, you use [GRBModel::set](#). Recall that you can also set parameters on an environment, but changes to the environment won't affect models that have already been created using that environment. It is generally simpler to set parameters on the model itself.

To set the [TimeLimit](#) parameter for a model, you'd do:

```
GRBModel *m = ...;  
m->set(GRB_DoubleParam_TimeLimit, 100.0);
```

You can also set the value of a parameter using strings for the parameter name and desired value. For example:

```
GRBModel *m = ...;  
m->set("TimeLimit", "100.0");
```

Use [GRBModel::get](#) to query the current value of a parameter:

```
currentlimit = m.get(GRB_DoubleParam_TimeLimit);
```

## C# Parameter Examples

In the C# interface, parameters are grouped by datatype into three enums: `GRB.DoubleParam`, `GRB.IntParam`, and `GRB.StringParam`. You would refer to the integer `Threads` parameter as `GRB.IntParam.Threads`.

To modify a parameter, set the corresponding .NET property from `Model.Parameters`. To set the `TimeLimit` parameter, for example:

```
GRBModel m = ...;
m.Parameters.TimeLimit = 100.0;
```

You can also use `GRBModel.Set`:

```
m.Set(GRB.DoubleParam.TimeLimit, 100.0);
```

You can also set the value of a parameter using strings for the parameter name and desired value. For example:

```
GRBModel m = ...;
m.Set("TimeLimit", "100.0");
```

To query the current value of a parameter, use:

```
currentlimit = m.Parameters.TimeLimit;
```

You can also use `GRBModel.Get`:

```
currentlimit = m.Get(GRB.DoubleParam.TimeLimit);
```

## Java Parameter Examples

In the Java interface, parameters are grouped by datatype into three enums: `GRB.DoubleParam`, `GRB.IntParam`, and `GRB.StringParam`. You would refer to the integer `Threads` parameter as `GRB.IntParam.Threads`.

To modify a parameter, you use `GRBModel.set`. Recall that you can also set parameters on an environment, but changes to the environment won't affect models that have already been created using that environment. It is generally simpler to set parameters on the model itself.

To set the `TimeLimit` parameter for a model, you'd do:

```
GRBModel m = ...;
m.set(GRB.DoubleParam.TimeLimit, 100.0);
```

You can also set the value of a parameter using strings for the parameter name and desired value. For example:

```
GRBModel m = ...;
m.set("TimeLimit", "100.0");
```

Use `GRBModel.get` to query the current value of a parameter:

```
currentlimit = m.get(GRB.DoubleParam.TimeLimit);
```

## MATLAB Parameter Examples

In the MATLAB interface, parameters are passed to Gurobi through a `struct`. To modify a parameter, you create a field in the `struct` with the appropriate name, and set it to the desired value. For example, to set the `TimeLimit` parameter to 100 you'd do:

```
params.timelimit = 100;
```

The case of the parameter name is ignored, as are underscores. Thus, you could also do:

```
params.timeLimit = 100;
```

...or...

```
params.TIME_LIMIT = 100;
```

All desired parameter changes should be stored in a single `struct`, which is passed as the second parameter to the `gurobi` function.

## Python Parameter Examples

In the Python interface, parameters are listed as constants within the `GRB.Param` class. You would refer to the `Threads` parameter as `GRB.Param.Threads`.

To modify a parameter, you can set the appropriate member of `Model.Params`. To set the time limit for model `m`, you'd do:

```
m.Params.timeLimit = 100.0
```

The case of the parameter name is actually ignored, as are underscores, so you could also do:

```
m.Params.timelimit = 100.0
```

...or...

```
m.Params.TIME_LIMIT = 100.0
```

You can also use the `Model.setParam` method:

```
m.setParam(GRB.Param.TimeLimit, 100.0)
```

If you'd prefer to use a string for the parameter name, you can also do:

```
m.setParam("TimeLimit", 100.0);
```

To query the current value of a parameter, use:

```
currentlimit = m.Params.timeLimit
```

## R Parameter Examples

In the R interface, parameters are passed to Gurobi through a `list`. To modify a parameter, you create a `named` component in the `list` with the appropriate name, and set it to the desired value. For example, to set the `TimeLimit` parameter to 100 you'd do:

```
params <- list(TimeLimit=100)
```

The case of the parameter name is ignored, as are underscores. Thus, you could also do:

```
params <- list(timeLimit = 100)
```

...or...

```
params <- list(TIME_LIMIT = 100)
```

All desired parameter changes should be stored in a single `list`, which is passed as the second parameter to the `gurobi` function.

## Visual Basic Parameter Examples

In the Visual Basic interface, parameters are grouped by datatype into three `enums`: `GRB.DoubleParam`, `GRB.IntParam`, and `GRB.StringParam`. You would refer to the integer `Threads` parameter as `GRB.IntParam.Threads`.

To modify a parameter, set the corresponding `.NET` property from `Model.Parameters`. To set the `TimeLimit` parameter, for example:

```
GRBModel m = ...  
m.Parameters.TimeLimit = 100.0
```

You can also use `GRBModel.Set`:

```
m.Set(GRB.DoubleParam.TimeLimit, 100.0)
```

You can also set the value of a parameter using strings for the parameter name and desired value. For example:

```
GRBModel m = ...  
m.Set("TimeLimit", "100.0")
```

To query the current value of a parameter, use:

```
currentlimit = m.Parameters.TimeLimit
```

You can also use `GRBModel.Get`:

```
currentlimit = m.Get(GRB.DoubleParam.TimeLimit)
```

# Optimization Status Codes

Once an optimize call has returned, the Gurobi optimizer sets the [Status](#) attribute of the model to one of several possible values. The attribute takes an integer value, but we recommend that you use one of the pre-defined status constants to check the status in your program. Each code has a name, and each language requires a prefix on this name to obtain the appropriate constant. You would access status code `OPTIMAL` in the following ways from the available Gurobi interfaces:

Language	Status Code
C	<code>GRB_OPTIMAL</code>
C++	<code>GRB_OPTIMAL</code>
Java	<code>GRB.Status.OPTIMAL</code>
.NET	<code>GRB.Status.OPTIMAL</code>
Python	<code>GRB.OPTIMAL</code>

Possible status codes are as follows:

Status code	Value	Description
<code>LOADED</code>	1	Model is loaded, but no solution information is available.
<code>OPTIMAL</code>	2	Model was solved to optimality (subject to tolerances), and an optimal solution is available.
<code>INFEASIBLE</code>	3	Model was proven to be infeasible.
<code>INF_OR_UNBD</code>	4	Model was proven to be either infeasible or unbounded. To obtain a more definitive conclusion, set the <a href="#">DualReductions</a> parameter to 0 and reoptimize.
<code>UNBOUNDED</code>	5	Model was proven to be unbounded. <i>Important note: an unbounded status indicates the presence of an unbounded ray that allows the objective to improve without limit. It says nothing about whether the model has a feasible solution. If you require information on feasibility, you should set the objective to zero and reoptimize.</i>
<code>CUTOFF</code>	6	Optimal objective for model was proven to be worse than the value specified in the <code>Cutoff</code> parameter. No solution information is available.
<code>ITERATION_LIMIT</code>	7	Optimization terminated because the total number of simplex iterations performed exceeded the value specified in the <code>IterationLimit</code> parameter, or because the total number of barrier iterations exceeded the value specified in the <code>BarIterLimit</code> parameter.
<code>NODE_LIMIT</code>	8	Optimization terminated because the total number of branch-and-cut nodes explored exceeded the value specified in the <code>NodeLimit</code> parameter.
<code>TIME_LIMIT</code>	9	Optimization terminated because the time expended exceeded the value specified in the <code>TimeLimit</code> parameter.

<b>SOLUTION_LIMIT</b>	10	Optimization terminated because the number of solutions found reached the value specified in the <code>SolutionLimit</code> parameter.
<b>INTERRUPTED</b>	11	Optimization was terminated by the user.
<b>NUMERIC</b>	12	Optimization was terminated due to unrecoverable numerical difficulties.
<b>SUBOPTIMAL</b>	13	Unable to satisfy optimality tolerances; a sub-optimal solution is available.
<b>INPROGRESS</b>	14	An asynchronous optimization call was made, but the associated optimization run is not yet complete.
<b>USER_OBJ_LIMIT</b>	15	User specified an objective limit (a bound on either the <a href="#">best objective</a> or the <a href="#">best bound</a> ), and that limit has been reached.

The Gurobi callback routines make use of a pair of arguments: **where** and **what**. When a user callback function is called, the **where** argument indicates from where in the Gurobi optimizer it is being called (presolve, simplex, barrier, MIP, etc.). When the user callback wishes to obtain more detailed information about the state of the optimization, the **what** argument can be passed to an appropriate **get** method for your language to obtain additional information (e.g., [GRBcbget](#) in C, [GRBCallback::getIntInfo](#) in C++, [GRBCallback.getIntInfo](#) in Java, [GRBCallback.GetIntInfo](#) in .NET, and [Model.cbGet](#) in Python).

More detailed information on how to use callbacks in your application can be found in the reference manuals for the different Gurobi language interfaces (C, C++, Java, .NET, and Python).

Possible values for the **where** and **what** arguments are listed in the following tables. Note that these values are referred to in slightly different ways from the different Gurobi interfaces. Consider the **SIMPLEX** value as an example. You would refer to this constant as follows from the different Gurobi APIs:

Language	Callback constant
C	GRB_CB_SIMPLEX
C++	GRB_CB_SIMPLEX
Java	GRB.Callback.SIMPLEX
.NET	GRB.Callback.SIMPLEX
Python	GRB.Callback.SIMPLEX

Possible **where** values are:

where	Numeric value	Optimizer status
<b>POLLING</b>	0	Periodic polling callback
<b>PRESOLVE</b>	1	Currently performing presolve
<b>SIMPLEX</b>	2	Currently in simplex
<b>MIP</b>	3	Currently in MIP
<b>MIPSOL</b>	4	Found a new MIP incumbent
<b>MIPNODE</b>	5	Currently exploring a MIP node
<b>MESSAGE</b>	6	Printing a log message
<b>BARRIER</b>	7	Currently in barrier

Allowable **what** values depend on the value of the **where** argument. Valid combinations are:

what	where	Result type	Description
<b>RUNTIME</b>	Any except <b>POLLING</b>	double	Elapsed solver runtime (seconds).
<b>PRE_COLDEL</b>	<b>PRESOLVE</b>	int	The number of columns removed by presolve to this point.
<b>PRE_ROWDEL</b>	<b>PRESOLVE</b>	int	The number of rows removed by presolve to this point.

PRE_SENCHG	PRESOLVE	int	The number of constraint senses changed by presolve to this point.
PRE_BNDCHG	PRESOLVE	int	The number of variable bounds changed by presolve to this point.
PRE_COECHG	PRESOLVE	int	The number of coefficients changed by presolve to this point.
SPX_ITRCNT	SIMPLEX	double	Current simplex iteration count.
SPX_OBJVAL	SIMPLEX	double	Current simplex objective value.
SPX_PRIMINF	SIMPLEX	double	Current primal infeasibility.
SPX_DUALINF	SIMPLEX	double	Current dual infeasibility.
SPX_ISPERT	SIMPLEX	int	Is problem current perturbed?
MIP_OBJBST	MIP	double	Current best objective.
MIP_OBJBND	MIP	double	Current best objective bound.
MIP_NODCNT	MIP	double	Current explored node count.
MIP_SOLCNT	MIP	int	Current count of feasible solutions found.
MIP_CUTCNT	MIP	int	Current count of cutting planes applied.
MIP_NODLFT	MIP	double	Current unexplored node count.
MIP_ITRCNT	MIP	double	Current simplex iteration count.
MIPSOL_SOL	MIPSOL	double *	Solution vector for new solution (C only). The resultP argument to C routine <a href="#">GRBcbget</a> should point to an array of doubles that is at least as long as the number of variables in the user model. Use the <code>getSolution</code> callback method in the object-oriented interfaces.
MIPSOL_OBJ	MIPSOL	double	Objective value for new solution.
MIPSOL_OBJBST	MIPSOL	double	Current best objective.
MIPSOL_OBJBND	MIPSOL	double	Current best objective bound.
MIPSOL_NODCNT	MIPSOL	double	Current explored node count.
MIPSOL_SOLCNT	MIPSOL	int	Current count of feasible solutions found.
MIPNODE_STATUS	MIPNODE	int	Optimization status of current MIP node (see the <a href="#">Status Code</a> section for further information).
MIPNODE_OBJBST	MIPNODE	double	Current best objective.
MIPNODE_OBJBND	MIPNODE	double	Current best objective bound.
MIPNODE_NODCNT	MIPNODE	double	Current explored node count.
MIPNODE_SOLCNT	MIPNODE	int	Current count of feasible solutions found.

<b>MIPNODE_REL</b>	<b>MIPNODE</b>	double *	Relaxation solution for the current node, when its optimization status is <code>GRB_OPTIMAL</code> (C only). The <code>resultP</code> argument to C routine <code>GRBcbget</code> should point to an array of doubles that is at least as long as the number of variables in the user model. Use the <code>getNodeRel</code> callback method in the object-oriented interfaces.
<b>BARRIER_ITRCNT</b>	<b>BARRIER</b>	int	Current barrier iteration count.
<b>BARRIER_PRIMOBJ</b>	<b>BARRIER</b>	double	Primal objective value for current barrier iterate.
<b>BARRIER_DUALOBJ</b>	<b>BARRIER</b>	double	Dual objective value for current barrier iterate.
<b>BARRIER_PRIMINF</b>	<b>BARRIER</b>	double	Primal infeasibility for current barrier iterate.
<b>BARRIER_DUALINF</b>	<b>BARRIER</b>	double	Dual infeasibility for current barrier iterate.
<b>BARRIER_COMPL</b>	<b>BARRIER</b>	double	Complementarity violation for current barrier iterate.
<b>MSG_STRING</b>	<b>MESSAGE</b>	char *	The message that is being printed.

Remember that the appropriate prefix must be added to the `what` or `where` name listed above, depending on the language you are using.

### Callback notes

Note that the `POLLING` callback does not allow any additional information to be retrieved. It is provided in order to allow interactive applications to regain control frequently, so that they can maintain application responsiveness.

The object-oriented interfaces have specialized methods for obtaining the incumbent or relaxation solution. While in C you would use `GRBcbget`, you use `getSolution` or `getNodeRel` in the object-oriented interfaces. Please consult the callback descriptions for `C++`, `Java`, `.NET`, or `Python` for further details.

Note that the `MIPNODE` callback will be called once for each cut pass during the root node solve. The `MIPNODE_NODCNT` value will remain at 0 until the root node is complete. If you query relaxation values from during the root node, the first `MIPNODE` callback will give the relaxation with no cutting planes, and the last will give the relaxation after all root cuts have been applied.

Errors can arise in most of the Gurobi library routines. In the C interface, library routines return an integer error code. In the C++, Java, .NET, and Python interfaces, Gurobi methods can throw an exception (a [C++ exception](#), a [Java exception](#), a [.NET exception](#), or a [Python exception](#))

Underlying all Gurobi error reporting is a set of error codes. These are integer values, but we recommend that you use one of the pre-defined error code constants to check the error status in your program. Each error code has a name, and each language requires a prefix on this name to obtain the appropriate constant. You would access error code `OUT_OF_MEMORY` in the following ways from the available Gurobi interfaces:

Language	Error Code
C	<code>GRB_ERROR_OUT_OF_MEMORY</code>
C++	<code>GRB_ERROR_OUT_OF_MEMORY</code>
Java	<code>GRB.Error.OUT_OF_MEMORY</code>
.NET	<code>GRB.Error.OUT_OF_MEMORY</code>
Python	<code>GRB.Error.OUT_OF_MEMORY</code>

Note that when an error occurs, it produces both an error code and an error message. The message can be obtained through `GRBgeterrormessage` in C, through `GRBException::getMessage()` in C++, through the inherited `getMessage()` method on the `GRBException` class in Java, through the inherited `Message` property on the `GRBException` class in .NET, or through the `e.message` attribute on the `GurobiError` object in Python.

Possible error codes are:

Error code	Error number	Description
<code>OUT_OF_MEMORY</code>	10001	Available memory was exhausted
<code>NULL_ARGUMENT</code>	10002	NULL input value provided for a required argument
<code>INVALID_ARGUMENT</code>	10003	An invalid value was provided for a routine argument
<code>UNKNOWN_ATTRIBUTE</code>	10004	Tried to query or set an unknown attribute
<code>DATA_NOT_AVAILABLE</code>	10005	Attempted to query or set an attribute that could not be accessed at that time
<code>INDEX_OUT_OF_RANGE</code>	10006	Tried to query or set an attribute, but one or more of the provided indices (e.g., constraint index, variable index) was outside the range of valid values
<code>UNKNOWN_PARAMETER</code>	10007	Tried to query or set an unknown parameter
<code>VALUE_OUT_OF_RANGE</code>	10008	Tried to set a parameter to a value that is outside the parameter's valid range
<code>NO_LICENSE</code>	10009	Failed to obtain a valid license

SIZE_LIMIT_EXCEEDED	10010	Attempted to solve a model that is larger than the limit for a demo license
CALLBACK	10011	Problem in callback
FILE_READ	10012	Failed to read the requested file
FILE_WRITE	10013	Failed to write the requested file
NUMERIC	10014	Numerical error during requested operation
IIS_NOT_INFEASIBLE	10015	Attempted to perform infeasibility analysis on a feasible model
NOT_FOR_MIP	10016	Requested operation not valid for a MIP model
OPTIMIZATION_IN_PROGRESS	10017	Tried to query or modify a model while optimization was in progress
DUPLICATES	10018	Constraint, variable, or SOS contained duplicated indices
NODEFILE	10019	Error in reading or writing a node file during MIP optimization
Q_NOT_PSD	10020	Q matrix in QP model is not positive semi-definite
QCP_EQUALITY_CONSTRAINT	10021	QCP equality constraint specified (only inequalities are supported)
NETWORK	10022	Problem communicating with the Gurobi Compute Server
JOB_REJECTED	10023	Gurobi Compute Server responded, but was unable to process the job (typically because the queuing time exceeded the user-specified timeout or because the queue has exceeded its maximum capacity)
NOT_SUPPORTED	10024	Indicates that a Gurobi feature is not supported under your usage environment (for example, some advanced features are not supported in a Compute Server environment)
EXCEED_2B_NONZEROS	10025	Indicates that the user has called a query routine on a model with more than 2 billion non-zero entries, and the result would exceed the maximum size that can be returned by that query routine. The solution is typically to move to the GRBX version of that query routine.
INVALID_PIECEWISE_OBJ	10026	Piecewise-linear objectives must have certain properties (as described in the documentation for the various <code>setPWLObj</code> methods). This error indicates that one of those properties was violated.
UPDATEMODE_CHANGE	10027	The <code>UpdateMode</code> parameter can not be modified once a model has been create.
CLOUD	10028	Problems launching a Gurobi Instant Cloud job.

<b>MODEL_MODIFICATION</b>	10029	Indicates that the user has modified the model in such a way that the model became invalid. For example, this happens when a general constraint exists in the model and the user deletes the resultant variable of this constraint. In such a case, the general constraint does not have any meaningful interpretation anymore. The solution is to also delete the general constraint when a resultant variable is deleted.
<b>NOT_IN_MODEL</b>	20001	Tried to use a constraint or variable that is not in the model, either because it was removed or because it has not yet been added
<b>FAILED_TO_CREATE_MODEL</b>	20002	Failed to create the requested model
<b>INTERNAL</b>	20003	Internal Gurobi error

The Gurobi optimizer works with a variety of file formats. The [MPS](#), [REW](#), [LP](#), [RLP](#), [ILP](#), and [OPB](#) formats are used to hold optimization models. The [MST](#) format is used to hold MIP start data. Importing this data into a MIP model allows the MIP model to start with a known feasible solution. The [HNT](#) format is used to hold MIP hints. Importing this data into a MIP model guides the MIP search towards a guess at a high-quality feasible solution. The [ORD](#) format is used to hold MIP variable branching priorities. Importing this data into a MIP model affects the search strategy. The [BAS](#) format holds simplex basis information. Importing this data into a continuous models allows the simplex algorithm to start from the given simplex basis. The [SOL](#) format holds a solution vector. It can be written once the model has been optimized. [PRM](#) format holds parameter values. Importing this data into a model changes the values of the referenced parameters.

Note that all of the Gurobi file I/O routines can work with compressed versions of these files. Specifically, we can read or write files with the following extensions: `.zip`, `.gz`, `.bz2`, and `.7z` (assuming that the associated compression tool, e.g., `7zip` for `.7z`, is installed on your machine and a corresponding entry is part of you `PATH` environment variable).

## 15.1 MPS format

MPS format is the oldest and most widely used format for storing math programming models. There are actually two variants of this format in wide use. In fixed format, the various fields must always start at fixed columns in the file. Free format is very similar, but the fields are separated by white space instead of appearing in specific columns. One important practical difference between the two formats is in name length. In fixed format, row and column names are exactly 8 characters, and spaces are part of the name. In free format, names can be arbitrarily long (although the Gurobi reader places a 255 character limit on name length), and names may not contain spaces. The Gurobi MPS reader reads both MPS types, and recognizes the format automatically.

Note that any line that begins with the `*` character is a comment. The contents of that line are ignored.

### NAME section

The first section in an MPS format file is the `NAME` section. It gives the name of the model:

```
NAME          AFIRO
```

In fixed format, the model name starts in column 15.

### ROWS section

The next section is the `ROWS` section. It begins with the word `ROWS` on its own line, and continues with one line for each row in the model. These lines indicate the constraint type (`E` for equality, `L` for less-than-or-equal, or `G` for greater-than-or-equal), and the constraint name. In fixed format, the type appears in column 2 and the row name starts in column 5. Here's a simple example:

## ROWS

```
E R09
E R10
L X05
N COST
```

Note that an N in the type field indicates that the row is a *free row*. The first free row is used as the objective function.

If the file includes multiple N rows, each including a priority, weight, relative, and absolute tolerance field, then each such row is treated as an objective in a multi-objective model. The additional fields must appear after the name, separated by spaces. For example, the following would capture a pair of objectives, where the first has priority 2 and the second has priority 1 (and both have identical weights, and relative and absolute tolerances):

```
N OBJ0 2 1 0 0
N OBJ1 1 1 0 0
```

Please refer to the [multi-objective](#), [ObjNPriority](#), [ObjNWeight](#), [ObjNRelTol](#), and [ObjNAbsTol](#) sections for information on the meanings of these fields. Note that all objectives of a multi-objective optimization problem have to be linear.

## COLUMNS section

The next and typically largest section of an MPS file is the COLUMNS section, which lists the columns in the model and the non-zero coefficients associated with each. Each line in the columns section provides a column name, followed by either zero, one, or two non-zero coefficients from that column. Coefficients are specified using a row name first, followed by a floating-point value. Consider the following example:

### COLUMNS

```
  X01      X48      .301  R09      -1.
  X01      R10     -1.06  X05       1.
  X02      X21     -1.    R09       1.
  X02      COST     -4.
```

The first line indicates that column X01 has a non-zero in row X48 with coefficient .301, and a non-zero in row R09 with coefficient -1.0. Note that multiple lines associated with the same column must be contiguous in the file.

In fixed format, the column name starts in column 5, the row name for the first non-zero starts in column 15, and the value for the first non-zero starts in column 25. If a second non-zero is present, the row name starts in column 40 and the value starts in column 50.

## Integrality markers

The COLUMNS section can optionally include integrality markers. The variables introduced between a pair of markers must take integer values. The beginning of an integer section is marked by an INTORG marker:

```
MARK0000 'MARKER'          'INTORG'
```

The end of the section is marked by an INTEND marker:

```
MARK0000 'MARKER' 'INTEND'
```

The first field (beginning in column 5 in fixed format) is the name of the marker (which is ignored). The second field (in column 15 in fixed format) must be equal to the string 'MARKER' (including the single quotes). The third field (in column 40 in fixed format) is 'INTORG' at the start and 'INTEND' at the end of the integer section.

The COLUMNS section can contain an arbitrary number of such marker pairs.

### RHS section

The next section of an MPS file is the RHS section, which specifies right-hand side values. Each line in this section may contain one or two right-hand side values.

RHS

```
B          X50          310.  X51          300.
B          X05          80.   X17          80.
```

The first line above indicates that row X50 has a right-hand side value of 310, and X51 has a right-hand side value of 300. In fixed format, the variable name for the first bound starts in column 15, and the first bound value starts in column 25. For the second bound, the variable name starts in column 40 and the value starts in column 50. The name of the RHS is specified in the first field (column 5 in fixed format), but this name is ignored by the Gurobi reader. If a row is not mentioned anywhere in the RHS section, that row takes a right-hand side value of 0.

### BOUNDS section

The next section in an MPS file is the optional BOUNDS section. By default, each variable takes a lower bound of 0 and an infinite upper bound. Each line in this section can modify the lower bound of a variable, the upper bound, or both. Each line indicates a bound type (in column 2 in fixed format), a bound name (ignored), a variable name (in column 15 in fixed format), and a bound value (in columns 25 in fixed format). The different bound types, and the meaning of the associate bound value, are as follows:

LO	lower bound
UP	upper bound
FX	variable is fixed at the specified value
FR	free variable (no lower or upper bound)
MI	infinite lower bound
PL	infinite upper bound
BV	variable is binary (equal 0 or 1)
LI	lower bound for integer variable
UI	upper bound for integer variable
SC	upper bound for semi-continuous variable

Consider the following example:

BOUNDS

```
UP BND          X50          80.
LO BND          X51          20.
FX BND          X52          30.
```

In this BOUNDS section, variable X50 gets a upper bound of 80 (lower bound is unchanged at 0, X51 gets a lower bound of 20 (infinite upper bound is unchanged), and X52 is fixed at 30.

### QUADOBJ section

The next section in an MPS file is the optional **QUADOBJ** section, which contains quadratic objective terms. Each line in this section represents a single non-zero value in the lower triangle of the Q matrix. The names of the two variable that participate in the quadratic term are found first (starting in columns 5 and 15 in fixed format), followed by the numerical value of the coefficient (in column 25 in fixed format). By convention, the Q matrix has an implicit one-half multiplier associated with it. Here's an example containing three quadratic terms:

```
QUADOBJ
  X01      X01      10.0
  X01      X02      2.0
  X02      X02      2.0
```

These three terms would represent the quadratic function  $(10X_1^2 + 2X_1 * X_2 + 2X_2 * X_1 + 2X_2^2)/2$  (recall that the single off-diagonal term actually represents a pair of non-zero values in the symmetric Q matrix).

### QCMATRIX section

The next section in an MPS file contains zero or more **QCMATRIX** blocks. These blocks contain the quadratic terms associated with the quadratic constraints. There should be one block for each quadratic constraint in the model.

Each **QCMATRIX** block starts with a line that indicates the name of the associated quadratic constraint (starting in column 12 in fixed format). This is followed by one or more quadratic terms. Each term is described on one line, which gives the names of the two involved variables (starting in columns 5 and 15 in fixed format), followed by the coefficient (in column 25 in fixed format). For example:

```
QCMATRIX  QCO
  X01      X01      10.0
  X01      X02      2.0
  X02      X01      2.0
  X02      X02      2.0
```

These four lines describe three quadratic terms: quadratic constraint **QCO** contains terms  $10X_1^2$ ,  $4X_1 * X_2$ , and  $2X_2^2$ . Note that a **QCMATRIX** block must contain a symmetric matrix, so for example an  $X_1 * X_2$  term must be accompanied by a matching  $X_2 * X_1$  term.

Linear terms for quadratic constraint **QCO** appear in the **COLUMNS** section. The sense and right-hand side value appear in the **ROWS** and **RHS** sections, respectively.

### PWLOBJ section

The next section in an MPS file is the optional **PWLOBJ** section, which contains piecewise-linear objective functions. Each line in this section represents a single point in a piecewise-linear objective function. The name of the associated variable appears first (starting in column 4), followed by the x and y coordinates of the point (starting in columns 14 and 17). Here's an example containing two piecewise-linear expressions, for variables **X01** and **X02**, each with three points:

```
  X01      1  1
  X01      2  2
```

X01	3	4
X02	1	1
X02	3	5
X02	7	10

### SOS section

The next section in an MPS file is the optional **SOS** section. The representation for a single SOS constraint contains one line that provides the type of the SOS set (**S1** for SOS type 1 or **S2** for SOS type 2, found in column 2 in fixed format) and the name of the SOS set (column 5 in fixed format) of the SOS set. This is followed by one line for each SOS member. The member line gives the name of the member (column 5 in fixed format) and the associated weight (column 15 in fixed format). Here's an example containing two SOS2 sets.

SOS

S2	sos1	
	x1	1
	x2	2
	x3	3
S2	sos2	
	x3	1
	x4	2
	x5	3

### Indicator Constraint section

The indicator constraint section is optional in the MPS format. It starts with the keyword **INDICATORS**. Each subsequent line of the indicator section starts with the keyword **IF** (placed at column 2 in fixed format) followed by a space and a row name (the row must have already been defined in the **ROWS** section). The line continues with a binary variable (placed at column 15 in fixed format) and finally a value 0 or 1 (placed at column 25 in fixed format).

Here a simple example:

INDICATORS

IF	row1	x1	0
IF	row2	y1	1

The first indicator constraint in this example states that **row1** has to be fulfilled if the **x1** takes a value of 0.

### General Constraint section

An MPS file may contain an optional section that captures more general constraints. The general constraint section starts with the keyword **GENCONS**.

Each general constraint in this section starts with a general constraint type specifier, such as *MIN*, *MAX*, *OR*, *AND*, or *ABS* (found in column 2 in fixed format). Optionally a space and a name may follow.

What follows this line depends on the general constraint type. All general constraints start with the so-called resultant variable, placed on its own line (starting at column 5 in fixed format). For *MIN* or *MAX* constraints, a non empty list of variables or values follows this (each on its own line).

For *OR* and *AND* constraints, a list of binary variables follows (each on its own line). For *ABS* constraints, one additional variable follows (on its own line). In fixed format all of these variables or values are placed at column 5.

The other general constraint type, the *INDICATOR* constraint, appears in a separate **Indicator** section, which is described above.

The following shows an example of a general constraint section:

```
GENCONS
MAX gc0
    r1
    x1
    x2
    x10
    0.7
MIN gencons1
    r2
    y0
    10
    y1
    r1
AND and1
    r
    b1
    b2
OR or1
    r
    b3
    b4
ABS GC14
    xabs
    x
```

For more information, consult the [general constraint discussion](#).

## ENDATA

The final line in an MPS file must be an **ENDATA** statement.

### Additional notes

Note that in the Gurobi optimizer, MPS models are always written in full precision. That means that if you write a model and then read it back, the data associated with the resulting model will be bit-for-bit identical to the original data.

## 15.2 REW format

The REW format is identical to the [MPS](#) format, except in how objects are named when files are written. When writing an MPS format file, the Gurobi optimizer refers to constraints and variables using their given names. When writing an REW format file, the Gurobi optimizer ignores the

given names and instead refers to the variables using a set of default names that are based on row and column numbers. The constraint name depends solely on the associated row number: row  $i$  gets name  $ci$ . The variable name depends on the type of the variable, the column number of the variable in the constraint matrix, and the number of non-zero coefficients in the associated column. A continuous variable in column 7 with column length 2 would get name  $C7(2)$ , for example. A binary variable with the same characteristics would get name  $B7(2)$ .

## 15.3 LP format

The LP format captures an optimization model in a way that is easier for humans to read than MPS format, and can often be more natural to produce. One limitation of the LP format is that it doesn't preserve several model properties. In particular, LP files do not preserve column order when read, and they typically don't preserve the exact numerical values of the coefficients (although this isn't inherent to the format).

Unlike MPS files, LP files do not rely on fixed field widths. Line breaks and white space characters are used to separate objects. Here is a simple example:

```
\ LP format example

Maximize
  x + y + z
Subject To
  c0: x + y = 1
  c1: x + 5 y + 2 z <= 10
  qc0: x + y + [ x ^ 2 - 2 x * y + 3 y ^ 2 ] <= 5
Bounds
  0 <= x <= 5
  z >= 2
Generals
  x y z
End
```

The backslash symbol starts a comment; the remainder of that line is ignored.

Variable names play a major role in LP files. Each variable must have its own unique name. A name should be no longer than 255 characters, and to avoid confusing the LP parser, it should not begin with a number, or contain any of the characters  $+$ ,  $-$ ,  $*$ ,  $^$ ,  $<$ ,  $>$ ,  $=$ ,  $($ ,  $)$ ,  $[$ ,  $]$ ,  $,$ , or  $:$ .

Note that white space is not optional in the Gurobi LP format. Thus, for example, the text  $x+y+z$  would be treated as a single variable name, while  $x + y + z$  would be treated as a three term expression.

LP files are structured as a list of sections, where each section captures a logical piece of the whole optimization model. Sections begin with particular keywords, and must generally come in a fixed order, although a few are allowed to be interchanged.

### Objective Section

The first section in an LP file is the objective section. This section begins with one of the following six keywords: *minimize*, *maximize*, *minimum*, *maximum*, *min*, or *max*. Capitalization is ignored.

This keyword may appear alone, or it may be immediately followed by *multi-objectives*, which indicates that the model contains multiple objective functions.

### Single-Objective Case

Let us consider single-objective models first, where this header is followed by a single linear or quadratic expression that captures the objective function.

The objective optionally begins with a label. A label consists of a name, followed by a colon character, following by a space. A space is allowed between the name and the colon, but not required.

The objective then continues with a list of linear terms, separated by the + or - operators. A term can contain a coefficient and a variable (e.g., 4.5 x), or just a variable (e.g., x). The objective can be spread over many lines, or it may be listed on a single line. Line breaks can come between tokens, but never within tokens.

The objective may optionally continue with a list of quadratic terms. The quadratic portion of the objective expression begins with a [ symbol and ends with a ] symbol, followed by / 2. These brackets should enclose one or more quadratic terms. Either squared terms (e.g., 2 x ^ 2) or product terms (e.g., 3 x \* y) are accepted. Coefficients on the quadratic terms are optional.

For variables with piecewise-linear objective functions, the objective section will include a `--pwl(x)` term, where x is the name of the variable. You should view these as comments; they are ignored by the LP reader. The actual piecewise-linear expressions are pulled from the later `PWLObj` section.

The objective expression must always end with a line break.

An objective section might look like the following:

Minimize

```
obj: 3.1 x + 4.5 y + 10 z + [ x ^ 2 + 2 x * y + 3 y ^ 2 ] / 2
```

### Multi-Objective Case

In the multi-objective case, the header is followed by one or more linear objective functions, where each starts with its own sub-header. The sub-header gives the name of the objective, followed by a number of optional fields that provide a *Priority*, *Weight*, absolute tolerance (*AbsTol*) and relative tolerance (*RelTol*) for that objective (see [ObjNPriority](#), [ObjNWeight](#), [ObjNRelTol](#), and [ObjNAbsTol](#) for details on the meanings of these fields). The fields start with the field name, followed by a =, followed by the value. For example:

```
OBJ0: Priority=2 Weight=1 AbsTol=0 RelTol=0
```

Please refer to the [multi-objective](#) section for additional details.

Each sub-header is followed by a linear expression that captures that objective.

A complete multi-objective section might look like the following:

Minimize multi-objectives

```
OBJ0: Priority=2 Weight=1 AbsTol=0 RelTol=0
```

```
3.1 x + 4.5 y + 10 z
```

```
OBJ1: Priority=1 Weight=1 AbsTol=0 RelTol=0
```

```
10 x + 0.1 y
```

The objective section is optional. The objective is set to 0 when it is not present.

## Constraints Section

The next section is the constraints section. It begins with one of the following headers, on its own line: *subject to*, *such that*, *st*, or *s.t.*. Capitalization is ignored.

The constraint section can have an arbitrary number of constraints. Each constraint starts with an optional label (constraint name, followed by a colon, followed by a space), continues with a linear expression, followed by an optional quadratic expression (enclosed in square brackets), and ends with a comparison operator, followed by a numerical value, followed by a line break. Valid comparison operators are =, <=, <, >=, or >. Note that LP format does not distinguish between strict and non-strict inequalities, so for example < and <= are equivalent.

Note that the left-hand side of a constraint may not contain a constant term; the constant must appear on the right-hand side.

The following is a simple example of a valid linear constraint:

```
c0: 2.5 x + 2.3 y + 5.3 z <= 8.1
```

The following is a valid quadratic constraint:

```
qc0: 3.1 x + 4.5 y + 10 z + [ x ^ 2 + 2 x * y + 3 y ^ 2 ] <= 10
```

The constraint section may also contain another constraint type: the so-called indicator constraint. Indicator constraints start with an optional label (constraint name, followed by a colon, followed by a space), followed by a binary variable, a space, a =, again a space and a value, either 0 or 1. They continue with a space, followed by ->, and again a space and finally a linear constraint (without a label).

For example:

```
c0: b1 = 1 -> 2.5 x + 2.3 y + 5.3 z <= 8.1
```

This example constraint requires the given linear constraint to be satisfied if the variable **b1** takes a value of 1.

Every LP format file must have a constraints section.

## Lazy Constraints Section

The next section is the lazy constraints section. It begins with the line **Lazy Constraints**, and continues with a list of linear constraints in the exact same format as the linear constraints in the constraints section. For example:

**Lazy Constraints**

```
c0: 2.5 x + 2.3 y + 5.3 z <= 8.1
```

Lazy constraints are handled differently from other constraints by the MIP solver. A lazy constraint only becomes active when the MIP solver finds a candidate solution that violates the constraint.

This section is optional.

## Bounds Section

The next section is the bounds section. It begins with the word **Bounds**, on its own line, and is followed by a list of variable bounds. Each line specifies the lower bound, the upper bound, or both for a single variable. The keywords **inf** or **infinity** can be used in the bounds section to specify infinite bounds. A bound line can also indicate that a variable is **free**, meaning that it is unbounded in either direction.

Here are examples of valid bound lines:

```
0 <= x0 <= 1
x1 <= 1.2
x2 >= 3
x3 free
x2 >= -Inf
```

It is not necessary to specify bounds for all variables; by default, each variable has a lower bound of 0 and an infinite upper bound. In fact, the entire bounds section is optional.

## Variable Type Section

The next section is the variable types section. Variables can be designated as being either binary, general integer, or semi-continuous. In all cases, the designation is applied by first providing the appropriate header (on its own line), and then listing the variables that have the associated type. For example:

```
Binary
  x y z
```

Variable type designations don't need to appear in any particular order (e.g., general integers can either precede or follow binaries). If a variable is included in multiple sections, the last one determines the variable type.

Valid keywords for variable type headers are: *binary*, *binaries*, *bin*, *general*, *generals*, *gen*, *semi-continuous*, *semis*, or *semi*.

The variable types section is optional. By default, variables are assumed to be continuous.

## SOS Section

An LP file can contain a section that captures SOS constraints of type 1 or type 2. The SOS section begins with the **SOS** header on its own line (capitalization isn't important). An arbitrary number of SOS constraints can follow. An SOS constraint starts with a name, followed by a colon (unlike linear constraints, the name is not optional here). Next comes the SOS type, which can be either **S1** or **S2**. The type is followed by a pair of colons.

Next come the members of the SOS set, along with their weights. Each member is captured using the variable name, followed by a colon, followed by the associated weight. Spaces can optionally be placed before and after the colon. An SOS constraint must end with a line break.

Here's an example of an SOS section containing two SOS constraints:

```
SOS
sos1: S1 :: x1 : 1  x2 : 2  x3 : 3
sos2: S2 :: x4:8.5  x5:10.2  x6:18.3
```

The SOS section is optional.

## PWLObj Section

An LP file can contain a section that captures piecewise-linear objective functions. The PWL section begins with the PWLObj header on its own line (capitalization isn't important). Each piecewise-linear objective function is associated with a model variable. A PWL function starts with the corresponding variable name, followed immediately by a colon (the name is not optional). Next come the points that define the piecewise-linear function. These points are represented as (x, y) pairs, with parenthesis surrounding the two values and a comma separating them. A PWL function must end with a line break.

Here's an example of a PWLObj section containing two simple piecewise-linear functions:

PWLObj

```
x1: (1, 1) (2, 2) (3, 4)
x2: (1, 3) (3, 5) (100, 300)
```

The PWLObj section is optional.

## General Constraint Section

An LP file may contain a section that captures more general constraints. The general constraint section starts with one of the following keywords *general constraints*, *general constraint*, *gencons*, or *g.c.*. Capitalization is ignored.

Each general constraint starts with an optional label (constraint name, followed by a colon, followed by a space), continues with a variable name, the so-called resultant, followed by a space, an equation character =, and a space again. The line continues with a general constraint type specifier, such as *MIN*, *MAX*, *OR*, *AND*, or *ABS* followed by a space and a ( and a space again. Capitalization is ignored.

What follows depends on the general constraint type. *MIN* or *MAX* constraints expect a non empty list of variables or values separated by a space, a comma, and space again. *OR* and *AND* constraints expect a list of binary variables, again separated by a space, a comma, and space again. *ABS* constraints only expect one variable name.

All these general constraints end with a space, ), and a line break.

The other general constraint type, the *INDICATOR* constraint, appears in the constraints section, which is described above.

The following is an example of a general constraint section :

General Constraints

```
gc0: r1 = MAX ( x1 , x2 , x10 , 0.7 )
gencons1: r2 = MIN ( y0 , 10 , y1 , r1 )
and1: r = AND ( b1 , b2 )
or1: r = OR ( b3 , b4 )
GC14: xabs = ABS ( x )
```

This section is optional.

For more information, consult the [general constraint discussion](#).

## End statement

The last line in an LP format file should be an **End** statement.

## 15.4 RLP format

The RLP format is identical to the LP format, except in how objects are named when files are written. When writing an LP format file, the Gurobi optimizer refers to constraints and variables using their given names. When writing an RLP format file, the Gurobi optimizer ignores the given names and instead refers to the variables using names that are based on variable or constraint characteristics. The constraint name depends solely on the associated row number: row  $i$  gets name  $ci$ . The variable name depends on the type of the variable, the column number of the variable in the constraint matrix, and the number of non-zero coefficients in the associated column. A continuous variable in column 7 with column length 2 would get name  $C7(2)$ , for example. A binary variable with the same characteristics would get name  $B7(2)$ .

## 15.5 ILP format

The ILP file format is identical to the LP format. The only difference is in how they are used. ILP files are specifically used to write computed Irreducible Inconsistent Subsystem (IIS) models.

## 15.6 OPB format

The OPB file format is used to store pseudo-boolean satisfaction and pseudo-boolean optimization models. These models may only contain binary variables, but these variables may be complemented and multiplied together in constraints and objectives. Pseudo-boolean models in OPB files are translated into a MIP representation by Gurobi. The syntax of the OPB format is described in detail by [Roussel and Manquinho](#). However, the OPB format supported by Gurobi is less restrictive, e.g., fractional coefficients are allowed.

The following is an example of a pseudo-boolean optimization model

$$\begin{aligned} \text{minimize} \quad & y - 1.3x(1 - z) + (1 - z) \\ \text{subject to} \quad & 2y - 3x + 1.7w = 1.7 \\ & -y + x + xz(1 - v) \geq 0 \\ & -y \leq 0, \\ & v, w, x, y, z \in \{0, 1\}. \end{aligned} \tag{1}$$

The corresponding OPB file for this example is given by

```
* This is a dummy pseudo-boolean optimization model
min: y - 1.3 x ~z + ~z;
2 y - 3 x + 1.7 w = 1.7;
-1 y + x + x z ~v >= 0;
-1 y <= 0;
```

Lines starting with `*` are treated as comments and ignored. Non-comment lines must end with a semicolon `;`. Whitespaces must be used to separate variables. The complement of a variable may be specified with a tilde `~`.

Only minimization models are supported. These models must be specified with the `min:` objective keyword. This keyword must appear before other constraints. Satisfiability models may be defined by omitting the objective.

Constraint senses  $\geq$ ,  $=$ , and  $\leq$  are supported.

## 15.7 MST format

A MIP start (MST) file is used to specify an initial solution for a mixed integer programming model. The file lists values to assign to the variables in the model. If a MIP start has been imported into a MIP model before optimization begins (using `GRBread`, for example), the Gurobi optimizer will attempt to build a feasible solution from the specified start values. A good initial solution often speeds the solution of the MIP model, since it provides an early bound on the optimal value, and also since the specified solution can be used to seed the local search heuristics employed by the MIP solver.

A MIP start file consists of variable-value pairs, each on its own line. Any line that begins with the hash sign (`#`) is a comment line and is ignored. The following is a simple example:

```
# MIP start
x1  1
x2  0
x3  1
```

Importing a MIP start into a model is equivalent to setting the `Start` attribute for each listed variable to the associated value. If the same variable appears more than once in a start file, the last assignment is used. Importing multiple start files is equivalent to reading the concatenation of the imported files.

Note that start files don't need to specify values for all variables. When variable values are left unspecified, the Gurobi solver will try to extend the specified values into a feasible solution for the full model.

## 15.8 HNT format

A MIP hint (HNT) file is used to provide hints for the values of the variables in a mixed integer programming model (typically obtained from a solution to a related model). The file lists values for variables in the model, and priorities for those hints. When MIP hints are imported into a MIP model before optimization begins (using `GRBread`, for example), the MIP search is guided towards the values captured in those hints. Good hints often allow the MIP solver to find high-quality solutions much more quickly.

A MIP hint file consists of variable-value-priority triples, each on its own line. Any line that begins with the hash sign (`#`) is a comment line and is ignored. The following is a simple example:

```
# MIP hints
x1  1 2
x2  0 1
x3  1 1
```

Importing hints into a model is equivalent to setting the `VarHintVal` and `VarHintPri` attributes for each listed variable to the associated values. If the same variable appears more than once in a hint file, the last assignment is used. Importing multiple hint files is equivalent to reading the concatenation of the imported files.

Note that hint files don't need to specify values for all variables. When values are left unspecified, the Gurobi MIP solver won't attempt to adjust the search strategy for those variables.

## 15.9 ORD format

A priority ordering (ORD) file is used to input a set of variable priority orders. Reading a priority file (using [GRBread](#), for example) modifies the MIP branch variable selection. When choosing a branching variable from among a set of fractional variables, the Gurobi MIP solver will always choose a variable with higher priority over one with a lower priority.

The file consists of variable-value pairs, each on its own line. The file contains one line for each variable in the model. Any line that starts with the hash sign (#) is treated as a comment line and is ignored. The following is a simple example:

```
# Branch priority file
x 1
y 1
z -1
```

Variables have a default branch priority value of 0, so it is not necessary to specify values for all variables.

Importing a priority order file is equivalent to replacing the [BranchPriority](#) attribute value for each variable in the model. Note that you can still modify the [BranchPriority](#) attribute after importing an ordering file.

## 15.10 BAS format

An LP basis (BAS) file is used to specify an initial basis for a continuous model. The file provides basis status information for each variable and constraint in the model. If a basis has been imported into a continuous model before optimization begins (using [GRBread](#), for example), and if a simplex optimizer has been selected (through the [Method](#) parameter), the Gurobi simplex optimizer begins from the specified basis.

A BAS file begins with a [NAME](#) line, and ends with an [ENDDATA](#) statement. No information is retrieved from these lines, but they are required by the format. Between these two lines are basis status lines, each consisting of two or three fields. If the first field is [LL](#), [UL](#), or [BS](#), the variable named in the second field is non-basic at its lower bound, non-basic at its upper bound, or basic, respectively. Any additional fields are ignored. If the first field is [XL](#) or [XU](#), the variable named in the second field is basic, while the variable named in the third field is non-basic at its lower or upper bound, respectively.

The following is a simple example:

```
NAME example.bas
XL x1 c1
XU x2 c2
BS c3
UL x3
LL x4
```

Importing a basis into a model is equivalent to setting the `VBasis` and `CBasis` attributes for each listed variable and constraint to the specified basis status.

A near-optimal basis can speed the solution of a difficult LP model. However, specifying a start basis that is not extremely close to an optimal solution will often slow down the solution process. Exercise caution when providing start bases.

## 15.11 SOL format

A Gurobi solution (SOL) file is used to output a solution vector. It can be written (using `GRBwrite`, for example) whenever a solution is available.

The file consists of variable-value pairs, each on its own line. The file contains one line for each variable in the model. The following is a simple example:

```
# Solution file
x  1.0
y  0.5
z  0.2
```

## 15.12 PRM format

A Gurobi parameter (PRM) file is used to specify parameter settings. Reading a parameter file (using `GRBread`, for example) causes the parameters specified in the file to take the specified values.

The file consists of parameter-value pairs, each on its own line. Any line that begins with the hash sign (`#`) is a comment line and is ignored. The following is a simple example:

```
# Parameter settings
Cuts          2
Heuristics    0.5
```

If an unknown parameter name is listed in the file, a warning is printed and the associated line is ignored.

The Gurobi Optimizer produces a log that allows you to track the progress of the optimization. By default, the log is put to both the screen and to a file. Screen output can be controlled using the [OutputFlag](#) parameter, and file output can be controlled using the [LogFile](#) parameter.

The format of the log depends on the algorithm that is used to solve the model (simplex, barrier, sifting, or branch-and-cut). We now describe the contents of the log for each algorithm.

## 16.1 Simplex Logging

The simplex log can be divided into three sections: the presolve section, the simplex progress section, and the summary section.

### Presolve Section

The first thing the Gurobi optimizer does when optimizing a model is to apply a *presolve* algorithm in order to simplify the model. The first section of the Gurobi log provides information on the extent to which presolve succeeds in this effort. Consider the following example output from NETLIB model `df1001`:

```
Presolve removed 2381 rows and 3347 columns
Presolve time: 0.12 sec.
Presolved: 3690 Rows, 8883 Columns, 31075 Nonzeros
```

The example output shows that presolve was able to remove 2381 rows and 3347 columns, and it required 0.12 seconds. The final line in the presolve section shows the size of the model after presolve. This is size of the model that is passed to the simplex optimizer. Note that the solution that is computed for this model is automatically transformed into a solution for the original problem once simplex finishes (in a process often called *uncrushing*), but this uncrush step is transparent and produces no log output.

### Progress Section

The second section of the Gurobi simplex output provides information on the progress of the simplex method:

Iteration	Objective	Primal Inf.	Dual Inf.	Time
0	1.7748600e+04	6.627132e+03	0.000000e+00	0s
9643	1.1574611e+07	1.418653e+03	0.000000e+00	5s
14440	1.1607748e+07	4.793500e+00	0.000000e+00	10s
15213	1.1266396e+07	0.000000e+00	0.000000e+00	11s

The five columns in each output row show the number of simplex iterations performed to that point, the objective value for the current basis, the magnitude of the primal infeasibility for the current basis (computed as the sum of the absolute values of all constraint and bound violations), the magnitude of the dual infeasibility (computed as the sum of the absolute values of all dual

constraint violations), and the amount of time expended to that point (measured using wall clock time). The default simplex algorithm in the Gurobi solver is dual simplex, which tries to maintain dual feasibility while performing simplex pivots to improve the objective. Thus, once the dual simplex algorithm has found an initial dual feasible basis, you will generally see a dual infeasibility value of zero. When the primal and dual infeasibilities both reach zero, the basis is optimal and optimization is complete.

By default, the Gurobi optimizer produces a log line every 5 seconds. The frequency of log lines can be changed by modifying the `DisplayInterval` parameter (see the [Parameter](#) section of this document for more information).

### Summary Section

The third section of the simplex log provides summary information. It provides a summary of the work that the simplex algorithm performed, including the iteration count and the runtime, and it provides information on outcome of the optimization. The summary for a model that is solved to optimality would look like this:

```
Solved in 15213 iterations and 10.86 seconds
Optimal objective 1.126639605e+07
```

Other termination states produce different summaries. For example, a user interrupt would produce a summary that looks like:

```
Stopped in 7482 iterations and 3.41 seconds
Solve interrupted
```

Hitting a time limit would produce a summary that looks like:

```
Stopped in 9221 iterations and 5.00 seconds
Time limit exceeded
```

## 16.2 Barrier Logging

The barrier log can be divided into five sections: the presolve section, the barrier preprocessing section, the barrier progress section, the crossover progress section, and the summary section.

### Presolve Section

As mentioned earlier, the first thing the Gurobi optimizer does when optimizing a model is to apply a *presolve* algorithm in order to simplify the model. The first section of the Gurobi log provides information on the extent to which presolve succeeds in this effort. Consider the following example output from NETLIB model `df1001`:

```
Presolve removed 2381 rows and 3347 columns
Presolve time: 0.12 sec.
Presolved: 3690 Rows, 8883 Columns, 31075 Nonzeros
```

The example output shows that presolve was able to remove 2381 rows and 3347 columns, and it required 0.12 seconds. The final line in the presolve section shows the size of the model after presolve. This is size of the model that is passed to the barrier optimizer. Note that the solution that is computed for this model is automatically transformed into a solution for the original problem once barrier finishes (in a process often called *uncrushing*), but this uncrush step is transparent and produces no log output.

## Barrier Preprocessing Section

The factor matrix for the linear system solved in each iteration of the barrier method can be quite large and quite expensive to compute. In order to reduce the cost of this computation, the first step of the barrier algorithm is to compute a fill-reducing reordering of the rows and columns of this matrix. This step can be quite expensive, but the cost is recouped in the reduced cost of the subsequent barrier iterations.

Once this fill-reducing reordering has been computed, the Gurobi Optimizer outputs information related to the barrier factor matrix:

Barrier statistics:

```
Dense cols : 10
Free vars  : 3
AA' NZ     : 9.353e+04
Factor NZ   : 1.139e+06 (roughly 14 MBytes of memory)
Factor Ops  : 7.388e+08 (roughly 2 seconds per iteration)
```

The first line indicates how many columns from the constraint matrix were treated as dense. The second line indicates how many variables in the model are free. Dense columns and free variables can sometimes lead to numerical difficulties in the barrier solver, so it is sometimes useful to know that they are present. Note that these lines are only printed when the model contains dense columns or free variables.

The next line shows the number of off-diagonal entries in the lower triangle of  $AA^T$ . A scaled version of this matrix is factored in each iteration of the barrier algorithm, so the structure of the Cholesky factor depends on the structure of  $AA^T$ .

The final two lines indicate the number of non-zero values in the factor matrix, and the number of floating-point operations required to factor it. Note that the log also provides an estimate of how much memory will be needed by the barrier algorithm, and how long each barrier iteration will require: These are rough estimates that are meant to provide a general sense of how difficult the model will be to solve. If you want to obtain an estimate of overall solution time, note that most models achieve convergence in roughly 50 iterations, but there are many exceptions. Crossover runtime is typically comparable to the cost of a few barrier iterations, but this time can vary considerably, depending on the model characteristics.

## Progress Section

The third section of the Gurobi barrier output provides information on the progress of the barrier method:

Iter	Objective		Residual		Compl	Time
	Primal	Dual	Primal	Dual		
0	1.11502515e+13	-3.03102251e+08	7.65e+05	9.29e+07	2.68e+09	2s
1	4.40523949e+12	-8.22101865e+09	3.10e+05	4.82e+07	1.15e+09	3s
2	1.18016996e+12	-2.25095257e+10	7.39e+04	1.15e+07	3.37e+08	4s
3	2.24969338e+11	-2.09167762e+10	1.01e+04	2.16e+06	5.51e+07	5s
4	4.63336675e+10	-1.44308755e+10	8.13e+02	4.30e+05	9.09e+06	6s
5	1.25266057e+10	-4.06364070e+09	1.52e+02	8.13e+04	2.21e+06	7s
6	1.53128732e+09	-1.27023188e+09	9.52e+00	1.61e+04	3.23e+05	9s
7	5.70973983e+08	-8.11694302e+08	2.10e+00	5.99e+03	1.53e+05	10s

8	2.91659869e+08	-4.77256823e+08	5.89e-01	5.96e-08	8.36e+04	11s
9	1.22358325e+08	-1.30263121e+08	6.09e-02	7.36e-07	2.73e+04	12s
10	6.47115867e+07	-4.50505785e+07	1.96e-02	1.43e-06	1.18e+04	13s

The seven columns in each output row show the number of barrier iterations performed to that point, the primal and dual objective values for the current barrier iterate, the magnitude of the primal and dual infeasibilities for the current iterate (computed as the infinity-norms of the primal and dual residual vectors, respectively), the magnitude of the complementarity violation of the current primal and dual iterates (the dot product of the primal solution and the dual reduced cost vector), and the amount of time expended to that point (measured using wall clock time). When the primal infeasibility, dual infeasibility, and complementarity satisfy barrier convergence tolerances (controlled using the `BarConvTol` parameter), the solution is declared optimal and optimization is complete.

Unlike the simplex and MIP optimizers, the barrier optimizer produces a log line for each iterate, independent of the value of the `DisplayInterval` parameter.

You may sometimes see a star after the iteration count in the barrier progress log:

15	2.42800468e+03	8.54543324e+04	1.68e+02	1.02e-09	8.30e+04	0s
16	4.05292006e+03	4.65997441e+04	1.82e+02	2.50e-01	4.25e+04	0s
17*	4.88742259e+08	4.30781025e+10	5.17e+00	1.31e-01	2.52e-02	0s
18*	1.21709951e+06	3.39471138e+13	8.55e-06	3.14e-06	3.14e-05	0s
19*	-1.38021972e+06	3.31580578e+16	3.42e-08	8.20e-09	3.22e-08	0s
20*	1.25182178e+06	3.31575855e+19	6.54e-12	7.34e-09	3.22e-11	0s

This indicates that the model may be primal or dual infeasible. Note that these intermediate indications of infeasibility won't necessarily turn into an infeasibility proof, so the star may disappear in later iterations.

### Crossover Section

The fourth section of the barrier log provides information on the crossover step. This section is only present when crossover is selected (as controlled through the `Crossover` parameter). Crossover converts the interior point solution produced by the barrier algorithm to a basic solution.

The first stage in crossover is to *push* variables to bounds in order to obtain a valid basic solution. By default, this is done for dual variables first, then for primal variables. Progress of this phase is tracked with this portion of the crossover log...

Crossover log...

1592 DPushes remaining with DInf	0.0000000e+00	2s	
0 DPushes remaining with DInf	2.8167333e-06	2s	
180 PPushes remaining with PInf	0.0000000e+00	2s	
0 PPushes remaining with PInf	0.0000000e+00	2s	
Push phase complete: Pinf	0.0000000e+00, Dinf	2.8167333e-06	2s

Each line indicates how many push steps remain, the amount of infeasibility in the current solution, and the elapsed barrier time.

Upon completion of the push phase, crossover has a basic solution that isn't necessarily optimal. The resulting basis is passed to simplex, and simplex completes the optimization...

Iteration	Objective	Primal Inf.	Dual Inf.	Time
1776	1.1266396e+07	0.000000e+00	0.000000e+00	2s

The five columns in each output row of the simplex log show the number of simplex iterations performed to that point in the crossover algorithm (including the push steps), the objective value for the current basis, the magnitude of the primal infeasibility for the current basis (computed as the sum of the absolute values of all constraint and bound violations), the magnitude of the dual infeasibility (computed as the sum of the absolute values of all dual constraint violations), and the amount of time expended by the crossover algorithm to that point (measured using wall clock time). When the primal and dual infeasibilities both reach zero, the basis is optimal and optimization is complete.

### Summary Section

The final section of the barrier log provides summary information. It provides a summary of the work that the barrier algorithm performed, including the iteration count and the runtime, and it provides information on outcome of the optimization. The summary for a model that is solved to optimality would look like this:

```
Solved in 7212 iterations and 48.38 seconds
Optimal objective 1.126639605e+07
```

Other termination states produce different summaries. For example, a user interrupt would produce a summary that looks like:

```
Stopped in 7482 iterations and 3.41 seconds
Solve interrupted
```

Hitting a time limit would produce a summary that looks like:

```
Stopped in 9221 iterations and 5.00 seconds
Time limit exceeded
```

## 16.3 Sifting Logging

Sifting will sometimes be used within the dual simplex method, either as a result of an automatic choice by the Gurobi Optimizer or because the user selected it through the [Sifting](#) parameter. The sifting log consists of three sections: the presolve section, the sifting progress section, and the summary section. The first and last are identical to those for simplex, so we'll only discuss the middle section here.

### Sifting Progress Section

As we mentioned, output for sifting and dual simplex are indistinguishable until the progress section begins. For sifting, the progress section begins with a clear indication that sifting has been selected:

```
Starting sifting (using dual simplex for sub-problems)...
```

The sifting algorithm performs a number of major iterations, where each iteration solves a smaller LP sub-problem. It uses the result to update the current primal and dual solution. The sifting log prints one line per major iteration, with information on the current primal and dual objective values:

Iter	Pivots	Primal Obj	Dual Obj	Time
0	0	infinity	2.0000000e+01	11s
1	4662	1.5220652e+03	2.7034420e+02	12s
2	8917	1.3127217e+03	4.6530259e+02	13s
3	16601	1.1651147e+03	6.4767742e+02	17s
4	30060	1.0881514e+03	7.8842688e+02	29s
5	45169	1.0618879e+03	8.8656855e+02	46s
6	59566	1.0549766e+03	9.5404159e+02	64s
7	73614	1.0540577e+03	1.0172213e+03	82s

The first column in the log gives the major iteration number. The second shows the total number of simplex iterations performed in solving the sifting sub-problems. The third and fourth columns show the primal and dual objective values for the current solution. The final column shows elapsed runtime.

The completion of sifting is indicated with the following message:

```
Sifting complete
```

The basis computed by sifting is then handed back to dual simplex, and the log from that point forward comes from the dual simplex algorithm.

## 16.4 MIP Logging

The MIP log can be divided into three sections: the presolve section, the simplex progress section, and the summary section.

### Presolve Section

As with the simplex and barrier logs, the first section of the MIP log is the presolve section. Here is presolve output for MIPLIB model `mas76`:

```
Presolve removed 0 rows and 3 columns
Presolve time: 0.00s
Presolved: 12 Rows, 148 Columns, 1615 Nonzeros
```

In this example, presolve was able to remove 3 columns. The final line shows the size of the model that is passed to the branch-and-cut algorithm.

### Progress Section

The next section in the MIP log tracks the progress of the branch-and-cut search. The search involves a number of different steps, so this section typically contains a lot of detailed information. The first thing to observe in the log for example `mas76` is these lines:

```
Found heuristic solution: objective 93644.999
Found heuristic solution: objective 87658.484
Found heuristic solution: objective 80811.127
```

These indicate that the Gurobi heuristics found three integer feasible solutions before the root relaxation was solved.

The next thing you will see in the log is the root relaxation solution display. For a model where the root solves quickly, this display contains a single line:

```
Root relaxation: objective 3.889390e+04, 43 iterations, 0.00 seconds
```

For models where the root relaxation takes more time (MIPLIB model `dano3mip`, for example), the Gurobi solver will automatically include a detailed simplex log for the relaxation itself:

```
Root relaxation log...
```

Iteration	Objective	Primal Inf.	Dual Inf.	Time
8370	5.6894789e+02	3.032449e+05	0.000000e+00	5s
13770	5.6906050e+02	2.875568e+06	0.000000e+00	10s
18758	5.6924158e+02	7.523521e+06	0.000000e+00	15s
25649	5.7101828e+02	1.463095e+06	0.000000e+00	20s
31400	5.7146225e+02	6.748823e+04	0.000000e+00	25s
34230	5.7623162e+02	0.000000e+00	0.000000e+00	28s

```
Root relaxation: objective 5.762316e+02, 34230 iterations, 28.47 seconds
```

To be more precise, this more detailed log is triggered whenever the root relaxation requires more than the `DisplayInterval` parameter value (5 seconds by default).

The next section provides progress information on the branch-and-cut tree search:

Nodes		Current Node				Objective Bounds			Work	
Expl	Unexpl	Obj	Depth	IntInf	Incumbent	BestBd	Gap	It/Node	Time	
	0	0	38893.904	0	11	80811.127	38893.904	51.9%	-	0s
H	0	0				45476.147	38893.904	14.5%	-	0s
	0	0	38903.750	0	13	45476.147	38903.750	14.5%	-	0s
	0	0	38926.214	0	12	45476.147	38926.214	14.4%	-	0s
	0	0	38950.968	0	13	45476.147	38950.968	14.3%	-	0s
	0	0	38952.279	0	14	45476.147	38952.279	14.3%	-	0s
H	0	2				43875.000	38952.279	11.2%	-	0s
H	0	2				40005.054	38952.279	2.63%	-	0s
	0	2	38952.279	0	14	40005.054	38952.279	2.63%	-	0s
	96386	22115	cutoff	37		40005.054	39504.729	1.25%	4.0	5s
	153831	18491	infeasible	42		40005.054	39576.907	1.07%	4.0	10s
	203266	12649	cutoff	30		40005.054	39756.344	0.62%	3.9	15s

This display is somewhat dense with information, but each column is hopefully fairly easy to understand. The `Nodes` section (the first two columns) provides general quantitative information on the progress of the search. The first column shows the number of branch-and-cut nodes that have been explored to that point, while the second shows the number of leaf nodes in the search tree that remain unexplored. At times, there will be an H or \* character at the beginning of the

output line. These indicate that a new feasible solution has been found, either by a MIP heuristic (H) or by branching (\*).

The **Current Node** section provides information on the specific node that was explored at that point in the branch-and-cut tree. It shows the objective of the associated relaxation, the depth of that node in the branch-and-cut tree, and the number of integer variables that have non-integral values in the associated relaxation.

The **Objective Bounds** section provides information on the best known objective value for a feasible solution (i.e., the objective value of the current incumbent), and the current objective bound provided by leaf nodes of the search tree. The optimal objective value is always between these two values. The third column in this section (**Gap**) shows the relative gap between the two objective bounds. When this gap is smaller than the **MIPGap** parameter, optimization terminates.

The **Work** section of the log provides information on how much work has been performed to that point. The first column shows the average number of simplex iterations performed per node in the branch-and-cut tree. The final column shows the elapsed time since the solve began.

By default, the Gurobi MIP solver prints a log line every 5 seconds (although the interval can sometimes be longer for models with particularly time-consuming nodes). The interval between log lines can be adjusted with the **DisplayInterval** parameter (see the **Parameter** section of this document for more information).

Note that the explored node count often stays at 0 for an extended period. This means that the Gurobi MIP solver is processing the root node. The Gurobi solver can often expend a significant amount of effort on the root node, generating cutting planes and trying various heuristics in order to reduce the size of the subsequent branch-and-cut tree.

## Summary Section

The third section in the log provides summary information once the MIP solver has finished:

Cutting planes:

Gomory: 6

Cover: 5

MIR: 8

Explored 226525 nodes (854805 simplex iterations) in 11.15 seconds

Thread count was 2 (of 2 available processors)

Optimal solution found (tolerance 1.00e-04)

Best objective 4.0005054142e+04, best bound 4.0001112908e+04, gap 0.0099%

In this example, the Gurobi solver required just over 11 seconds to solve the model to optimality, and it used two processors to do so (the processor count can be limited with the **Threads** parameter). The gap between the best feasible solution objective and the best bound is just under 0.01%, which produces an **Optimal** termination status, since the achieved gap is smaller than the default **MIPGap** parameter value.

## 16.5 Multi-Objective Logging

The contents of the log for a multi-objective solve will depend on the approach you use to solve the model. As noted in the section on [multi-objective models](#), you have two options. In a blended

approach, where the objectives are combined into a single objective, the log will be the same as what you'd see for a single-objective model. When using a hierarchical approach, a series of models is solved, one for each objective priority level. If your model is a pure hierarchical multi-objective problem with three objectives, the optimization process log will start with

```
-----
Multi-objectives: starting optimization with 3 objectives ...
-----
```

If your model is a mixed hierarchical-blended multi-objective problem with five objectives but only three priorities, the optimization log will start with

```
-----
Multi-objectives: starting optimization with 5 objectives (3 combined) ...
-----
```

You will also see a log for each solve, introduced by a small header

```
-----
Multi-objectives: optimize objective 1 Name ...
-----
```

Where `Name` will be the name of the objective function being optimize, or `(weighted)` if the objective function is the result of blending more than one objective function.

The logs for the individual solves will again be the same as what you'd see for a single-objective model.

## 16.6 Distributed MIP Logging

Logging for distributed MIP is very similar to the standard MIP logging. The main difference is in the progress section. The header for the standard MIP logging looks like this:

```
Nodes      | Current Node      | Objective Bounds      | Work
Expl Unexpl | Obj Depth IntInf | Incumbent BestBd Gap | It/Node Time
```

In contrast, the distributed MIP header has a different label for the second-to-last field:

```
Nodes      | Current Node      | Objective Bounds      | Work
Expl Unexpl | Obj Depth IntInf | Incumbent BestBd Gap | ParUtil Time
```

Instead of showing iterations per node, this field in the distributed log shows parallel utilization. Specifically, it shows the fraction of the preceding time period (the time since the previous progress log line) that the workers spent actively processing MIP nodes.

Here is an example of a distributed MIP progress log:

```
Nodes      | Current Node      | Objective Bounds      | Work
Expl Unexpl | Obj Depth IntInf | Incumbent BestBd Gap | ParUtil Time
H    0      |                   | 157344.61033         -   -   0s
H    0      |                   | 40707.729144        -   -   0s
```

H	0				28468.534497		-	-		0s
H	0				18150.083886		-	-		0s
H	0				14372.871258		-	-		0s
H	0				13725.475382		-	-		0s
	0	0	10543.7611	0	19	13725.4754	10543.7611	23.2%	99%	0s
*	266					12988.468031	10543.7611	18.8%		0s
H	1503					12464.099984	10630.6187	14.7%		0s
*	2350					12367.608657	10632.7061	14.0%		1s
*	3360					12234.641804	10641.4586	13.0%		1s
H	3870					11801.185729	10641.4586	9.83%		1s

Ramp-up phase complete - continuing with instance 2 (best bd 10661)

16928	2731	10660.9626	0	12	11801.1857	10660.9635	9.66%	99%	2s
135654	57117	11226.5449	19	12	11801.1857	11042.3036	6.43%	98%	5s
388736	135228	11693.0268	23	12	11801.1857	11182.6300	5.24%	96%	10s
705289	196412	cutoff			11801.1857	11248.8963	4.68%	98%	15s
1065224	232839	11604.6587	28	10	11801.1857	11330.2111	3.99%	98%	20s
1412054	238202	11453.2202	31	12	11801.1857	11389.7119	3.49%	99%	25s
1782362	209060	cutoff			11801.1857	11437.2670	3.08%	97%	30s
2097018	158137	11773.6235	20	11	11801.1857	11476.1690	2.75%	92%	35s
2468495	11516	cutoff			11801.1857	11699.9393	0.86%	78%	40s
2481830	0	cutoff			11801.1857	11801.1857	0.00%	54%	40s

One thing you may find in the progress section is that node counts may not increase monotonically. Distributed MIP tries to create a single, unified view of node numbers, but with multiple machines processing nodes independently, possibly at different rates, some inconsistencies are inevitable.

Another difference is the line that indicates that the distributed ramp-up phase is complete. At this point, the distributed strategy transitions from a concurrent approach to a distributed approach. The log line indicates which worker was the *winner* in the concurrent approach. Distributed MIP continues by dividing the partially explored MIP search tree from this worker among all of the workers.

Another difference in the distributed log is in the summary section. The distributed MIP log includes a breakdown of how runtime was spent:

Runtime breakdown:

Runtime breakdown:

Active: 37.85s (93%)

Sync: 2.43s (6%)

Comm: 0.34s (1%)

This is an aggregated view of the utilization data that is displayed in the progress log lines. In this example, the workers spent 93% of runtime actively working on MIP nodes, 6% waiting to synchronize with other workers, and 1% communicating data between machines.

# Gurobi Command-Line Tool

The Gurobi command-line tool allows you to perform simple commands without the overhead or complexity of an interactive interface. While the most basic usage of the command-line tool is quite straightforward, the tool has a number of uses that are perhaps less obvious. This section talks about its full capabilities.

To use this tool, you'll need to type commands into a command-line interface. Linux and Mac users can use a *Terminal* window. Windows users will need to open a *Command Prompt* (also known as a *Console* window or a *cmd* window). To launch one, hold down the *Start* and *R* keys simultaneously, and then type *cmd* into the *Run* box that appears.

The command to solve a model using the command-line tool is:

```
gurobi_cl [parameter=value]* modelfile
```

The Gurobi log file is printed to the screen as the model solves, and the command terminates when the solve is complete. Parameters are chosen from among the [Gurobi parameters](#). The final argument is the name of a file that contains an optimization model, stored in MPS or LP format. You can learn more about using the command-line tool to solve models in [this section](#).

The command-line tool can also be used to replay [recordings of API calls](#). The command for this usage is:

```
gurobi_cl recordingfile
```

A recording file is a binary file generated by Gurobi with a *.grbr* extension. You can learn more about using the command-line tool to replay recordings in [this section](#).

The command-line tool can also be used to administer [Gurobi Remote Services](#) and [Gurobi Compute Server](#). The syntax for this usage is:

```
gurobi_cl [--command]*
```

A list of supported commands can be found in [this section](#).

The command-line tool can also be used to check on the status of a Gurobi token server. The command is:

```
gurobi_cl --tokens
```

This command will show you whether the token server is currently serving tokens, and which users and machines are currently using tokens.

You can also type:

```
gurobi_cl --help
```

to get help on the use of the tool, or:

```
gurobi_cl --version
```

to get version information, or:

```
gurobi_cl --license
```

to get the location of the current Gurobi license file.

## 17.1 Solving a Model

The command-line tool provides an easy way to solve a model stored in a file. The model can be stored in several different formats, including MPS, REW, LP, and RLP, and the file can optionally be compressed using `gzip`, `bzip2`, or `7z`. See the [File Format](#) discussion for more information on accepted formats.

The most basic command-line command is the following:

```
gurobi_cl model.mps
```

This will read the model from the indicated file, optimize it, and display the Gurobi log file as the solve proceeds.

You can optionally include an arbitrary number of `parameter=value` commands before the name of the file. For example:

```
gurobi_cl Method=2 TimeLimit=100 model.mps
```

The full set of Gurobi parameters is described in the [Parameter](#) section.

Gurobi Compute Server users can add the `--server=` switch to specify a server. For example, the command:

```
gurobi_cl --server=server1 Method=2 TimeLimit=100 model.mps
```

would solve the model stored in file `model.mps` on machine `server1`, assuming it is running Gurobi Compute Server. If the Compute Server has an access password, use the `--password=` switch to specify it.

### Writing Result Files

While it is often useful to simply solve a model and display the log, it is also common to want to review the resulting solution. You can use the [ResultFile](#) parameter to write the solution to a file:

```
gurobi_cl ResultFile=model.sol model.mps
```

The file name suffix determines the type of file written. Useful file formats for solution information are `.sol` (for solution vectors) and `.bas` (for simplex basis information). Again, you should consult the section on [File Formats](#) for a list of the supported formats

If you have an infeasible model, you may want to examine a corresponding Irreducible Inconsistent Subsystem (IIS) to identify the cause of the infeasibility. You can ask the command-line tool to write a `.ilp` format file. It will attempt to solve the model, and if the model is found to be infeasible, it will automatically compute an IIS and write it to the requested file name.

Another use of `ResultFile` is to translate between file formats. For example, if you want to translate a model from MPS format to LP format, you could issue the following command:

```
gurobi_cl TimeLimit=0 ResultFile=model.lp model.mps
```

Gurobi can write compressed files directly, so this command would also work (assuming that 7zip is installed on your machine):

```
gurobi_cl TimeLimit=0 ResultFile=model.lp.7z model.mps
```

The `ResultFile` parameter works differently from other parameters in the command-line interface. While a parameter normally takes a single value, you can actually specify multiple result files. For example, the following command:

```
gurobi_cl ResultFile=model.sol ResultFile=model.bas model.mps
```

will write two files.

### Reading Input Files

You can use the `InputFile` parameter to read input files during the optimization. The most common input formats are `.bas` (a simplex basis), `.mst` (a MIP start), `.sol` (also a MIP start), `.hnt` (MIP hints), and `.ord` (a MIP priority order). For example, the following command:

```
gurobi_cl InputFile=model.bas model.mps
```

would start the optimization of the continuous model stored in file `model.mps` using the basis provided in file `model.bas`.

Reading input files is equivalent to setting the values of Gurobi attributes. A `.bas` file populates the `VBasis` and `CBasis` attributes, while a `.ord` file populates the `BranchPriority` attribute. A `.mst` or `.sol` file populates the `Start` attribute. A `.hnt` file populates the `VarHintVal` and `VarHintPri` attributes.

Again, you should consult the [File Formats](#) section for more information on supported file formats

## 17.2 Replaying Recording Files

If you've generated a [recording](#) of the Gurobi API calls made by your program, you may use the command-line tool to replay this recording.

Recordings are stored in files with `.grbr` extensions. To replay a recording from a file named `recording000.grbr` issue the following command:

```
gurobi_cl recording000.grbr
```

You should adjust the file name to match the recording you wish to replay.

You will know you have succeeded in replaying a recording, if you see lines similar to the following at the beginning of the command-line tool's output:

```
*Replay* Replay of file 'recording000.grbr'  
*Replay* Recording captured Tue Sep 13 19:28:48 2016  
*Replay* Recording captured with Gurobi version 7.0.0 (linux64)
```

For information about recording API calls and replaying them, see the [Recording API Calls](#) chapter.

## 17.3 Gurobi Remote Services and Compute Server Administration

The command-line tool can also be used to administer [Gurobi Remote Services](#) and [Gurobi Compute Server](#). The format of an administrative command is simply:

`gurobi_cl [--command]*`

Available administrative commands are:

`--status`: Obtain a list of running and queued jobs.

`--killjob=`: Kill a job. The argument identifies the job to kill. You specify a job by giving the client hostname, followed by a comma, followed by the process ID (PID) of the job. You typically obtain this information from the output of `gurobi_cl --status`.

`--joblimit=`: Change the server job limit. The argument gives the new limit. Note that this command is useful for taking a Compute Server off-line: setting the job limit to zero allows currently running jobs to finish, but prevents new ones from starting.

`--newadminpassword`: Change the administrator password.

Administrative commands can be run from any machine on the same network as the server. All except `--status` prompt you for the administrator password. Alternatively, you can provide the password on the command line using the `--adminpassword=` command. For security reasons, if no initial administrator password is specified (via the `grb_rs.cnf` file), server administration is disabled.

One additional command-line argument that you may need in conjunction with these commands is `--server=` (`--servers=` is also accepted). This argument specifies the machine where the requested command should be performed. If you omit this argument, the machine name will be pulled from the `COMPUTESERVER=` line of your client license file.

Note that the `--joblimit` and `--newadminpassword` commands can only be applied to a single server at a time. If you specify multiple servers (either through the `--servers` switch or through your client license file), the command will only be applied to the first member of the list.

The following shows sample output from `gurobi_cl --status...`

```
-----  
Checking status of Gurobi Remote Services on server 'server1'...  
-----
```

```
Gurobi Remote Services (version 7.0.0) functioning normally  
Available services: Distributed Worker, Compute Server  
Job limit: 2, currently running: 2
```

```
Jobs currently running: 2 ...
```

Client HostName	Client IP Address	UserName	PID
client1	192.168.1.101	smith	7416
client2	192.168.1.102	jones	1536

```
Jobs currently queued: 1 ...
```

Client HostName	Client IP Address	UserName	PID	Priority
-----------------	-------------------	----------	-----	----------

---

client3	192.168.1.103	jim	2620	5
---------	---------------	-----	------	---

The report shows two jobs currently running (one from user `smith` on client machine `client1`, and one from user `jones` on client machine `client2`), and one job queued (from user `jim` on client machine `client3`).

Here are a few more example administrator commands:

```
> gurobi_cl --killjob=client1,7416
> gurobi_cl --newadminpassword --server=gurobiserver1
> gurobi_cl --joblimit=0 --server=gurobiserver1
```

While the default goal of the Gurobi Optimizer is to find one proven optimal solution to your model, with a possible side-effect of finding other solutions along the way, the solver provides a number of parameters that allow you to change this behavior.

## 18.1 Finding Multiple Solutions

By default, the Gurobi MIP solver will try to find one proven optimal solution to your model. It will typically find multiple sub-optimal solutions along the way, which can be retrieved later (using the `SolutionNumber` parameter, and the `Xn`, `PoolObjVal` attributes). However, these solutions aren't produced in a systematic way. The set of solutions that are found depends on the exact path the solver takes through the MIP search. You could solve a MIP model once, obtaining a set of interesting sub-optimal solutions, and then solve the same problem again with different parameter settings, and find only the optimal solution.

If you'd like more control over how solutions are found and retained, the Gurobi Optimizer has a number of parameters available for this. The first and simplest is `PoolSolutions`, which controls the size of the solution pool. Changing this parameter won't affect the number of solutions that are found - it simply determines how many of those are retained.

You can use the `PoolSearchMode` parameter to control the approach used to find solutions. In its default setting (0), the MIP search simply aims to find one optimal solution. Setting the parameter to 1 causes the MIP search to expend additional effort to find more solutions, but in a non-systematic way. You will get more solutions, but not necessarily the best solutions. Setting the parameter to 2 causes the MIP to do a systematic search for the  $n$  best solutions. For both non-default settings, the `PoolSolutions` parameter sets the target for the number of solutions to find.

If you are only interested in solutions that are within a certain gap of the best solution found, you can set the `PoolGap` parameter. Solutions that are not within the specified gap are discarded.

Obtaining an `OPTIMAL` optimization return status when using `PoolSearchMode=2` indicates that the MIP solver succeeded in finding the desired number of best solutions, or it proved that the model doesn't have that many distinct feasible solutions. If the solver terminated early (e.g., due to a time limit), you can use the `PoolObjBound` attribute to evaluate the quality of the solutions that were found. This attribute gives a bound on the objective of any solution that isn't already in the solution pool. The difference between this attribute and `ObjBound` is that the latter gives a bound on the objective for any solution, and which is often looser than `PoolObjBound`.

There are a few subtleties associated with finding multiple solutions that you should be aware of. For example, the notion of finding the  $n$  best solutions can be a bit ambiguous when you have a non-zero optimality tolerance. Also, it isn't obvious whether two solutions should be considered different when the model has continuous variables. We'll discuss these issues later in this section.

## 18.2 Examples

Let's continue with a few examples of how these parameters would be used. Imagine that you are solving a MIP model with an optimal (minimization) objective of 100. Further imagine that, using default settings, the MIP solver finds four solutions to this model with objectives 100, 110, 120, and 130.

If you set the `PoolSolutions` parameter to 3 and solve the model again, the MIP solver would discard the worst solution and return with 3 solutions in the solution pool (i.e., the `SolCount` attribute would have value 3). If you instead set the `PoolGap` parameter to value 0.2, the MIP solver would discard any solutions whose objective value is worse than 120 (which would also leave 3 solutions in the solution pool).

If you set the `PoolSearchMode` parameter to 2 and the `PoolSolutions` parameter to 10, the MIP solver would attempt to find the 10 best solutions to the model. An `OPTIMAL` return status would indicate that either (i) it found the 10 best solutions, or (ii) it found all feasible solutions to the model, and there were fewer than 10. If you also set the `PoolGap` parameter to a value of 0.1, the MIP solver would try to find 10 solutions with objective no worse than 110. While this may appear equivalent to asking for 10 solutions and simply ignoring those with objective worse than 110, the solve will typically complete significantly faster with this parameter set, since the solver does not have to expend effort looking for solutions beyond the requested gap.

## 18.3 Retrieving Solutions

After optimization has completed, you can retrieve solutions from the solution pool using a few parameters and attributes. The `SolCount` attribute indicates how many solutions were retained by the MIP solver. The best solution can always be obtained through the `X` attribute. Sub-optimal solutions can be obtained by setting the `SolutionNumber` parameter and then querying the `Xn` attribute.

For example, to retrieve the worst solution kept by the MIP solver, you'd first query `SolCount` to determine how many solutions are available, then set the `SolutionNumber` parameter to `SolCount-1`, then query the `Xn` attribute.

The `PoolObjBound` attribute gives a bound on the objective of undiscovered solutions. Further tree exploration won't find better solutions. You can use this parameter to get a count of how many of the  $n$  best solutions you found: any solutions whose objective values are at least as good as `PoolObjBound` are among the  $n$  best.

## 18.4 Subtleties and Limitations

There are a few subtleties associated with finding multiple solutions that we'll cover now.

### Continuous Variables

One subtlety arises when considering multiple solutions for models with continuous variables. Specifically, you may have two solutions that take identical values on the integer variables but where some continuous variables differ. By choosing different points on the line between these two solutions, you actually have an infinite number of choices for feasible solutions to the problem. To avoid this issue, we define two solutions as being equivalent if they take the same values on all

integer variables (and on all continuous variables that participate in SOS constraints). A solution will be discarded if it is equivalent to another solution that is already in the pool.

### Optimality Gap

The interplay between the optimality gap (`MIPGap` or `MIPGapAbs`) and multiple solutions can be a bit subtle. When using the default `PoolSearchMode`, a non-zero optimality gap indicates that you are willing to allow the MIP solver to declare a solution optimal, even though the model may have other, better solutions. The claim the solver makes upon termination is that no other solution would improve the incumbent objective by more than the optimality gap. Terminating at this point is ultimately a pragmatic choice - we'd probably rather have the true best solution, but the cost of reducing the optimality gap to zero can often be prohibitive.

This pragmatic choice can produce a bit of confusion when finding multiple optimal solutions. Specifically, if you ask for the  $n$  best solutions, the optimality gap plays a similar role as it does in the default case, but the implications may be a bit harder to understand. Specifically, a non-zero optimality gap means that you are willing to allow the solver to declare that it has found the  $n$  best solutions, even though there may be solutions that are better than those that were returned. The claim in this case is that any solution not among the reported  $n$  best would improve on the objective for the worst among the  $n$  best by less than the optimality gap.

If you want to avoid this source of potential confusion, you should set the optimality gap to 0 when using `PoolSearchMode=2`.

### Logging

If you browse the log from a MIP solve with `PoolSearchMode` set to a non-default value, you may see the lower bound on the objective exceed the upper bound. This can't happen with the default `PoolSearchMode` - if you are only looking for one optimal solution, the search is done as soon as the lower bound reaches the upper bound. However, if you are looking for the  $n$  best solutions, you have to prove that the model has no solution better than the  $n$ th best. The objective for that  $n$ th solution could be much worse than that of the incumbent. In this situation, the log file will include a line of the form:

```
Optimal solution found at node 123 - now completing solution pool...
```

### Distributed MIP

One limitation that we should point out related to multiple solutions is that the distributed MIP solver has not been extended to support non-default `PoolSearchMode` settings. Distributed MIP will typically produce many more feasible solutions than non-distributed MIP, but there's no way to ask it to find the  $n$  best solutions.

While typical optimization models have a single objective function, real-world optimization problems often have multiple, competing objectives. For example, in a production planning model, you may want to both maximize profits and minimize late orders, or in a workforce scheduling application, you may want to both minimize the number of shifts that are short-staffed while also respecting worker's shift preferences.

The main challenge you face when working with multiple, competing objectives is deciding how to manage the tradeoffs between them. Gurobi provides tools that simplify the task: Gurobi allows you to *blend* multiple objectives, to treat them *hierarchically*, or to combine the two approaches. In a blended approach, you optimize a weighted combination of the individual objectives. In a hierarchical or lexicographic approach, you set a priority for each objective, and optimize in priority order. When optimizing for one objective, you only consider solutions that would not degrade the objective values of higher-priority objectives. Gurobi allows you to enter and manage your objectives, to provide weights for a blended approach, or to set priorities for a hierarchical approach.

## 19.1 Specifying Multiple Objectives

Let us first discuss the interface for managing multiple objectives. An empty model starts with one objective function, which is initially just 0.0. We'll refer to this as the *primary* objective. You can modify it in a few ways: you can set the `Obj` attribute, or you can use the `setObjective` method from your language API (e.g., `Model.setObjective` in Python). Note that for a multi-objective model, all objective functions must be linear, including the primary objective. In general, attributes and methods that aren't specific to multi-objective optimization will work with the primary objective function.

If you'd like to input additional objectives, your first step is to tell Gurobi how many objectives you'd like to have in your model. You do this by setting the `NumObj` attribute on the Gurobi model. Objectives are numbered 0 through `NumObj-1`. Once you've done this, you then modify or query objective  $n$  in two steps. The first is to set parameter `ObjNumber` to the desired objective number; the second is to use the `ObjN` variable attribute to access the corresponding objective entry. The primary objective is always objective 0, so `ObjN` and `Obj` are equivalent when `ObjNumber` is 0. Additional objectives are always linear.

To give an example, after you set `NumObj` to 3, then `ObjNumber` can be set to 0, 1, or 2. This parameter setting will determine the effect of setting attribute `ObjN` on a variable. Thus, for example, if you set `ObjN` to 5 for a variable  $x$  when `ObjNumber` is 2, then the objective coefficient in objective 2 for variable  $x$  will be set to 5.

You can also set an objective constant for each objective, using `ObjNCon`. Again, `ObjNCon` and `ObjCon` are equivalent when `ObjNumber` is 0. You can also give each objective a name through `ObjNName`.

Note that a model has a single objective sense (controlled by the `ModelSense` attribute). This

means that you can't maximize the first objective and minimize the second. However, you can achieve the same result with a simple trick. Each objective has a weight, and these weights are allowed to be negative. Minimizing an objective function is equivalent to maximizing the negation of that function.

You can change the number of objectives in your model as many times as you like. When you increase the objective count, the new objectives and their associated attributes are set to 0. When you decrease the count, objectives beyond the new count are discarded. If you set the number of objectives to zero, the model becomes a pure feasibility problem.

We have extended the LP and MPS file formats, so writing a model with multiple objectives to a file will capture those objectives. Similarly, if you read a model file that contains multiple objectives, then `NumObj` and `ObjN` will capture the objectives stored in the file. See the [file format](#) section for details.

## 19.2 Working With Multiple Objective

Of course, specifying a set of objectives is only the first step in solving a multi-objective optimization problem. The next step is to indicate how the objectives should be combined. As noted earlier, we support two approaches: blended and hierarchical.

### Blended Objectives

A blending approach creates a single objective by taking a linear combination of your objectives. You specify the weight for each objective through the `ObjNWeight` attribute. Again, you use the `ObjNumber` parameter to modify or query the weight for a particular objective. The default weight for an objective is 1.0.

To give an example, if your model has two objectives,  $1 + x + 2y$  and  $y + 2z$ , and if you give weights of  $-1$  and  $2$  to them, respectively, then Gurobi would solve your model with a blended objective of  $-1 \cdot (1 + x + 2y) + 2 \cdot (y + 2z) = -1 - x + 4z$ .

You should avoid weights that are very large or very small. A very large weight (i.e., larger than  $10^6$ ) may lead to very large objective coefficients, which can cause numerical difficulties. A very small weight (i.e., smaller than  $1e - 6$ ) may cause the contribution from that objective to the overall blended objective to be smaller than tolerances, which may lead to that objective being effectively ignored.

### Hierarchical Objectives

A hierarchical or lexicographic approach assigns a priority to each objective, and optimizes for the objectives in decreasing priority order. At each step, it finds the best solution for the current objective, but only from among those that would not degrade the solution quality for higher-priority objectives. You specify the priority for each objective through the `ObjNPriority` attribute. Priorities are integral, not continuous. Larger values indicate higher priorities. The default priority for an objective is 0.

To give an example, if your model has two objectives, with priorities 10 and 5, and the optimal solution for the first objective has value 100, then the solver will find the solution that optimizes the second objective from among all solutions with objective 100 for the first objective.

By default, our hierarchical approach won't allow later objectives to degrade earlier objectives. This behavior can be relaxed through a pair of attributes: `ObjNRelTol` and `ObjNAbsTol`. By setting one of these for a particular objective, you can indicate that later objectives are allowed to degrade

this objective by the specified relative or absolute amount, respectively. In our earlier example, if the optimal value for the first objective is 100, and if we set `ObjNAbsTo1` for this objective to 20, then the second optimization step would find the best solution for the second objective from among all solutions with objective 120 or better for the first objective. Note that if you modify both tolerances, later optimizations would use the looser of the two values (i.e., the one that allows the larger degradation).

### Combining Blended and Hierarchical Objectives

You can actually set both a weight and a priority for each objective. This allows you to combine the blended and hierarchical approaches. To understand how this works, we should first provide more detail on how hierarchical objectives are handled.

When you specify a different priority for each of  $n$  objectives, the solver performs  $n$  separate optimization steps. In each step, in decreasing priority order, it optimizes for the current objective, while imposing constraints that ensure that the quality of higher-priority objectives isn't degraded by more than the specified tolerances.

If you give the same priority to multiple objectives, then they will be handled in the same optimization step, resulting in fewer than  $n$  total steps for  $n$  objectives. More precisely, one optimization step is performed per distinct priority value, in order of decreasing priority, and all objectives with the same priority are blended together, using the weights for those objectives. This gives you quite a bit of flexibility when combining the blended and hierarchical approaches.

One subtle point when blending multiple objectives within a single level in a hierarchical approach relates to the handling of degradations from lower-priority levels. The objective degradation allowed after a blended optimization step is the maximum absolute and relative degradations allowed by each of the participating objectives. For example, if we have three objectives with `ObjNPriority` equal to  $\{2, 2, 1\}$ , and `ObjNRelTo1` equal to  $\{0.10, 0.05, 0.00\}$  and `ObjNAbsTo1` equal to  $\{0, 1, 2\}$ ; and the best solution for the first priority objective is 10; then the allowed degradation for the first priority objective is  $\max\{10 \cdot 0.10, 10 \cdot 0.05, 0, 1\} = 1$ .

## 19.3 Additional Details

Note that the optimality criteria for each optimization pass of a multiple-objective problem are defined as usual by the global parameters `MIPGap` and `MIPGapAbs`. This means that you can not set different optimality criteria for different objective functions.

We haven't attempted to generalize the notions of dual solutions or simplex bases for continuous multi-objective models, so you can't query attributes such as `Pi`, `RC`, `VBasis`, or `CBasis` for multi-objective solutions. Because of this, we've concluded that the most consistent result to return for attribute `IsMIP` is 1.

Gurobi will only solve multi-objective models with strictly linear objectives. If the primary objective is quadratic or piecewise linear, the solve call will return an error.

When solving a continuous multi-objective model using a hierarchical approach, you have a choice of which optimization algorithm to use for the different steps (primal simplex, dual simplex, or barrier). The first step will always use the algorithm specified in the `Method` parameter. The algorithm for subsequent steps is controlled by the `MultiObjMethod` parameter. This parameter has no effect for multi-objective MIP models.

For the hierarchical approach, Gurobi will perform a conservative presolve step at the beginning of the multi-objective optimization, and a more aggressive presolve step at the beginning of each step

(assuming presolve hasn't been turned off). You can optionally perform a more aggressive presolve step at the beginning of the multi-objective optimization by setting parameter [MultiObjPre](#) to value 2. This can help performance, but it makes a few simplifying assumptions that could lead to small degradations in the values achieved for lower-priority objectives.

The log file when using a hierarchical approach will show optimization progress for each step of the process. You'll see log lines that look like this:

```
Multi-objectives: optimize objective 1 (Obj1Name) ...  
...  
Multi-objectives: optimize objective 2 (weighted) ...  
...
```

For further details, please see section [Multi-Objective Logging](#).

The Gurobi Optimizer provides the option to record the set of Gurobi commands issued by your program and store them to a file. The commands can be played back later using the [Gurobi Command-Line Tool](#). If you replay the commands on a machine with the same specs (operating system, core count, and instruction set) as the machine where you created the recording, your Gurobi calls will take the exact same computational paths that they took when you ran your original program.

Recording can be useful in a number of situations...

- If you want to understand how much time is being spent in Gurobi routines, the replay will show you the total time spent in Gurobi API routines, and the total time spent in Gurobi algorithms.
- If you want to check for leaks of Gurobi data, the replay will show you how many Gurobi models and environments were never freed by your program.
- If you run into a question or an issue and you would like to get help from Gurobi, your recording will allow Gurobi technical support to reproduce the exact results that you are seeing without requiring you to send your entire application.

## 20.1 Recording

To enable recording, you simply need to set the [Record](#) parameter to 1 as soon as you create your Gurobi environment. The easiest way to do this is with a `gurobi.env` file. This file should contain the following line:

```
Record 1
```

If you put this file in the same directory as your application, Gurobi will pick up the setting when your applications makes its first Gurobi call. You can also set this parameter through the standard [parameter modification routines](#) in your program.

Once this parameter is set, you should see the following in your log:

```
*** Start recording in file recording000.grbr
```

If your application creates more than one Gurobi environment, you may see more than one of these messages. Each will write to a different file:

```
*** Start recording in file recording001.grbr
```

As your program runs, Gurobi will write the commands and data that are passed into Gurobi routines to these files. Recording continues until you free your Gurobi environment (or until your program ends). When you free the environment, if Gurobi logging is enabled you will see the following message:

```
*** Recording complete - close file recording000.grbr
```

At this point, you have a recording file that is ready for later replay.

## 20.2 Replay

To replay a Gurobi recording, you issue the following command:

```
> gurobi_cl recording000.grbr
```

You should adjust the file name to match the file you wish to replay. If your program generated multiple recording files, you will need to replay each one separately.

When the replay starts, the first output you will see will look like this:

```
*Replay* Replay of file 'recording000.grbr'  
*Replay* Recording captured Tue Sep 13 19:28:48 2016  
*Replay* Recording captured with Gurobi version 7.0.0 (linux64)
```

After this output, the replay will start executing the commands issued by your program...

```
*Replay* Load new Gurobi environment  
*Replay* Create new Gurobi model (0 rows, 0 cols)  
*Replay* Update Gurobi model  
*Replay* Change objective sense to -1  
*Replay* Add 3 new variables
```

This continues until the recording file ends. At that point, the replay will print out a final runtime accounting...

```
*Replay* Replay complete  
  
*Replay* Gurobi API routine runtime: 0.05s  
*Replay* Gurobi solve routine runtime: 2.31s
```

If your program leaked any Gurobi models or environments, you may also see that in the output:

```
*Replay* Models leaked: 2  
*Replay* Environments leaked: 1
```

## 20.3 Limitations

Recording works with most programs that call Gurobi. There are a few Gurobi features that aren't supported, though:

- Recording won't capture calls to the Gurobi tuning tool.
- You can't use recording if you are a client of a Gurobi Compute Server.
- Recording won't capture data passed into control callbacks. In other words, you can't record a program that adds lazy constraints, user cuts, or solutions through callbacks.

Concurrent optimization is a simple approach for exploiting multiple processors. It starts multiple, independent solves on a model, using different strategies for each. Optimization terminates when the first one completes. By pursuing multiple different strategies simultaneously, the concurrent optimizer can often obtain a solution faster than it would if it had to choose a single strategy.

Concurrent optimization is our default choice for solving LP models, and a user-selectable option for solving MIP models. The concurrent optimizer can be controlled in a few different ways. These will be discussed in this section. To avoid confusion when reporting results from multiple simultaneous solves, we've chosen to produce simplified [logs](#) and [callbacks](#) when performing concurrent optimization. These will also be discussed in this section.

## Controlling Concurrent Optimization

If you wish to use the concurrent optimizer to solve your model, the steps you need to take depend on the model type. As mentioned earlier, the concurrent optimizer is the default choice for LP models. This choice is controlled by the [Method](#) parameter. For MIP models, you can select the concurrent optimizer by modifying the [ConcurrentMIP](#) parameter.

When controlling the concurrent optimizer using these parameters, the strategies used for the different independent solves are chosen automatically. While we reserve the right to change our choices in the future, for LP models we currently devote the first concurrent thread to dual simplex, the second through fourth to a single parallel barrier solve, and the fifth to primal simplex. Additional threads are devoted to the one parallel barrier solve. Thus, for example, a concurrent LP solve using four threads would devote one thread to dual simplex and three to parallel barrier. For MIP, we divide available threads evenly among the independent solves, and we choose different values for the [MIPFocus](#) and [Seed](#) parameters for each.

If you want more control over concurrent optimization (e.g., to choose the exact strategies used for each independent solve), you can do so by creating two or more *concurrent environments*. These can be created via API routines (in [C](#), [C++](#), [Java](#), [.NET](#), or [Python](#)), or they can be created from `.prm` files using the [ConcurrentSettings](#) parameter if you are using our command-line interface. Once these have been created, subsequent optimization calls will start one independent solve for each concurrent environment you created. To control the strategies used for each solve, you simply set the parameters in each environment to the values you would like them to take in the corresponding solve. For example, if you create two concurrent environments and set the [MIPFocus](#) parameter to 1 in the first and 2 in the second, subsequent MIP optimize calls will perform two solves in parallel, one with `MIPFocus=1` and the other with `MIPFocus=2`.

## Logging

Your first indication that the concurrent optimizer is being used is output in the Gurobi log that looks like this...

```
Concurrent LP optimizer: dual simplex and barrier
Showing barrier log only...
```

...or like this...

Concurrent MIP optimizer: 2 concurrent instances (2 threads per instance)

These log lines indicate how many independent solves will be launched. For the LP case, the lines also indicate which methods will be used for each.

Since it would be quite confusing to see results from multiple solves interleaved in a single log, we've chosen to use a simplified log format for concurrent optimization. For concurrent LP, we only present the log for a single solve. For concurrent MIP, the log is similar to our standard MIP log, except that it only provides periodic summary information (see the [MIP logging](#) section if you are unfamiliar with our standard MIP log). Each concurrent MIP log line shows the objective for the best feasible solution found by any of the independent solves to that point, the best objective bound proved by any of the independent solves, and the relative gap between these two values:

Nodes		Current Node			Objective Bounds			Work	
Expl	Unexpl	Obj	Depth	IntInf	Incumbent	BestBd	Gap	It/Node	Time
0	0	-	-	-	24.00000	13.00000	45.8%		0s
0	0	-	-	-	16.50000	13.21154	19.9%		0s
0	0	-	-	-	16.50000	13.25000	19.7%		0s
0	0	-	-	-	16.50000	13.37500	18.9%		0s
0	0	-	-	-	16.50000	13.37500	18.9%		0s
0	0	-	-	-	16.50000	13.37500	18.9%		0s
0	6	-	-	-	15.50000	13.37500	13.7%		0s
310	149	-	-	-	15.00000	13.66923	8.87%		0s
3873	1634	-	-	-	15.00000	14.00000	6.67%		5s
9652	4298	-	-	-	15.00000	14.12500	5.83%		10s
16535	6991	-	-	-	15.00000	14.18056	5.46%		15s
23610	9427	-	-	-	15.00000	14.22333	5.18%		20s

...

We also include node counts from one of the independent solves, as well as elapsed times, to give some indication of forward progress.

### Determinism

Concurrent optimization essentially sets up a race between multiple threads to solve your model, with the winning thread returning the solution that it found. In cases where multiple threads solve the model in roughly the same amount of time, small variations in runtime from one run to the next could mean that the winning thread is not the same each time. If your model has multiple optimal solutions (which is quite common in LP and MIP), then it is possible that running a concurrent solver multiple times on the same model could produce different optimal solutions. This is known as non-deterministic behavior.

By default, the Gurobi concurrent solvers all produce non-deterministic behavior. You can obtain deterministic behavior for the concurrent LP solver by setting the [Method](#) parameter to value 4. This setting typically increases runtimes slightly, but if your application is dependent on deterministic behavior, deterministic concurrent LP is often your best option. There is no similar setting for the concurrent MIP solver.

## Callbacks

Rather than providing callbacks from multiple independent solves simultaneously, we've again chosen to simplify behavior for the concurrent optimizer. In particular, we only supply callbacks from a single solve. A few consequences of this choice:

- Information retrieved by your callback (solutions, objective bounds, etc.) will come from a single model.
- User cutting planes are only applied to a single model.
- You aren't allowed to use lazy constraints with concurrent MIP, since they would only be applied to one model.

The Gurobi Optimizer provides a wide variety of [parameters](#) that allow you to control the operation of the optimization engines. The level of control varies from extremely coarse-grained (e.g., the [Method](#) parameter, which allows you to choose the algorithm used to solve continuous models) to very fine-grained (e.g., the [MarkowitzTol](#) parameter, which allows you to adjust the tolerances used during simplex basis factorization). While these parameters provide a tremendous amount of user control, the immense space of possible options can present a significant challenge when you are searching for parameter settings that improve performance on a particular model. The purpose of the Gurobi tuning tool is to automate this search.

The Gurobi tuning tool performs multiple solves on your model, choosing different parameter settings for each solve, in a search for settings that improve runtime. The longer you let it run, the more likely it is to find a significant improvement. If you are using a [Gurobi Compute Server](#), you can harness the power of multiple machines to perform [distributed parallel tuning](#) in order to speed up the search for effective parameter settings.

The tuning tool can be invoked through two different interfaces. You can either use the [grbtune command-line tool](#), or you can invoke it from one of our [programming language APIs](#). Both approaches share the same underlying tuning algorithm, and both allow you to modify the same set of tuning parameters.

A number of tuning-related parameters allow you to control the operation of the tuning tool. The most important is probably [TuneTimeLimit](#), which controls the amount of time spent searching for an improving parameter set. Other parameters include [TuneTrials](#) (which attempts to limit the impact of randomness on the result), [TuneCriterion](#) (which specifies the tuning criterion), [TuneResults](#) (which controls the number of results that are returned), and [TuneOutput](#) (which controls the amount of output produced by the tool).

Before we discuss the actual operation of the tuning tool, let us first provide a few caveats about the results. While parameter settings can have a big performance effect for many models, they aren't going to solve every performance issue. One reason is simply that there are many models for which even the best possible choice of parameter settings won't produce an acceptable result. Some models are simply too large and/or difficult to solve, while others may have numerical issues that can't be fixed with parameter changes.

Another limitation of automated tuning is that performance on a model can experience significant variations due to random effects (particularly for MIP models). This is the nature of search. The Gurobi algorithms often have to choose from among multiple, equally appealing alternatives. Seemingly innocuous changes to the model (such as changing the order of the constraint or variables), or subtle changes to the algorithm (such as modifying the random number seed) can lead to different choices. Often times, breaking a single tie in a different way can lead to an entirely different search. We've seen cases where subtle changes in the search produce 100X performance swings. While the tuning tool tries to limit the impact of these effects, the final result will typically still be heavily influenced by such issues.

The bottom line is that automated performance tuning is meant to give suggestions for param-

eters that could produce consistent, reliable improvements on your models. It is not meant to be a replacement for efficient modeling or careful performance testing.

## 22.1 Command-Line Tuning

The `grbtune` command-line tool provides a very simple way to invoke parameter tuning on a model (or a set of models). You specify a list of `parameter=value` arguments first, followed by the name of the file containing the model to be tuned. For example, you can issue the following command (in a Windows command window, or in a Linux/Mac terminal window)...

```
> grbtune TuneTimeLimit=10000 c:\gurobi550\win64\examples\data\misc07
```

(substituting the appropriate path to a model, stored in an MPS or LP file). The tool will try to find parameter settings that reduce the runtime on the specified model. When the tuning run completes, it writes a set of `.prm` files in the current working directory that capture the best parameter settings that it found. It also writes the Gurobi log files for these runs (in a set of `.log` files).

You can also invoke the tuning tool through our programming language APIs. That will be discussed [shortly](#).

If you specify multiple model files at the end of the command line, the tuning tool will try to find settings that minimize the total runtime for the listed models.

### Running the Tuning Tool

The first thing the tuning tool does is to perform a baseline run. The parameters for this run are determined by your choice of initial parameter values. If you set a parameter, it will take the chosen value throughout tuning. Thus, for example, if you set the `Method` parameter to 2, then the baseline run and all subsequent tuning runs will include this setting. In the example above, you'd do this by issuing the command:

```
> grbtune Method=2 TuneTimeLimit=100 misc07
```

For a MIP model, you will note that the tuning tool actually performs several baseline runs, and captures the mean runtime over all of these trials. In fact, the tool will perform multiple runs for each parameter set considered. This is done to limit the impact of random effects on the results, as discussed earlier. Use the `TuneTrials` parameter to adjust the number of trials performed.

Once the baseline run is complete, the time for that run becomes the time to beat. The tool then starts its search for improved parameter settings. Under the default value of the `TuneOutput` parameter, the tool prints output for each parameter set that it tries...

```
Testing candidate parameter set 7...
```

```
Method 2  
MIPFocus 1
```

```
Solving with random seed #1 ... runtime 3.63s  
Solving with random seed #2 ... runtime 4.12s+
```

```
Progress so far: baseline runtime 3.38s, best runtime 2.88s  
Total elapsed tuning time 34s (66s remaining)
```

This output indicates that the tool has tried 7 parameter sets so far. For the seventh set, it changed the value of the [MIPFocus](#) parameter (the [Method](#) parameter was changed in our initial parameter settings, so this change will appear in every parameter set that the tool tries). The first trial solved the model in 3.63 seconds, while the second hit a time limit that was set by the tuning tool (as indicated by the + after the runtime output). If any trial hits a time limit, the corresponding parameter set is considered worse any set that didn't hit a time limit. The output also shows that the best parameter set found so far gives a runtime of 2.88s. Finally, it shows elapsed and remaining runtime.

Tuning normally proceeds until the elapsed time exceeds the tuning time limit. However, hitting CTRL-C will also stop the tool.

When the tuning tool finishes, it prints a summary...

```
Tested 20 parameter sets in 97.89s
```

```
Baseline parameter set: runtime 3.38s
```

```
Improved parameter set 1 (runtime 1.62s):
```

```
Method 2
Heuristics 0
VarBranch 1
CutPasses 3
GomoryPasses 0
```

```
Improved parameter set 2 (runtime 2.03s):
```

```
Method 2
Heuristics 0
VarBranch 1
CutPasses 3
```

```
Improved parameter set 3 (runtime 2.38s):
```

```
Method 2
VarBranch 1
```

```
Wrote parameter files tune1.prm through tune3.prm
```

```
Wrote log files: tune1.log through tune3.log
```

The summary shows the number of parameter sets it tried, and provides details on a few of the best parameter sets it found. It also shows the names of the `.prm` and `.log` files it writes. You can change the names of these files using the [ResultFile](#) parameter. If you set `ResultFile=model.prm`, for example, the tool would write `model1.prm` through `model3.prm` and `model1.log` through `model3.log`.

The number of sets that are retained by the tuning tool is controlled by the [TuneResults](#) parameter. The default behavior is to keep the sets that achieve the best tradeoff between runtime

and the number of changed parameters. In other words, we report the set that achieves the best result when changing one parameter, when changing two parameters, etc. We actually report a Pareto frontier, so for example we won't report a result for three parameter changes if it is worse than the result for two parameter changes.

### Other Tuning Parameters

So far, we've only talked about using the tuning tool to minimize the time to find an optimal solution. For MIP models, you can also minimize the optimality gap after a specified time limit. You don't have to take any special action to do this; you just set a time limit. Whenever a baseline run hits this limit, the tuning tool will automatically try to minimize the MIP gap. To give an example, the command...

```
> grbtune TimeLimit=100 glass4
```

...will look for a parameter set that minimizes the optimality gap achieved after 100s of runtime on model `glass4`. If the tool happens to find a parameter set that solves the model within the time limit, it will then try to find settings that minimize mean runtime.

For models that don't solve to optimality in the specified time limit, you can gain more control over the criterion used to choose a *winning* parameter set with the `TuneCriterion` parameter. This parameter allows you to tell the tuning tool to search for parameter settings that produce the best incumbent solution or the best lower bound, rather than always minimizing the MIP gap,

You can modify the `TuneOutput` parameter to produce more or less output. The default value is 2. A setting of 0 produces no output; a setting of 1 only produces output when an improvement is found; a setting of 3 produces a complete Gurobi log for each run performed.

If you would like to use a MIP start with your tuning run, you can include the name of the start file immediately after the model name in the argument list. For example:

```
> grbtune misc07.mps misc07.mst
```

You can also use MIP starts when tuning over multiple models; any model that is immediately followed by a start file in the argument list will use the corresponding start. For example:

```
> grbtune misc07.mps misc07.mst p0033.mps p0548.mps p0548.mst
```

## 22.2 Tuning API

The tuning tool can be invoked from our [C](#), [C++](#), [Java](#), [.NET](#), and [Python](#) interfaces. The tool behaves slightly differently when invoked from these interfaces. Rather than writing the results to a set of files, upon completion the tool populates a `TuneResultCount` attribute, which gives a count of the number of improving parameter sets that were found and retained. The user program can then query the value of this attribute, and then use the `GetTuneResult` method to copy any of these parameter sets into a model (using [C](#), [C++](#), [Java](#), [.NET](#), or [Python](#)). Once loaded into the model, the parameter set can be used to perform a subsequent optimization, or the list of changed parameters can be written to a `.prm` file using the appropriate `Write` routine (from [C](#), [C++](#), [Java](#), [.NET](#), or [Python](#)).

Gurobi Remote Services allow a machine to perform Gurobi computations on behalf of other machines. It is a Windows Service on Windows systems, and a daemon on Linux and Mac systems. The set of services provided will depend on your license. The most basic service is the Distributed Worker, which allows a machine to be used as a worker in a [Distributed Algorithm](#). Another, more powerful service is [Compute Server](#), which allows you to offload Gurobi computations from a set of client machines onto one or more servers. Later sections will discuss the use of these services. This section is devoted to the configuration and administration of Gurobi Remote Services.

## 23.1 Setting Up and Administering Gurobi Remote Services

Setting up Gurobi Remote Services is generally quite straightforward. One option is to simply follow the basic setup instructions in the [Quick Start Guide](#). The default settings have been chosen to work well in most usage environment. However, even if you choose to use the defaults, you'll probably want to be aware of the additional options and capabilities described here, including [server parameters](#), [firewall issues](#), and [remote administration options](#).

### Gurobi Remote Services Parameters

As noted in the Quick Start Guide, you start Gurobi Remote Services by running the `grb_rs` program on the server machine. This starts a Windows service on Windows systems, and a daemon on Linux or Mac OS systems. When Gurobi Remote Services starts, it picks up user parameter settings from an optional `grb_rs.cnf` file (the file must be in the directory that contains the `grb_rs` executable).

To modify the default settings, you should place a list of `parameter=value` lines in this configuration file. Lines that begin with the `#` symbol are treated as comments and are ignored. Here's an example file:

```
# Configuration file
PASSWORD=abcd1234
ADMINPASSWORD=1234abcd
```

You can create this file using your favorite text editor ([Notepad](#) is a good choice on Windows).

Some Gurobi Remote Services parameters are generic, while others are specific to a particular service. The generic parameters are:

**PASSWORD:** The password that the client program must supply in order to submit a job. Note that all user data is passed between the client and server using 256-bit AES encryption, whether you supply a password or not. The server password simply prevents unauthorized clients from submitting jobs to the server. The default is no password.

**ADMINPASSWORD:** The password for performing administrative tasks. This is different from the password that client programs must provide. Administrative tasks are performed using the

`gurobi_cl` program. Example tasks include changing the job limit and killing jobs ([details will follow](#)). Note that the administrator password must be set if you wish to enable remote administration.

**THREADLIMIT:** A limit on the number of threads a single job can launch on the server. By default, a job can create as many threads as it likes (although by default the Gurobi algorithms won't create more than one thread per core).

A few Gurobi Remote Services parameters are specific to Compute Server. They control the job queuing features...

**JOBLIMIT:** A limit on the number of client jobs that are allowed to run on the server at a time. Client requests beyond this limit are queued. The default limit is 2.

**HARDJOBLIMIT:** A hard limit on the number of simultaneous client jobs. Certain jobs (those with priority 100) are allowed to ignore the **JOBLIMIT**, but they aren't allowed to ignore this limit. Client requests beyond this limit are queued. The default hard limit is 100.

**IGNOREPRIORITIES:** When set to 1, the server ignores user job priorities.

The configuration file is only read once, when Gurobi Remote Services first starts. Subsequent changes to the file won't affect parameter values on a running server.

## Firewalls

A machine running Gurobi Remote Services communicates with clients through a number of network ports on the server machine. By default, it uses ports 61000-65000. You generally don't need to be aware of the details, since in most cases the server will either silently allow Gurobi Remote Services to use these ports or it will ask you to confirm that these ports can be used. However, some situations require you to manually open these ports.

One notable example is Amazon EC2, where most network ports are closed by default. You'll need to create an EC2 *Security Group* (or modify your default group) when you start your instance in order to open these ports.

If for some reason our default port range is unavailable on your server, you can include a **PORT=** statement *in both the client and the server license files* to choose a different range. For example, the line:

```
PORT=43000
```

would use ports 43000-47000 instead.

If you run into trouble with firewall issues, we suggest you share this section with your network administrator.

## Administrative Commands

Gurobi Remote Services provides a number of administration features. These allow you to check the status of a server, kill a running job, etc. All are accessed through the `gurobi_cl` command-line tool. Refer to [this section](#) (and [this subsection](#) in particular) for more information.

## Copyright Notice for 3rd Party Library

Gurobi Compute Server uses an AES encryption library written Brian Gladman for encrypting messages between the client and the server. Here is the copyright notice for that library:

-----  
Copyright (c) 1998-2010, Brian Gladman, Worcester, UK. All rights reserved.

The redistribution and use of this software (with or without changes) is allowed without the payment of fees or royalties provided that:

source code distributions include the above copyright notice, this list of conditions and the following disclaimer;

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This software is provided 'as is' with no explicit or implied warranties in respect of its operation, including, but not limited to, correctness and fitness for purpose.

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# Distributed Parallel Algorithms

Gurobi Optimizer implements a number of distributed algorithms that allow you to use multiple machines to solve a problem faster. Available distributed algorithms are:

- **A distributed MIP solver**, which allows you to divide the work of solving a single MIP model among multiple machines. A manager machine passes problem data to a set of worker machines in order to coordinate the overall solution process.
- **A distributed concurrent solver**, which allows you to use multiple machines to solve an LP or MIP model. Unlike the distributed MIP solver, the concurrent solver doesn't divide the work associated with solving the problem among the machines. Instead, each machine uses a different strategy to solve the whole problem, with the hope that one strategy will be particularly effective and will finish much earlier than the others. For some problems, this concurrent approach can be more effective than attempting to divide up the work.
- **Distributed parameter tuning**, which automatically searches for parameter settings that improve performance on your optimization model. Tuning solves your model with a variety of parameter settings, measuring the performance obtained by each set, and then uses the results to identify the settings that produce the best overall performance. The distributed version of tuning performs these trials on multiple machines, which makes the overall tuning process run much faster.

These distributed algorithms are designed to be nearly transparent to the user. The user simply modifies a few parameters, and the work of distributing the computation among multiple machines is handled behind the scenes by the Gurobi library.

## 24.1 Configuring a Distributed Worker Pool

Before your program can perform a distributed optimization task, you'll need to identify a set of machines to use as your distributed workers. Ideally these machines should give very similar performance. Identical performance is best, especially for distributed tuning, but small variations in performance won't hurt your overall results too much.

### Specifying the Distributed Worker Pool

Once you've identified your distributed worker machines, you'll need to start [Gurobi Remote Services](#) on these machines. Instructions for setting up Gurobi Remote Services can be found in the [Gurobi Quick Start Guide](#). As noted in the Quick Start Guide, run following command to make sure a machine is available to be used as a distributed worker:

```
> gurobi_cl --server=machine --status
```

(replace `machine` with the name or IP address of your machine). If you see `Distributed Worker` listed among the set of available services...

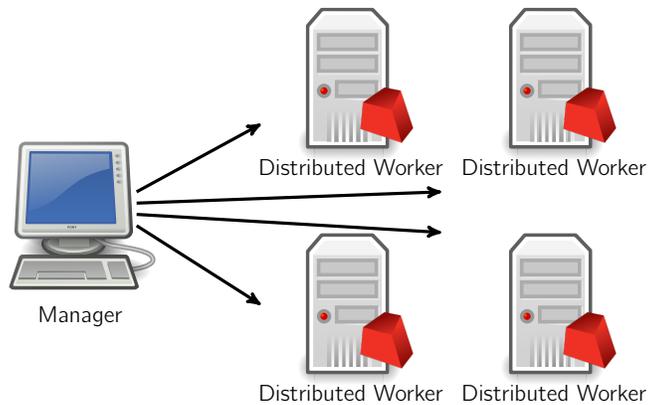
Gurobi Remote Services (version 7.0.0) functioning normally  
Available services: Distributed Worker

then that machine is good to go.

We should reiterate a point that is raised in the Quick Start Guide: you do not need a Gurobi license to run Gurobi Remote Services on a machine. Some services are only available with a license (e.g., [Compute Server](#)). However, any machine that is running Gurobi Remote Services will provide the Distributed Worker service.

### The Distributed Manager Machine

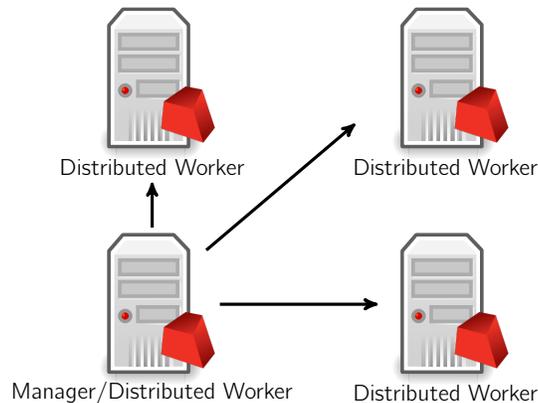
Once you have identified a set of distributed worker machines, you'll need to choose a manager machine. This is the machine where your application actually runs. In addition to building the optimization model, your manager machine will coordinate the efforts of the distributed workers during the execution of the distributed algorithm.



Note that once the distributed algorithm completes, only the manager retains any information about the solution. The distributed workers go off to work on other things.

You'll need to choose a manager machine that is licensed to run the distributed algorithms. You'll see a `DISTRIBUTED=` line in your license file if distributed algorithms are enabled.

Note that, by default, the manager does *not* participate in the distributed optimization. It simply coordinates the efforts of the distributed workers. If you would like the manager to also act as one of the workers, you'll need to start Gurobi Remote Services on the manager machine as well.



The workload associated with managing the distributed algorithm is quite light, so a machine can handle both the manager and worker role without degrading performance.

Note that we only allow a machine to act as manager for a single distributed job. If you want to run multiple distributed jobs simultaneously, you'll need multiple manager machines.

### Specifying the Distributed Worker Pool

If you'd like to invoke a distributed algorithm from your application, you'll need to provide the names of the distributed worker machines. You do this by setting the [WorkerPool](#) parameter (refer to the [Gurobi Parameter](#) section for information on how to set a parameter). The parameter should be set to a string that contains a comma-separated list of either machine names or IP addresses. For example, you might use the following in your `gurobi_cl` command line:

```
> gurobi_cl WorkerPool=server1,server2,server3 ...
```

If you have set up an access password on the distributed worker machines, you'll need to provide it through the [WorkerPassword](#) parameter. All machines in the worker pool must have the same access password.

Note that providing a list of available workers is strictly a configuration step. Your program won't actually use any of the distributed algorithms unless it specifically requests them. Instructions for doing so are next.

### Requesting A Distributed Algorithm

Once you've set the `WorkerPool` parameter to the appropriate value, your final step is to set the [ConcurrentJobs](#), [DistributedMIPJobs](#), or [TuneJobs](#) parameter. These parameters indicate how many distinct distributed worker jobs you would like to start. For example, if you set `TuneJobs` to 2 in `grbtune...`

```
> grbtune WorkerPool=server1,server2 TuneJobs=2 misc07.mps
```

...you should see the following output in the log...

```
Started distributed worker on server1
Started distributed worker on server2
```

```
Distributed tuning: launched 2 distributed worker jobs
```

This output indicates that two jobs have been launched, one on machine `server1` and the other on machine `server2`. These two jobs will continue to run until your tuning run completes.

Similarly, if you launch distributed MIP...

```
> gurobi_cl WorkerPool=server1,server2 DistributedMIPJobs=2 misc07.mps
```

...you should see the following output in the log...

```
Started distributed worker on server1
Started distributed worker on server2
```

```
Distributed MIP job count: 2
```

Note that, in most cases, each machine runs one distributed worker job at a time. Distributed workers are allocated on a first-come, first-served basis, so if multiple users are sharing a set of distributed worker machines, you should be prepared for the possibility that some or all of them may be busy when the manager requests them. The manager will grab as many as it can, up to the requested count. If none are available, it will return an error.

### Compute Server Considerations

If you have one or more [Gurobi Compute Servers](#), you can use them for distributed optimization as well. Compute Servers offer a lot more flexibility than distributed workers, though, so they require a bit of additional explanation.

The first point you should be aware of is that one Compute Server can actually host multiple distributed worker jobs. Compute Servers allow you to set a limit on the number of jobs that can run simultaneously. Each of those jobs can be a distributed worker. For example, if you have a pair of Compute Servers, each with a job limit of 2, then issuing the command...

```
> gurobi_cl DistributedMIPJobs=3 WorkerPool=server1,server2 misc07.mps
```

...would produce the following output...

```
Started distributed worker on server1
Started distributed worker on server2
Started distributed worker on server1
```

Compute Server assigns a new job to the machine with the most available capacity, so assuming that the two servers are otherwise idle, the first distributed worker job would be assigned to `server1`, the second to `server2`, and the third to `server1`.

Another point to note is that, if you are working in a Compute Server environment, it is often better to use the Compute Server itself as the distributed manager, rather than the client machine. This is particularly true if the Compute Server and the workers are physically close to each other, but physically distant from the client machine. In a typical environment, the client machine will offload the Gurobi computations onto the Compute Server, and the Compute Server will then act as the manager for the distributed computation.

To give an example, running following command on machine `client1`:

```
> gurobi_cl --server=server1 WorkerPool=server1,server2 DistributeMIPJobs=2 misc07.mps
```

...will lead to the following sequence of events...

- The model will be read from the disk on `client1` and passed to Compute Server `server1`.
- Machine `server1` will act as the manager of the distributed optimization.
- Machine `server1` will start two distributed worker jobs, one that also runs on `server1` and another that runs on `server2`.

Compute Server provides load balancing among multiple machines, so it is common for the user to provide a list of available servers when a Gurobi application starts. We'll automatically copy this list into the `WorkerPool` parameter. Of course, you can change the value of this parameter in your program, but the default behavior is to draw from the same set of machines for the distributed workers. Thus, the following command would be equivalent to the previous command:

```
> gurobi_cl --server=server1,server2 DistributedMIPJobs=2 misc07.mps
```

Please refer to the [next section](#) section for more information on using a Gurobi Compute Server.

## 24.2 Writing Your Own Distributed Algorithms

Gurobi provides a set of routines that allow you to write your own distributed algorithms. Doing so requires a Compute Server, though. This capability will be discussed in the [Compute Server](#) section.

## 24.3 Distributed Algorithm Considerations

So far in this section, we've focused almost entirely on configuration and setup issues for the distributed algorithms in this section. These algorithms have been designed to be nearly indistinguishable from the single machine versions. Our hope is that, if you know how to use the single machine version, you'll find it straightforward to use the distributed version. The distributed algorithms respect all of the usual parameters. For distributed MIP, you can adjust strategies, adjust tolerances, set limits, etc. For concurrent MIP, you can allow Gurobi to choose the settings for each machine automatically or you can use [concurrent environments](#) to make your own choices. For distributed tuning, you can use the usual tuning parameters, including [TuneTimeLimit](#), [TuneTrials](#), and [TuneOutput](#).

### Performance Across Distributed Workers

There are a few things to be aware of when using distributed algorithms, though. One relates to relative machine performance. As we noted earlier, distributed algorithms work best if all of the workers give very similar performance. For example, if one machine in your worker pool were much slower than the others in a distributed tuning run, any parameter sets tested on the slower machine would appear to be less effective than if they were run on a faster machine. Similar considerations apply for distributed MIP and distributed concurrent. We strongly recommend that you use machines with very similar performance. Note that if your machines have similarly performing cores but different numbers of cores, we suggest that you use the [Threads](#) parameter to make sure that all machines use the same number of cores.

### Callbacks

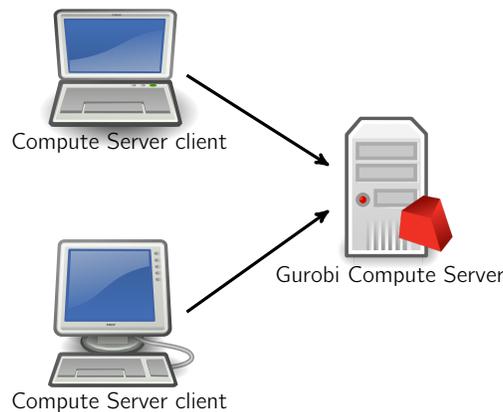
Another difference between the distributed algorithms and our single-machine algorithms is in the callbacks. The distributed MIP and distributed concurrent solvers do not provide the full range of callbacks that are available with our standard solvers. They will only provide the MIP, MIPNODE, and POLLING callbacks. See the [Callback](#) section for details on the different callback types.

### Logging

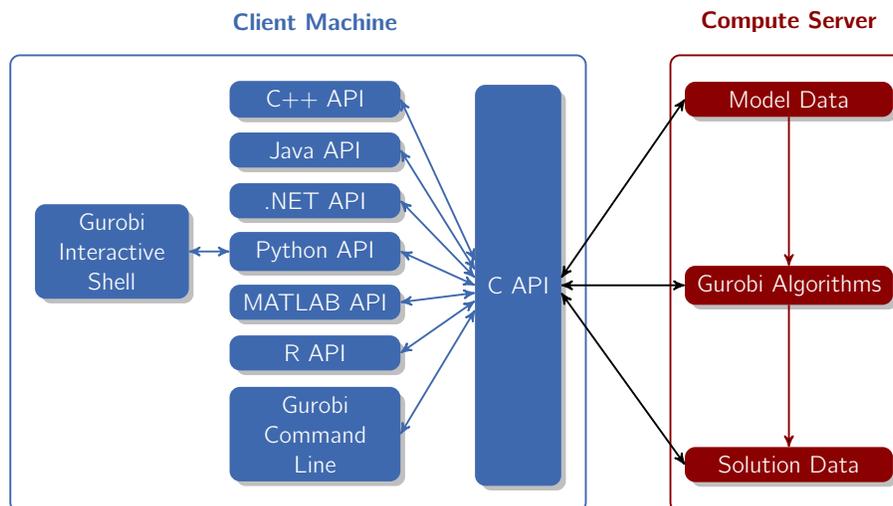
The distributed algorithms provide slightly different logging information from the standard algorithms. Consult the [Distributed MIP Logging](#) section for details.

# Gurobi Compute Server

This section describes Gurobi Compute Server, an optional component of [Gurobi Remote Services](#) that allows you to choose one or more servers to run your Gurobi computations. You can then offload the work associated with solving optimization problems onto these servers from as many client machines as you like:



When considering a program that uses Gurobi Compute Server, you can think of the optimization as being split into two parts. A client program builds an optimization model using any of the standard Gurobi interfaces (C, C++, Java, .NET, Python, MATLAB, R). This happens in the left box of this figure:

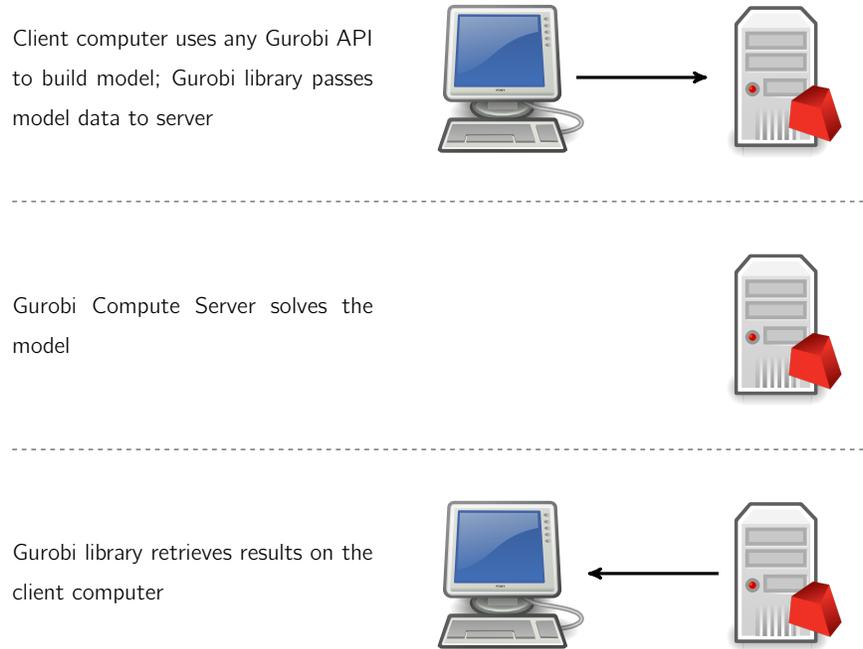


All of our API's sit on top of our C API. The C API is in charge of building the internal model data structures, invoking the Gurobi algorithms, retrieving solution information, etc. When running Gurobi on a single machine, the C API would build the necessary data structures in

memory. The Gurobi algorithms would take the data stored in these data structures as input, and produce solution data as output.

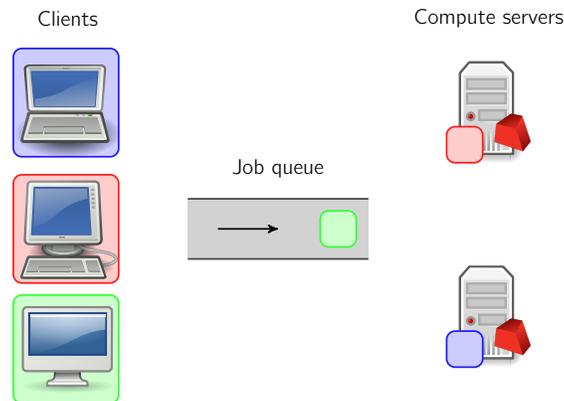
When running on a Compute Server, the C API instead passes model data to the server, where it is stored. When the Gurobi algorithms are invoked, the C API simply passes a message to the server, indicating that optimization should be performed on the stored model data. Solution data is computed and stored on the server. When the client program later queries the solution information, the client sends a message to the server in order to obtain the requested data. All communication between the client and server happens behind the scenes,

In other words, the overall process can be viewed as happening in three phases:



Of course, programs that use the Gurobi API's in more complex ways would have additional steps.

Gurobi Compute Servers support queuing and load balancing. You can set a limit on the number of simultaneous jobs each Compute Server will run. When this limit has been reached, subsequent jobs will be queued. If you have multiple Compute Servers, the current job load is automatically balanced among the available servers.



By default, the Gurobi job queue is serviced in a First-In, First-Out (FIFO) fashion. However, jobs can be given different priorities (through a client license file, or through API calls). Jobs with higher priorities are then selected from the queue before jobs with lower priorities.

While the Gurobi Compute Server is meant to be transparent to both developers and users, there are a few aspects of Compute Server usage that you do need to be aware of. These include performance considerations, APIs for configuring client programs, and a few features that are not supported for Compute Server applications. Please proceed to [Compute Server usage](#) for details.

## 25.1 Setting Up and Administering a Gurobi Compute Server

To use Compute Server, you'll need to start [Gurobi Remote Services](#) on one or more servers. Once you've got a Compute Server running, you can check to make sure that you will be able to submit jobs to it by issuing the following command from any machine that can reach the server on your network:

```
> gurobi_cl --server=servername --status
```

(replace `servername` with the name of your server). If you see the following lines in the resulting output, Compute Server is ready to go:

```
Gurobi Remote Services (version 7.0.0) functioning normally
Available services: Distributed Worker, Compute Server
```

Compute Server provides a number of user configurable parameters to control things like the user and administrator passwords, limits on the number of jobs that can run simultaneously, etc. Compute Server also has a number of administrative commands that allow you to kill jobs, obtain a list of running and queued jobs, and change parameters. Please refer to the [Gurobi Remote Services](#) section for details.

## 25.2 Compute Server Usage

The Gurobi Compute Server feature was designed to be almost entirely transparent to both the developers and the users of the programs that use it. However, there are a few topics that you may need to be aware of, including [setting up a Compute Server client](#), [setting job priorities](#), [performance considerations](#), [callbacks](#), and a few [coding practices for Compute Server](#).

### Client Configuration

Compute Server clients must know how to reach the desired servers. You have a few options for providing this information. Your first is through the client `gurobi.lic` file. That file should contain a line like the following:

```
COMPUTESERVER=server1.mydomain.com,server2.mydomain.com
```

You can create this license file yourself, using your favorite text editor (`Notepad` is a good choice on Windows). You simply need to provide a list of the names of the machines that are acting as Compute Servers. You can refer to the Compute Server machines using their names (e.g., `server.mydomain.com`) or their IP addresses (e.g., `192.168.1.100`).

Your client license file may optionally specify a few additional pieces of information. The first is the Compute Server password:

```
PASSWORD=abcd
```

This should match the password that you chose when you started the Compute Server. The second is the job priority:

```
PRIORITY=10
```

As you might expect, higher priority jobs take precedence over lower priority jobs. Priorities will be discussed in more detail shortly. The third is the queuing timeout:

```
TIMEOUT=60
```

A job that has been sitting in queue for longer than the specified `TIMEOUT` value (in seconds) will return with a `JOB_REJECTED` error.

Your second option for specifying the desired Compute Servers is through API calls. The appropriate call depends on your programming language. From C, you would call `GRBloadclientenv`. From our object-oriented interfaces, the `GRBEnv` constructors each provide a signature that allows you to specify the compute server(s), the compute server password, the job priority, and a timeout for jobs submitted by that program.

Your final option for specifying the desired Compute Servers is specific to the Gurobi command-line tool. The `--server=` or `--servers=` argument allows you to provide a comma-separated list of Compute Servers (and the optional `--password` argument allows you to specify the user password):

```
> gurobi_cl --servers=server1,server2 --password=password1 misc07.mps
```

## Job Priorities

As noted earlier, Gurobi Compute Servers support job priorities. You can assign an integer priority between -100 and 100 to each job (the default is 0). When choosing among queued jobs, the Compute Server will run the highest priority job first. Note that servers will never preempt running jobs.

We have chosen to give priority 100 a special meaning. A priority 100 job will start immediately, even if this means that a server will exceed its job limit. You should be cautious with priority 100 jobs, since submitting too many at once could lead to very high server loads, which could lead to poor performance and even crashes in extreme cases.

## Performance Considerations on a Wide-Area Network (WAN)

While using Gurobi Compute Server doesn't typically require you to make any modifications to your code, performance considerations can sometimes force you to do some tuning when your client and server are connected by a slow network (e.g., the internet). We'll briefly talk about the source of the issue, and the changes required to work around it.

In a Gurobi Compute Server, a call to a Gurobi routine typically results in network messages between the client and the server. While each individual message is not that expensive, sending hundreds or thousands of messages can be quite time-consuming. Compute Server makes heavy use of caching to reduce the number of such messages. However, not all methods are cached. As a result, we suggest that you avoid doing the following things:

- Retrieving the non-zero values for individual rows and columns of the constraint matrix (using, for example, [GRBgetconstrs](#) in C, [GRBModel::getRow](#) in C++, [GRBModel.getRow](#) in Java, [GRBModel.GetRow](#) in .NET, and [Model.getRow](#) in Python).
- Retrieving individual string-valued attributes.

Please note that you don't need to be too concerned about this issue. Caching generally works well. In particular, when building a model, our *lazy update* approach avoids the issue entirely. You should feel free to build your model one constraint at a time, for example. Your changes are communicated to the server in one large message when you request a model update.

Of course, network overhead depends on both the number of messages that are sent and the sizes of these messages. We automatically perform data compression to reduce the time spent transferring very large messages. However, as you may expect, you will notice some lag when solving very large models over slow networks.

## Callbacks

As you might imagine, since the actual optimization task runs on a remote system in a Compute Server environment, Gurobi callbacks give different behavior than they do when the task runs locally. In particular, callbacks are both less frequent and more restrictive. You will only receive `MESSAGE`, `BARRIER`, `SIMPLEX`, `MIP`, and `MIPSOL` callbacks; you will not receive `PRESOLVE` or `MIPNODE` callbacks. As a result, you will only have access to a subset of the callback information that you would be able to obtain when running locally. You can still request that the optimization be terminated from any of the callbacks you receive. Please refer to the [Callback Code](#) section for more information on the various callback codes.

## Developing for Compute Server

With only a few exceptions, using Gurobi Compute Server requires no changes to your program. This section covers the exceptions. We'll talk about program robustness issues that may arise specifically in a Compute Server environment, and we'll give a full list of the Gurobi features that aren't supported in Compute Server.

### Coding for Robustness

Client-server computing introduces a few robustness situations that you wouldn't face when all of your computation happens on a single machine. Specifically, by passing data between a client and a server, your program is dependent on both machines being available, and on an uninterrupted network connection between the two systems. The queuing and failover capabilities of Gurobi Compute Server can handle the vast majority of issues that may come up, but you can take a few additional steps in your program if you want to achieve the maximum possible robustness.

The one scenario you may need to guard against is the situation where you lose the connection to the server while the portion of your program that builds and solves an optimization model is running. Gurobi Compute Server will automatically route queued jobs to another server, but jobs that are running when the server goes down are interrupted (the client will receive a `NETWORK` error). If you want your program to be able to survive such failures, you will need to architect it in such a way that it will rebuild and resolve the optimization model in response to a `NETWORK` error. The exact steps for doing so are application dependent, but they generally involve encapsulating

the code between the initial Gurobi environment creation and the last Gurobi call into a function that can be reinvoked in case of an error.

### Features Not Supported in Compute Server

As noted earlier, there are a few Gurobi features that are not supported in Compute Server. We've mentioned some of them already, but we'll give the full list here for completeness. You will need to avoid using these features if you want your application to work in a Compute Server environment.

The unsupported features are:

- **Lazy constraints:** While we do provide MIPSOL callbacks, we don't allow you to add lazy constraints to cut off the associated MIP solutions.
- **User cuts:** The MIPNODE callback isn't supported, so you won't have the opportunity to add your own cuts. User cuts aren't necessary for correctness, but applications that heavily rely on them may experience performance issues.
- **Multi-threading within a single Gurobi environment:** This isn't actually supported in Gurobi programs in general, but the results in a Compute Server environment are sufficiently difficult to track down that we wanted to mention it again here. All models built from an environment share a single socket connection to the Compute Server. This one socket can't handle multiple simultaneous messages. If you wish to call Gurobi from multiple threads in the same program, you should make sure that each thread works within its own Gurobi environment.
- **Advanced simplex basis routines:** The C routines that work with the simplex basis ( [GRBFSolve](#), [GRBBSolve](#), [GRBBinvColj](#), [GRBBinvRowi](#), and [GRBgetBasisHead](#) ) are not supported.

### Acknowledgement of 3rd Party Icons

The icons used in this chapter come from the [Open Security Architecture](#).

Gurobi Instant Cloud allows you to start and stop [Gurobi Compute Servers](#) on the cloud. You can start multiple machines without the need for your own hardware or local Gurobi licenses. Computations are seamlessly offloaded to these servers. Depending on your cloud license type, these machines provide the full set of Compute Server features, including queuing, load balancing, and [distributed parallel computing](#).

## Overview

When using the Instant Cloud, there are always three systems involved: your client machine, the [Instant Cloud Manager](#), and a cloud Compute Server.

The program that requests a Gurobi Instant Cloud machine and submits optimization models to this server runs on your client machine. Note, however, that this program does not actually need to be aware that it will be using Gurobi Instant Cloud. You have a few options for configuring the client to use the Instant Cloud. The simplest and most seamless is to set up a cloud license file. The alternative is to use a programming language API, which gives your program additional control over how it uses the cloud. Details on launching cloud machines from your client program follow [shortly](#).

The [Instant Cloud Manager](#) manages the configuration and launching of cloud machines. Your client program will send credential information to this website, along with a request to launch an Instant Cloud machine. The specific action taken in response to this request depend on configuration information that you manage through the website. For each license, you set up things like the number of servers to launch, the types and geographic regions of these machines, the maximum number of simultaneous jobs to run on each server, etc.

Once the Instant Cloud Manager launches the requested Compute Servers, it passes information about these servers back to your client program. The client program then directly interacts with the servers, sending the Gurobi model, launching a solve on the model, requesting solution information, etc. As with any Gurobi Compute Server, this process is entirely transparent to the client program.

Now that we've given a high-level description of the overall process, we need to cover a few important details.

## 26.1 Client Setup

As noted previously, a client program that wishes to launch a Gurobi Instant Cloud machine must pass credential information to the Instant Cloud Manager. Every Instant Cloud license has such credentials associated with it. This information is captured in a pair strings, an *access ID* and a *secret key*. These strings can be retrieved from your account on the [Instant Cloud Manager](#). Note that you shouldn't share these credentials with others, since anyone who knows these two strings can launch Instant Cloud machines in your account.

Once you have the credentials associated with your license, there are two ways to configure your client program to use them. The simplest is to use a cloud license file. This is just like any other

Gurobi license file, except that its fields are specific to the cloud. A cloud license file will contain two lines with credential information:

```
CLLOUDACCESSID=312e9gef-e0bc-4114-b6fb-26ed7klaeff9
CLLOUDKEY=ae32L0H321dgaL
```

It may also contain an optional third line:

```
CLLOUDPOOL=pool1
```

We'll discuss cloud pools a bit later. You can download a *gurobi.lic* file containing this information from the Instant Cloud website, or you can create one yourself in a text editor. If you follow the standard process for setting up a Gurobi license file (refer to the Quick Start Guide for details), then Gurobi will automatically use the Instant Cloud rather than running locally.

The other option for passing credential information to the Instant Cloud Manager is to call a Gurobi API routine. The appropriate routine depends on your programming language. Our [C](#) and [Python](#) APIs have calls devoted to launching cloud servers. Our [C++](#), [Java](#), and [.NET](#) APIs each have a special GRBEnv constructor (look for the one that accepts an access ID and secret key in its argument list). In all cases, you pass the access ID and secret key to the method or constructor, and the method creates a Gurobi environment that you can use like any other Gurobi environment (to build, solve, and modify optimization models, to retrieve solutions, etc.).

## 26.2 Instant Cloud Setup

As noted previously, cloud configuration is done via the [Instant Cloud Manager](#). The client program requests that a cloud machine be launched, but the Instant Cloud Manager determines exactly how to respond to that request.

One essential concept when configuring your Instant Cloud license is the notion of a *cloud pool*. Pools allow you to create multiple configurations within a single cloud license. For example, you may set up one pool for jobs in the US and another for jobs in Europe, or one for short-running jobs and another for long-running jobs, or one for single-machine jobs and another for distributed parallel jobs. For each of the available cloud configuration options (which will be discussed below), you can select different values for different pools. Every license always has a default pool, which comes pre-configured with what we consider to be reasonable default values. Thus, you always have the option of ignoring cloud pools and simply using the default pool if you don't need multiple configurations.

The main things that a user may want to configure on the Instant Cloud website are the idle shutdown time, the number of machines to launch, the number of distributed workers to launch, the machine region, and the machine type. These can take different values in different pools.

The idle shutdown time is a vital concept in the Instant Cloud. When a client program requests a cloud server, it takes some time (typically less than 2 minutes) to launch that server. Rather than forcing client programs to incur this delay each time they run, the Gurobi Instant Cloud leaves a server running until it has been idle for the specified idle shutdown time. In this way, later client programs may find a cloud server already available. You can set this to a small value if you want your server to shut down immediately after your job finishes, or to a very large value if you want your server to always be available.

Another configuration option is the number of machines associated with the pool. Gurobi Compute Server automatically handles queuing and load balancing between servers, so launching

multiple machines allows you to distribute the work of many simultaneous client programs among them. A pool can also be configured to launch any number of distributed workers, if you want to use distributed computing.

Cloud machines can be launched in multiple geographic regions, including the US, Europe, Asia, and South America. You should visit the website to see the full list. We offer several options for machine type, although we've chosen what we believe is the best general-purpose machine for running Gurobi as the default, so you are unlikely to want to change this setting.

## 26.3 Copyright Notice for 3rd Party Libraries

Gurobi Instant Cloud uses the `libcurl` library, which utilizes a number of other libraries. In particular, this product includes software developed by the OpenSSL Project for use in the OpenSSL Toolkit. (<http://www.openssl.org/>).

Here is the copyright notice for `libcurl`:

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