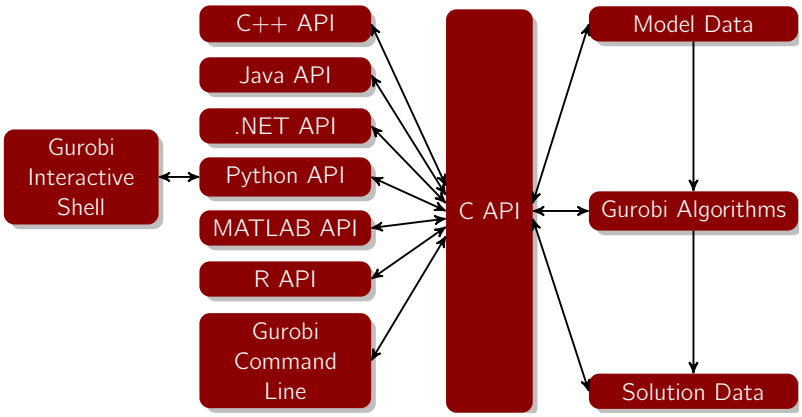
GUROBI OPTIMIZER REFERENCE MANUAL

Contents



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, and on Gurobi Compute Server, which allows you to offload Gurobi computations from a set of client machines onto one or more servers.

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`.

C API Overview

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 or quadratic 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.

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 or GRBaddqconstr 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/constraint indices are assigned as variables/constraints are added to the model, in a contiguous fashion. 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, or Special Ordered Set (SOS) 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.).

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 constraint matrix and to the quadratic portion 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 very important item to note about model modifications in the Gurobi optimizer is that they are performed in a *lazy* fashion, meaning that they don't actually affect the model until the next call to GRBoptimize or GRBupdatemodel. This approach provides the advantage that the model remains unchanged while you are in the process of making multiple modifications. The downside, of course, is that you have to remember to call GRBupdatemodel() in order to see the effect of your changes.

If you forget to call update, your program won't crash. The most common symptom of a missing update is an INDEX_OUT_OF_RANGE error, which indicates that the object you are trying to reference isn't in the model yet.

If you find the need to call GRBupdatemodel inconvenient, you can adjust the behavior of lazy updates with the UpdateMode parameter. By setting this parameter to 1, you can use newly added variables and constraints immediately. This setting does have a few downsides, though. It causes Gurobi to use a small amount of additional internal storage, and it introduces a small performance overhead. In addition, this setting may cause Gurobi to make less aggressive use of warm-start information when you modify a model and resolve it using simplex.

Managing Parameters

The Gurobi optimizer provides a set of parameters to 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.

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.

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);
```

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, 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    constrs = 2;
```

```
int    vbeg[]  = {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, constrs, -1, 0.0,
                     obj, sense, rhs, vbeg, 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 GRBgeterrormsg.

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 constraint to an existing model. Note that the new constraint won't actually be added until the next call to GRBoptimize or GRBupdatemodel.

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 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 constraints to an existing model. Note that the new constraints won't actually be added until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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.

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 an existing model. Note that the new constraint won't actually be added until the next call to GRBoptimize or GRBupdatemodel.

A quadratic constraint consists of a set of quadratic terms, a set of linear terms, a sense, and a right-hand side value: $x^T Q x + q^T x \leq b$. 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 $2x0^2 + x0 * x1 + x1^2$, 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");
```

GRBaddqpterms

```
int  GRBaddqpterms (  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 the new quadratic terms won't actually be added until the next call to GRBoptimize or GRBupdatemodel.

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 $2x0^2 + x0 * x1 + x1^2$, you would call this routine with `numqnz=3`, `qrow[] = {0, 0, 1}`, `qcol[] = {0, 1, 1}`, and `qval[] = {2, 1, 1}`.

`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 multipler 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 = GRBaddqpterms(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 an existing 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 the new constraint won't actually be added until the next call to GRBoptimize or GRBupdatemodel.

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 an existing 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 the new constraints won't actually be added until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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 an existing model. Note that the new SOS constraints won't actually be added until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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 an existing model. Note that the new variable won't actually be added until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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 an existing model. Note that the new variables won't actually be added until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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 the changes won't take effect until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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 the constraints won't actually be removed until the next call to GRBoptimize or GRBupdatemodel.

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 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);
```

GRBdelq

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

Delete all quadratic objective terms from an existing model. Note that the quadratic terms won't actually be removed until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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 the quadratic constraints won't actually be removed until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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 the SOS constraints won't actually be removed until the next call to GRBoptimize or GRBupdatemodel.

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 the variables won't actually be removed until the next call to GRBoptimize or GRBupdatemodel.

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);
```

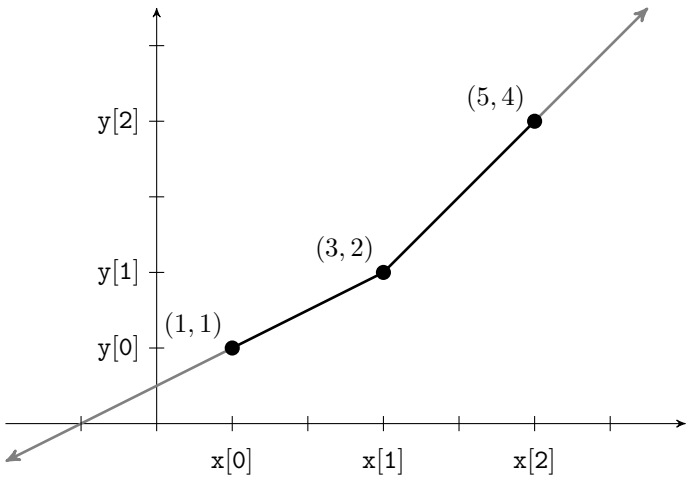
GRBsetpwlobj

```
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

$$\mathtt{x} = \{x_1, \ldots, x_n\}, \quad \mathtt{y} = \{y_1, \ldots, y_n\}$$

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 a new piecewise-linear objective won't actually be added to the model until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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 constraints to an existing model. Note that the new constraints won't actually be added until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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 an existing 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 the new constraints won't actually be added until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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 an existing model. Note that the new variables won't actually be added until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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 the changes won't take effect until the next call to GRBoptimize or GRBupdatemodel.

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 GRBgeterrormsg.

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 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`, 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    constrs = 2;
size_t vbeg[]  = {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 = GRBXloadmodel(env, &model, "example", vars, constrs, -1, 0.0,
                      obj, sense, rhs, vbeg, 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).

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 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, IISQConstr, IISSOS, 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, IISQConstr, IISSOS, 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 GRBgeterrormsg.

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 GRBgeterrormsg.

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 GRBgeterrormsg.

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 GRBgeterrormsg.

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 constraint from its name. If multiple 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 GRBgeterrormsg.

Arguments:

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

name: The name of the desired constraint.

constrnumP: Constraint number for a 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 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 GRBgeterrormsg.

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.

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);
```

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 $2x0^2 + x0 * x1 + x1^2$, this routine would return `qrow[] = {0, 0, 1}`, `qcol[] = {0, 1, 1}`, and `qval[] = {2, 1, 1}`.

`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 GRBgeterrormsg.

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 $2x0^2 + x0 * x1 + x1^2$, this routine would return ***numqnzP=3**, **qrow[] = {0, 0, 1}**, **qcol[] = {0, 1, 1}**, and **qval[] = {2, 1, 1}**.

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 GRBgeterrormsg.

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 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 GRBgeterrormsg.

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 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.

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.

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 GRBgeterrormsg.

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 GRBgeterrormsg.

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), or (3) SOS 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 GRBgeterrormsg.

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 GRBgeterrormsg.

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 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 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 GRBreadmodel.

attrname: The name of a 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 GRBreadmodel.

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 GRBgeterrormsg.

Arguments:

model: A loaded optimization model, typically created by routine GRBnewmodel or GRBreadmodel.

attrname: The name of a integer-valued array attribute. Available attributes are listed and described in the Attributes section of this document.

len: The number of attribute elements to retrive.

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 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.

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 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 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 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 attribute elements to retrive.

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.

values: 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 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 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 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 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 retrive.

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 GRBreadmodel.

`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.

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 GRBreadmodel.

`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 scalar attributes only (i.e., model attributes). To modify a single element of an array attribute, use GRBsetstrattrelement 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 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.

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

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

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.

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 **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 = GRBsetstrattrarray(model, "VarName", 0, NUMVARS, varnames);
```

GRBgetstrattrlist

```
int  GRBgetstrattrlist (  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 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 attribute elements to retrive.

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.

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:

```
int desired[] = {0, 2, 4, 6};
char **varnames[4];
error = GRBgetstrattrarray(model, "VarName", 4, desired, varnames);
```

GRBsetstrattrlist

```
int  GRBsetstrattrlist (  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 chage[] = {0, 1, 3};
char **varnames[] = {"Var0", "Var1", "Var3"};
error = GRBsetstrattrarray(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 GRBgettuneresult

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;
```

GRBgettuneresult

```
int  GRBgettuneresult ( 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 = GRBgettuneresult(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 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 = 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 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 = 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 a 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 GRBgeterrormsg.

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, GRBcbsolution). 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 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 `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 )
```

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.

Example usage:

```
if (where == GRB_CB_MIPNODE) {
  error = GRBcbsolution(cbdata, solution);
  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 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.

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,
                    GRBsvec   *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,
                    GRBsvec   *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 constaint 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 GRBgeterrormsg.

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 articifial variables. If `bhead[i]` is greater than or equal to `cols` (the number of columns in A), then the corresponding basis column is the articial or slack variable from row `bhead[i]-cols`.

C++ API Overview

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, or GRBSOS). 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.

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 or GRBModel::addQConstr 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, or Special Ordered Set (SOS) 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, and GRBQConstr 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.).

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, or GRBModel::get, and modified using GRBVar::set, GRBConstr::set, GRBQConstr::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 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 very important item to note about attribute and model modifications in the Gurobi optimizer is that they are performed in a *lazy* fashion, meaning that they don't actually affect the model until the next call to optimize or update on that model object. This approach provides the advantage that the model remains unchanged while you are in the process of making multiple modifications. The downside, of course, is that you have to remember to call update in order to see the effect of your changes.

If you forget to call update, your program won't crash. The most common symptom of a missing update is a `NOT_IN_MODEL` exception, which indicates that the object you are trying to reference isn't in the model yet.

If you find the need to call update inconvenient, you can adjust the behavior of lazy updates with the UpdateMode parameter. By setting this parameter to 1, you can use newly added variables and constraints immediately. This setting does have a few downsides, though. It causes Gurobi to use a small amount of additional internal storage, and it introduces a small performance overhead. In addition, this setting may cause Gurobi to make less aggressive use of warm-start information when you modify a model and resolve it using simplex.

Managing Parameters

The Gurobi optimizer provides a set of parameters to 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 methods on a GRBEnv object (e.g., GRBEnv::set). Current values may also be retrieved with GRBEnv::get. Parameters can

be of type *int*, *double*, or *string*. You can also 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.

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 GRBModel::getEnv to retrieve the environment associated with a particular model if you want to change a parameter for that model.

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, GRBSOS, 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 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).

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, 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 (  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::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::getErrorMsg()

Query the error message for the most recent exception associated with this environment.

```
const string  getErrorMsg ( )
```

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::getEnv to retrieve the environment associated with a model if you would like a parameter change to affect that 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 <= 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::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.

```
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_SEMICONT, 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_SEMICONT, 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_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.

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_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.

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 the change won't take effect until the next call to GRBModel::optimize or GRBModel::update on that model.

```
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 the changes won't take effect until the next call to GRBModel::optimize or GRBModel::update on that model.

```
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` and `IISQCONSTR` constraint attributes, the `IISSOS` 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::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 contraints 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 an attribute. Use this method for scalar model attributes, or for arrays of constraint or variable attributes.

```
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 constraint from its name. If multiple constraints have the same name, this method chooses one arbitrarily.

```
GRBConstr  getConstrByName (  const string&  name )
```

Arguments:

name: The name of the desired constraint.

Return value:

The requested constraint.

GRBModel::getConstrs()

Retrieve an array of all constraints in the model.

```
GRBConstr*  getConstrs ( )
```

Return value:

An array of all 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::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::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:

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.

```
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 isn't 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 the constraint isn't actually removed from the model until the next call to GRBModel::optimize or GRBModel::update on that model.

Arguments:

constr: The linear constraint to remove.

```
void  remove ( GRBQConstr  qconstr )
```

Remove a quadratic constraint from the model. Note that the constraint isn't actually removed from the model until the next call to GRBModel::optimize or GRBModel::update on that model.

Arguments:

qconstr: The quadratic constraint to remove.

```
void  remove ( GRBSOS  sos )
```

Remove an SOS constraint from the model. Note that the SOS isn't actually removed from the model until the next call to GRBModel::optimize or GRBModel::update on that model.

Arguments:

sos: The SOS constraint to remove.

```
void  remove ( GRBVar  var )
```

Remove a variable from the model. Note that the variable isn't actually removed from the model until the next call to GRBModel::optimize or GRBModel::update on that model.

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 an attribute. Use this method for scalar model attributes and for arrays of constraint or variable attributes.

```
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.

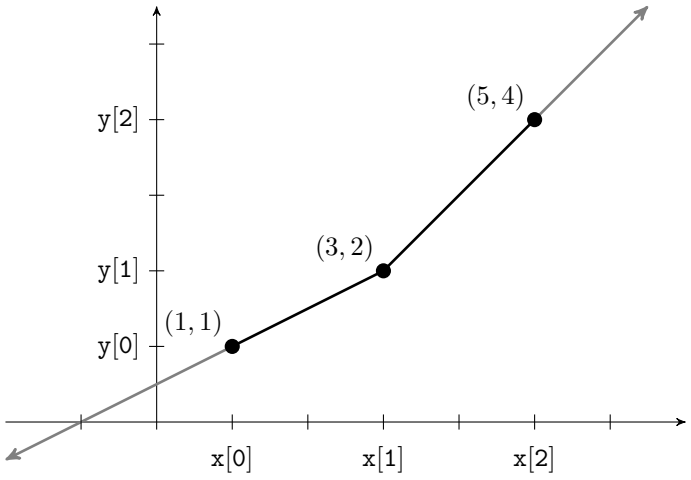
sense (optional): Optimization sense (GRB_MINIMIZE for minimization, GRB_MAXIMIZE for maximization). Omit this argument to use the ModelSense attribute value.

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

$$\mathtt{x} = \{x_1, \ldots, x_n\}, \quad \mathtt{y} = \{y_1, \ldots, y_n\}$$

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.

```
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.

```
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, `IISSOS`, 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 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.

3.8 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.

3.9 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.

3.10 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 `GRBTempContr`, which is then immediately passed to method GRBModel::addConstr or GRBModel::addQConstr.

3.11 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.

```
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*  constrs,
                  int               count )
```

Add a list of terms into a column.

Arguments:

`coeffs`: Coefficients for new terms.

`constrs`: 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.

3.12 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 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.

3.13 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.

3.14 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.

3.15 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-valud 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.

3.16 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 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 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 GRBEnv::get or GRBEnv::set). Please refer to the Parameters section to see a list of all int parameters and their functions.

Java API Overview

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, or GRBSOS). 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.

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 or GRBModel.addQConstr 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, or Special Ordered Set (SOS) 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, and GRBQConstr 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.).

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, or GRBModel.get, and modified using GRBVar.set, GRBConstr.set, GRBQConstr.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 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 very important item to note about attribute and model modifications in the Gurobi optimizer is that they are performed in a *lazy* fashion, meaning that they don't actually affect the model until the next call to optimize or update on that model object. This approach provides the advantage that the model remains unchanged while you are in the process of making multiple modifications. The downside, of course, is that you have to remember to call update in order to see the effect of your changes.

If you forget to call update, your program won't crash. The most common symptom of a missing update is a `NOT_IN_MODEL` exception, which indicates that the object you are trying to reference isn't in the model yet.

If you find the need to call update inconvenient, you can adjust the behavior of lazy updates with the UpdateMode parameter. By setting this parameter to 1, you can use newly added variables and constraints immediately. This setting does have a few downsides, though. It causes Gurobi to use a small amount of additional internal storage, and it introduces a small performance overhead. In addition, this setting may cause Gurobi to make less aggressive use of warm-start information when you modify a model and resolve it using simplex.

Managing Parameters

The Gurobi optimizer provides a set of parameters to 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 GRBEnv.set. Current values may also be retrieved with GRBEnv.get. Parameters can be of type *int*, *double*, or *String*. You

can also 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.

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 GRBModel.getEnv to retrieve the environment associated with a particular model if you want to change a parameter for that model.

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.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.getEnv to retrieve the environment associated with a model if you would like a parameter change to affect that 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,
                        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.

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 <= 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.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 (  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: 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.

```
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 the change won't take effect until the next call to GRBModel.optimize or GRBModel.update on that model.

```
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 the changes won't take effect until the next call to GRBModel.optimize or GRBModel.update on that model.

```
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` and `IISQCONSTR` constraint attributes, the `IISSOS` 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 `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,
                     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 an attribute. Use this method for scalar model attributes and for arrays of constraint or variable attributes.

```
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 constraint from its name. If multiple constraints have the same name, this method chooses one arbitrarily.

```
GRBConstr  getConstrByName ( String  name )
```

Arguments:

`name`: The name of the desired constraint.

Return value:

The requested constraint.

GRBModel.getConstrs()

Retrieve an array of all constraints in the model.

```
GRBConstr[]  getConstrs ( )
```

Return value:

All 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.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 accomodate 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.

```
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.

```
void  optimize ( )
```

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 isn't 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 the constraint isn't actually removed from the model until the next call to GRBModel.optimize or GRBModel.update on that model.

Arguments:

constr: The linear constraint to remove.

```
void  remove ( GRBQConstr  qconstr )
```

Remove a quadratic constraint from the model. Note that the constraint isn't actually removed from the model until the next call to GRBModel.optimize or GRBModel.update on that model.

Arguments:

qconstr: The quadratic constraint to remove.

```
void  remove ( GRBSOS  sos )
```

Remove an SOS constraint from the model. Note that the SOS isn't actually removed from the model until the next call to GRBModel.optimize or GRBModel.update on that model.

Arguments:

`sos`: The SOS constraint to remove.

```
void  remove ( GRBVar  var )
```

Remove a variable from the model. Note that the variable isn't actually removed from the model until the next call to GRBModel.optimize or GRBModel.update on that model.

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 an attribute. Use this method for scalar model attributes, or for arrays of constraint or variable attributes.

```
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.

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:

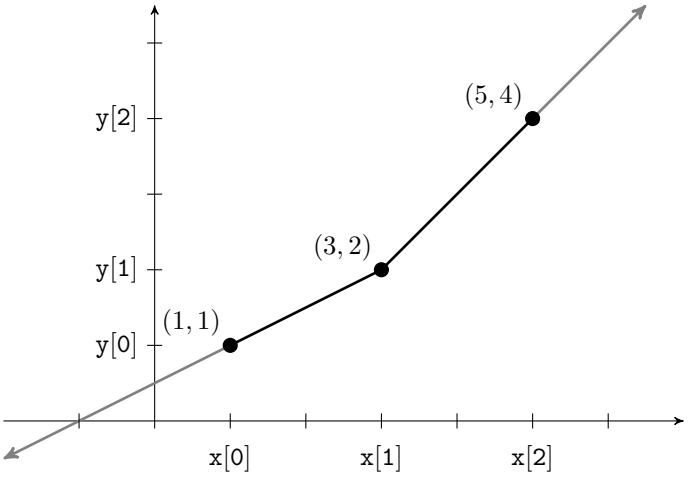
expr: New model objective.

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

$$\mathtt{x} = \{x_1, \ldots, x_n\}, \quad \mathtt{y} = \{y_1, \ldots, y_n\}$$

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.

```
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.

```
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, `IISSOS`, 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 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.

4.8 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.

4.9 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.

4.10 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.

4.11 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.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.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.

4.12 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.

4.13 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;
}

// 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;

// 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 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-valud 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 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 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 GRBEnv.get or GRBEnv.set). Please refer to the Parameters section to see a list of all string parameters and their functions.

.NET API Overview

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, or GRBSOS). 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.

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 or GRBModel.AddQConstr 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, or Special Ordered Set (SOS) 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, and GRBQConstr 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.).

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, or GRBModel.Get, and modified using GRBVar.Set, GRBConstr.Set, GRBQConstr.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 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 very important item to note about attribute and model modifications in the Gurobi optimizer is that they are performed in a *lazy* fashion, meaning that they don't actually affect the model until the next call to Optimize or Update on that model object. This approach provides the advantage that the model remains unchanged while you are in the process of making multiple modifications. The downside, of course, is that you have to remember to call Update in order to see the effect of your changes.

If you forget to call update, your program won't crash. The most common symptom of a missing update is a `NOT_IN_MODEL` exception, which indicates that the object you are trying to reference isn't in the model yet.

If you find the need to call Update inconvenient, you can adjust the behavior of lazy updates with the UpdateMode parameter. By setting this parameter to 1, you can use newly added variables and constraints immediately. This setting does have a few downsides, though. It causes Gurobi to use a small amount of additional internal storage, and it introduces a small performance overhead. In addition, this setting may cause Gurobi to make less aggressive use of warm-start information when you modify a model and resolve it using simplex.

Managing Parameters

The Gurobi optimizer provides a set of parameters to 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 GRBEnv.Set. Current values may also be retrieved with GRBEnv.Get. Parameters can be of type *int*, *double*, or *string*. You

can also 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.

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 GRBModel.GetEnv to retrieve the environment associated with a particular model if you want to change a parameter for that model.

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 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 .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.

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.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.ErrorMsg

(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.GetEnv to retrieve the environment associated with a model if you would like a parameter change to affect that 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).

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.

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 <= 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.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.

```
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 the change won't take effect until the next call to GRBModel.Optimize or GRBModel.Update on that model.

```
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 the changes won't take effect until the next call to GRBModel.Optimize or GRBModel.Update on that model.

```
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` and `IISQCONSTR` constraint attributes, the `IISSOS` 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 an attribute. Use this method for scalar model attributes and for arrays of constraint or variable attributes.

```
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 constraint from its name. If multiple constraints have the same name, this method chooses one arbitrarily.

```
GRBConstr  GetConstrByName ( string  name )
```

Arguments:

`name`: The name of the desired constraint.

Return value:

The requested constraint.

GRBModel.GetConstrs()

Retrieve an array of all constraints in the model.

```
GRBConstr[]  GetConstrs ( )
```

Return value:

All 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.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 accomodate 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.

```
void  Optimize ( )
```

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 isn't 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 constraint from a model.

```
void  Remove (  GRBConstr  constr )
```

Remove a constraint from the model. Note that the constraint isn't actually removed from the model until the next call to GRBModel.Optimize or GRBModel.Update on that model.

Arguments:

`constr`: The constraint to remove.

```
void  Remove (  GRBQConstr  qconstr )
```

Remove a quadratic constraint from the model. Note that the quadratic constraint isn't actually removed from the model until the next call to GRBModel.Optimize or GRBModel.Update on that model.

Arguments:

`qconstr`: The constraint to remove.

```
void  Remove (  GRBSOS  sos )
```

Remove an SOS constraint from the model. Note that the SOS isn't actually removed from the model until the next call to GRBModel.Optimize or GRBModel.Update on that model.

Arguments:

`sos`: The SOS constraint to remove.

```
void  Remove ( GRBVar  var )
```

Remove a variable from the model. Note that the variable isn't actually removed from the model until the next call to GRBModel.Optimize or GRBModel.Update on that model.

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 an attribute. Use this method for scalar model attributes, or for arrays of constraint or variable attributes.

```
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.

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:

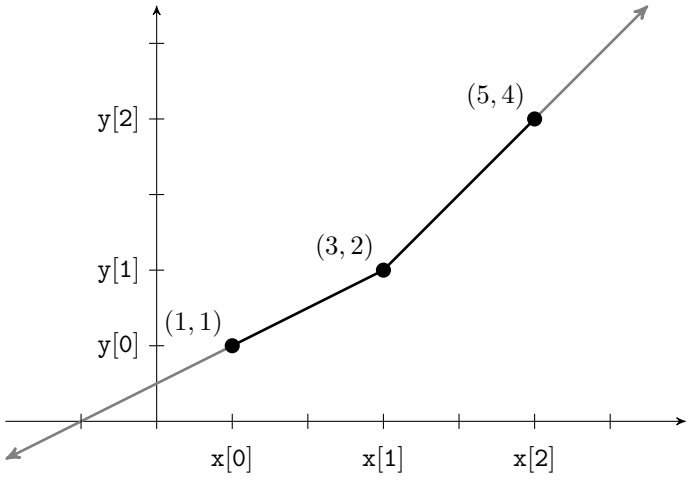
expr: New model objective.

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

$$\mathtt{x} = \{x_1, \ldots, x_n\}, \quad \mathtt{y} = \{y_1, \ldots, y_n\}$$

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.

```
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.

```
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, `IISSOS`, 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 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.

5.8 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 (  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.

5.9 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 (  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.

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.

5.10 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.

5.11 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 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 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

(Property) The number of terms in the column.

5.12 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: Coefficient.

var: Variable.

Return value:
A linear expression that is equal to the sum of the constant and the variable arguments.

```
GRBLinExpr  operator + (  GRBVar  var,
                          double  a )
```

Arguments:
var: Variable.
a: Coefficient.
Return value:
A linear expression that is equal to the sum of the constant and the variable arguments.

```
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.

5.13 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 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.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.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.

5.14 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.

5.15 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;
}

// 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;

// 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 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-valud 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 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 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 GRBEnv.Get or GRBEnv.Set). Please refer to the Parameters section to see a list of all string parameters and their functions.

Python API Overview

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, setParam, 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, or SOS). 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.

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 to add additional variables, and Model.addConstr or Model.addQConstr 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, or Special Ordered Set (SOS) 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.).

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 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 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 very important item to note about attribute and model modifications in the Gurobi optimizer is that they are performed in a *lazy* fashion, meaning that they don't actually affect the model until the next call to optimize or update on that model object. This approach provides the advantage that the model remains unchanged while you are in the process of making multiple modifications.

The downside, of course, is that you have to remember to call update in order to see the effect of your changes.

If you forget to call update, your program won't crash. The most common symptom of a missing update is a `NOT_IN_MODEL` exception, which indicates that the object you are trying to reference isn't in the model yet.

If you find the need to call update inconvenient, you can adjust the behavior of lazy updates with the UpdateMode parameter. By setting this parameter to 1, you can use newly added variables and constraints immediately. This setting does have a few downsides, though. It causes Gurobi to use a small amount of additional internal storage, and it introduces a small performance overhead. In addition, this setting may cause Gurobi to make less aggressive use of warm-start information when you modify a model and resolve it using simplex.

Managing Parameters

The Gurobi optimizer provides a set of parameters to 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 to call from within a long running iPython Notebook session, as otherwise Gurobi will consume a token for as long as the notebook is open.

Note that models built with the default environment must be garbaged collected before the default environment can be freed. You can force a model `m` be garbaged 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 dictionaries.

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), addConstr (adds a new constraint), and update (integrates model changes into the model).

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.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.

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.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.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.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 the change won't take effect until the next call to Model.update or Model.optimize.

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` and `IISQCONSTR` constraint attributes, the `IISSOS` 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.

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 constraint from its name. If multiple 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 constraints in the model.

Return value:

All constraints in the model.

Example usage:

```
constrs = model.getConstrs()
c0 = constrs[0]
```

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.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.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.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 ( )
```

Retrieve a list of all SOS constraints in the model.

Return value:

All SOS constraints in the model.

Example usage:

```
sos = model.getSOS()
```

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.

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 isn't 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 constraints.

Return value:

Relaxed version of model.

Example usage:

```
r = model.relax()
```

Model.remove()

```
remove ( item )
```

Remove a variable, linear constraint, quadratic constraint, or SOS from a model.

Arguments:

item: The item to remove from the model. The item can be a Var, a Constr, QConstr, or an SOS

Example usage:

```
model.remove(model.getVars()[0])
model.remove(model.getConstrs()[0])
model.remove(model.getQConstrs()[0])
model.remove(model.getSOS()[0])
```

Model.reset()

```
reset ( )
```

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

Example usage:

```
model.reset()
```

Model.setAttr()

```
setAttr ( attrname, newvalue )
```

Set the value of an attribute. Note that attribute changes are handled in a lazy fashion. The effect of a change isn't visible until the next call to Model.update or Model.optimize.

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.

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)
```

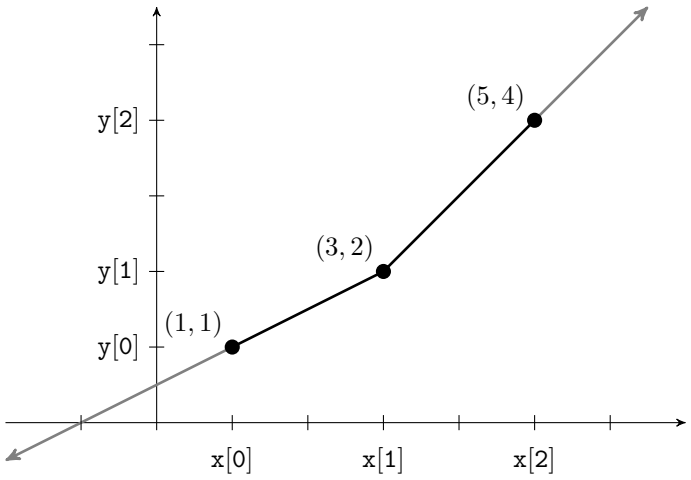
Model.setPWLObj()

```
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

$$\mathtt{x} = [x_1, \ldots, x_n], \quad \mathtt{y} = [y_1, \ldots, y_n]$$

define the following piecewise-linear function:

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

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 Model.cbGet. 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.

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 or Model.optimize 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 optimiazation 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.

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 attribute changes are handled in a lazy fashion. The effect of a change isn't visible until the next call to Model.update or Model.optimize.

The full list of available attributes can be found in the Attributes section.

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 or Model.optimize 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.

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 attribute changes are handled in a lazy fashion. The effect of a change isn't visible until the next call to Model.update or Model.optimize.

The full list of available attributes can be found in the Attributes section.

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.

Qudaratic 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 or Model.optimize 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 `qcpi` 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.

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 attribute changes are handled in a lazy fashion. The effect of a change isn't visible until the next call to Model.update or Model.optimize.

The full list of available attributes can be found in the Attributes section.

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, `IISSOS`, 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.

Arguments:

`attrname`: The attribute being queried.

Return value:

The current value of the requested attribute.

Example usage:

```
print sos.getAttr(GRB.Attr.IISSOS)
```

6.7 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)
```

6.8 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)
```

6.9 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.

6.10 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()
```

6.11 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.

6.12 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.

6.13 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  ( logfilename="" )
```

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:

logfilename: Name of the log file for this environment. Pass an 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  ( logfilename="", 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 place on a Compute Server.

Arguments:

`logfilename`: Name of the log file for this environment. Pass an 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.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")
```

6.14 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

# 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

# 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_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`).

6.15 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.

While you can use a `tuplelist` anywhere you would normally use a list, we suggest that you only use them when you wish to populate the list with tuples and use the sub-list selection facilities provided by select.

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 should provide one value for each field in the member tuples. A `'*'` value indicates that any value is appropriate in that field.

Arguments:

`pattern`: Pattern to match for a member tuple.

Example usage:

```
l.select(1, 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()
```

MATLAB API Overview

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	$x^T Q x + c^T x +$ 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)
	$x^T Q c\, x + q^T x \leq$ 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.

`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 >= sum(x(idx).^2)`, `x(k) >= 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: $x^T Qc\, x + q^T x \leq$ 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-zeros 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`.

`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
```

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 a 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 6.5 in the default location, you should run

```
>> cd c:/Users/jones/gurobi650/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/gurobi650/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
```

R API Overview

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	$x^T Q x + c^T x +$ 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)
	$x^T Q c\, x + q^T x \leq$ 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.

`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`.

`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: $x^T Qc\, x + q^T x \leq$ 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-zeros 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`.

`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$modelsense <- "max"
model$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 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)
```

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$modelsense <- "max"
model$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 6.5.0 is `/opt/gurobi650/linux64` for Linux, `c:\gurobi650` for Windows, and `/Library/gurobi650` 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_6.5-0_R_x86_64-pc-li` the Windows package is in file `gurobi_6.5-0.zip`, and the Mac package is in file `gurobi_6.5-0.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 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, constraint, and SOS attributes contain one entry per variable, constraint, or SOS 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).

Attribute name	Description
NumVars	Number of variables
NumConstrs	Number of linear constraints
NumSOS	Number of SOS constraints
NumQConstrs	Number of quadratic 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)
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)
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.

Attribute name	Description
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.

Attribute name	Description
Sense	Constraint sense (`'<'`, `'>'`, or `'='`)
RHS	Right-hand side value
ConstrName	Constraint name
Pi	Dual value (also known as the *shadow price*)
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.

Attribute name	Description
IISSOS	Indicates whether the SOS constraint participates in the IIS

Quadratic constraint attributes:

These attributes provide information that is associated with specific quadratic constraints.

Attribute name	Description
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

Solution quality attributes:

Attribute name	Description
BoundVio	Maximum (unscaled) bound violation
BoundSVio	Maximum (scaled) bound violation
BoundVioIndex	Index of variable with the largest (unscaled) bound violation
BoundSVioIndex	Index of variable with the largest (scaled) bound violation
BoundVioSum	Sum of (unscaled) bound violations
BoundSVioSum	Sum of (scaled) bound violations
ConstrVio	Maximum (unscaled) constraint violation
ConstrSVio	Maximum (scaled) constraint violation
ConstrVioIndex	Index of constraint with the largest (unscaled) violation
ConstrSVioIndex	Index of constraint with the largest (scaled) violation
ConstrVioSum	Sum of (unscaled) constraint violations
ConstrSVioSum	Sum of (scaled) constraint violations
ConstrResidual	Maximum (unscaled) primal constraint error
ConstrSResidual	Maximum (scaled) primal constraint error
ConstrResidualIndex	Index of constraint with the largest (unscaled) primal constraint error
ConstrSResidualIndex	Index of constraint with the largest (scaled) primal constraint error
ConstrResidualSum	Sum of (unscaled) primal constraint errors
ConstrSResidualSum	Sum of (scaled) primal constraint errors
DualVio	Maximum (unscaled) reduced cost violation
DualSVio	Maximum (scaled) reduced cost violation
DualVioIndex	Index of variable with the largest (unscaled) reduced cost violation
DualSVioIndex	Index of variable with the largest (scaled) reduced cost violation
DualVioSum	Sum of (unscaled) reduced cost violations
DualSVioSum	Sum of (scaled) reduced cost violations
DualResidual	Maximum (unscaled) dual constraint error
DualSResidual	Maximum (scaled) dual constraint error
DualResidualIndex	Index of variable with the largest (unscaled) dual constraint error
DualSResidualIndex	Index of variable with the largest (scaled) dual constraint error
DualResidualSum	Sum of (unscaled) dual constraint errors
DualSResidualSum	Sum of (scaled) dual constraint errors
ComplVio	Maximum complementarity violation
ComplVioIndex	Index of variable with the largest complementarity violation
ComplVioSum	Sum of complementarity violations
IntVio	Maximum integrality violation
IntVioIndex	Index of variable with the largest integrality violation
IntVioSum	Sum of integrality violations

9.1 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.

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.

MIPGap

Type: double
Modifiable: No

Current relative MIP optimality gap; computed as (ObjBound-ObjVal)/|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, and semi-integer variables, and SOS constraints.

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.

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.

9.2 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.

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`.

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 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.

9.3 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 ≥ 0.
- Dual values for $\leq$ constraints are ≤ 0.
- Dual values for $=$ constraints are unconstrained.

For models with a maximization sense, the senses of the dual values are reversed: the dual is ≥ 0 for a $\leq$ constraint and ≤ 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 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.

9.4 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.

IISSOS

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.

9.5 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.

9.6 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, 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.

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.

BoundVioIndex

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.

BoundSVioIndex

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.

ConstrVioIndex

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.

ConstrSVioIndex

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.

IntVioIndex

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.

9.7 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`
Python	`GRB.Attr.lb`, or just `var.lb`

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	GRBgetdblattrelement`(model, GRB_DBL_ATTR_LB, var_index, &value);`
C++	var.get`(GRB_DoubleAttr_LB)`
Java	var.get`(GRB.DoubleAttr.LB)`
.NET	var.Get`(GRB.DoubleAttr.LB)`
Python	var.getAttr`(GRB.Attr.lb)`, or just `var.lb`

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 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).

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 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 j As Integer = 0 To cols - 1
  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:

```
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).

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
BarIterLimit	Barrier iteration limit
Cutoff	Objective cutoff
IterationLimit	Simplex iteration limit
NodeLimit	MIP node limit
SolutionLimit	MIP feasible solution limit
TimeLimit	Time limit

Tolerances: These parameters control the allowable feasibility or optimality violations.

Parameter name	Purpose
BarConvTol	Barrier convergence tolerance
BarQCPConvTol	Barrier QCP convergence tolerance
FeasibilityTol	Primal feasibility tolerance
IntFeasTol	Integer feasibility tolerance
MarkowitzTol	Threshold pivoting tolerance
MIPGap	Relative MIP optimality gap
MIPGapAbs	Absolute MIP optimality gap
OptimalityTol	Dual feasibility tolerance
PSDTol	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
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
TuneJobs	Enables distributed tuning
TuneOutput	Tuning output level
TuneResults	Number of improved parameter sets returned
TuneTimeLimit	Time limit for tuning
TuneTrials	Perform multiple runs on each parameter set to limit the effect of random noise

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
Cuts	Global cut generation control
CliqueCuts	Clique cut generation
CoverCuts	Cover cut generation
FlowCoverCuts	Flow cover cut generation
FlowPathCuts	Flow path cut generation
GUBCoverCuts	GUB cover cut generation
ImpliedCuts	Implied bound cut generation
MIPSepCuts	MIP separation cut generation
MIRCuts	MIR cut generation
ModKCuts	Mod-k cut generation
NetworkCuts	Network cut generation
SubMIPCuts	Sub-MIP cut generation
ZeroHalfCuts	Zero-half cut generation
CutAggPasses	Constraint aggregation passes performed during cut generation
CutPasses	Root cutting plane pass limit
GomoryPasses	Root Gomory cut pass limit

Distributed algorithms: Parameters that are used to control our distributed parallel algorithms (distributed MIP, distributed concurrent, and distributed tuning).

Parameter name	Purpose
WorkerPassword	Password for distributed workers
WorkerPool	List of available distributed workers
WorkerPort	Non-default port number for distributed workers

Other: Other parameters.

Parameter name	Purpose
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
NumericFocus	Set the numerical focus
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 converstion to binary form
PreSOS2BigM	Controls SOS2 converstion 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

10.1 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.

10.2 Parameter Descriptions

AggFill

Presolve aggregation fill level	**Type:**	int
	Default value:	-1
	Minimum value:	-1
	Maximum value:	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

Presolve aggregation	**Type:**	int
	Default value:	1
	Minimum value:	0
	Maximum value:	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

Barrier convergence tolerance	**Type:**	double
	Default value:	1e-8
	Minimum value:	0.0
	Maximum value:	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

Barrier central corrections

Type: int
Default value: -1
Minimum value: -1
Maximum value: 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

Barrier homogeneous algorithm

Type: int
Default value: -1
Minimum value: -1
Maximum value: 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

Barrier ordering algorithm

Type: int
Default value: -1
Minimum value: -1
Maximum value: 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

Barrier convergence tolerance for QCP models

Type:	double
Default value:	1e-6
Minimum value:	0.0
Maximum value:	1.0

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

Barrier iteration limit

Type:	int
Default value:	1000
Minimum value:	0
Maximum value:	MAXINT

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.

BranchDir

Preferred branch direction

Type:	int
Default value:	0
Minimum value:	-1
Maximum value:	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.

CliqueCuts

Clique cut generation

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Distributed concurrent optimizer job count

Type:	int
Default value:	0
Minimum value:	0
Maximum value:	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

Enables the concurrent MIP solver

Type:	int
Default value:	1
Minimum value:	1
Maximum value:	MAXINT

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

Create concurrent environments from a set of .prm files

Type:	string
Default value:	""

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

Cover cut generation

Type: int
Default value: -1
Minimum value: -1
Maximum value: 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

Barrier crossover strategy

Type: int
Default value: -1
Minimum value: -1
Maximum value: 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

Crossover basis construction strategy

Type:	int
Default value:	0
Minimum value:	0
Maximum value:	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

Objective cutoff

Type:	double
Default value:	Infinity for minimization, -Infinity for maximization
Minimum value:	-Infinity
Maximum value:	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

Constraint aggregation passes in cut generation

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Cutting plane passes

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Global cut control

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Disconnected component strategy

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Frequency of log lines	**Type:**	int
	Default value:	5
	Minimum value:	1
	Maximum value:	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

Distributed MIP job count	**Type:**	int
	Default value:	0
	Minimum value:	0
	Maximum value:	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

Controls dual reductions	**Type:**	int
	Default value:	1
	Minimum value:	0
	Maximum value:	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

Primal feasibility tolerance	**Type:**	double
	Default value:	1e-6
	Minimum value:	1e-9
	Maximum value:	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

Big-M value for feasibility relaxations

Type:	double
Default value:	1e6
Minimum value:	0
Maximum value:	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

Flow cover cut generation

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Flow path cut generation

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Gomory cut passes	**Type:**	int
	Default value:	-1
	Minimum value:	-1
	Maximum value:	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

GUB cover cut generation	**Type:**	int
	Default value:	-1
	Minimum value:	-1
	Maximum value:	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

Time spent in feasibility heuristics	**Type:**	double
	Default value:	0.05
	Minimum value:	0
	Maximum value:	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

Selects method used to compute IIS

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	1

Chooses the IIS method to use. Method 0 is often faster, while method 1 can produce a smaller IIS. 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

Implied bound cut generation

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Solution improvement strategy control

Type:	double
Default value:	0.0
Minimum value:	0.0
Maximum value:	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

Solution improvement strategy control

Type:	double
Default value:	Infinity
Minimum value:	0.0
Maximum value:	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

Solution improvement strategy control

Type:	double
Default value:	Infinity
Minimum value:	0.0
Maximum value:	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.

InfUnbdInfo

Additional info for infeasible/unbounded models

Type:	int
Default value:	0
Minimum value:	0
Maximum value:	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

Import data into a model before beginning optimization

Type:	string
Default value:	""

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.

Note: Command-line only

For examples of how to query or modify parameter values from our different APIs, refer to our Parameter Examples.

IntFeasTol

Integer feasibility tolerance

Type:	double
Default value:	1e-5
Minimum value:	1e-9
Maximum value:	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

Simplex iteration limit

Type:	double
Default value:	Infinity
Minimum value:	0
Maximum value:	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

Programs that use lazy constraints must set this parameter

Type:	int
Default value:	0
Minimum value:	0
Maximum value:	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

Name for Gurobi log file

Type:	string
Default value:	""

Determines the name of the Gurobi log file. Modifying this parameter closes the current log file and opens the specified file. Use an emptry 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

Control console logging

Type:	int
Default value:	1
Minimum value:	0
Maximum value:	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

Threshold pivoting tolerance

Type:	double
Default value:	0.0078125
Minimum value:	1e-4
Maximum value:	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

Algorithm used to solve continuous models

Type: int
Default value: -1
Minimum value: -1
Maximum value: 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

Minimum relaxation heuristic

Type: int
Default value: -1
Minimum value: -1
Maximum value: 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

MIP solver focus

Type:	int
Default value:	0
Minimum value:	0
Maximum value:	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

Relative MIP optimality gap

Type:	double
Default value:	1e-4
Minimum value:	0
Maximum value:	Infinity

The MIP solver will terminate (with an optimal result) when the relative gap between the lower and upper objective bound is less than `MIPGap` times 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

Absolute MIP optimality gap

Type:	double
Default value:	1e-10
Minimum value:	0
Maximum value:	Infinity

The MIP solver will terminate (with an optimal result) when the absolute 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

MIP separation cut generation

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Method used to solve MIQCP models

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

MIR cut generation

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Mod-k cut generation

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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.

NetworkCuts

Network cut generation

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Type:	string
Default value:	"."

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

Write MIP nodes to disk

Type:	double
Default value:	Infinity
Minimum value:	0
Maximum value:	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

MIP node limit

Type:	double
Default value:	Infinity
Minimum value:	0
Maximum value:	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

Method used to solve MIP node relaxations

Type:	int
Default value:	1
Minimum value:	0
Maximum value:	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

Choose simplex pricing norm.

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Numerical focus

Type:	int
Default value:	0
Minimum value:	0
Maximum value:	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

Objective scaling

Type:	double
Default value:	0.0
Minimum value:	-1
Maximum value:	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

Dual feasibility tolerance

Type:	double
Default value:	1e-6
Minimum value:	1e-9
Maximum value:	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.

OutputFlag

Controls Gurobi output

Type:	int
Default value:	1
Minimum value:	0
Maximum value:	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

Simplex perturbation

Type:	double
Default value:	0.0002
Minimum value:	0
Maximum value:	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.

PreCrush

Controls presolve reductions that affect user cuts

Type:	int
Default value:	0
Minimum value:	0
Maximum value:	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

Controls the presolve dependent row reduction

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Controls presolve model dualization

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Format of presolved MIQCP model

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Presolve pass limit

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Presolve quadratic linearization

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Controls the presolve level

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Threshold for SOS1-to-binary reformulation

Type:	double
Default value:	-1
Minimum value:	-1
Maximum value:	1e10

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.

PreSOS2BigM

Threshold for SOS2-to-binary reformulation

Type:	double
Default value:	0
Minimum value:	-1
Maximum value:	1e10

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.

PreSparsify

Controls the presolve sparsify reduction

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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.

PSDTol

Positive semi-definite tolerance

Type:	double
Default value:	1e-6
Minimum value:	0
Maximum value:	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

Passes of the feasibility pump heuristic

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Dual variables for QCP models

Type:	int
Default value:	0
Minimum value:	0
Maximum value:	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

Controls quad precision in simplex

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Enables API call recording

Type:	int
Default value:	0
Minimum value:	0
Maximum value:	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 should 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. Possible suffixes are `.sol` (the solution vector), `.bas` (the simplex basis), or `.mst` (the solution vector on the integer variables). 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

Model scaling

Type:	int
Default value:	1
Minimum value:	0
Maximum value:	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

Random number seed

Type:	int
Default value:	0
Minimum value:	0
Maximum value:	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

Controls sifting within dual simplex

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

LP method used to solve sifting sub-problems

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Simplex pricing strategy

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

MIP solution limit

Type:	int
Default value:	MAXINT
Minimum value:	1
Maximum value:	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

Select a sub-optimal MIP solution

Type:	int
Default value:	0
Minimum value:	0
Maximum value:	MAXINT

When querying attribute Xn 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.

SubMIPCuts

Sub-MIP cut generation

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Nodes explored in sub-MIP heuristics

Type:	int
Default value:	500
Minimum value:	0
Maximum value:	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

MIP symmetric detection

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Thread count	**Type:**	int
	Default value:	0
	Minimum value:	0
	Maximum value:	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

Time limit	**Type:**	double
	Default value:	Infinity
	Minimum value:	0
	Maximum value:	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.

TuneJobs

Distributed tuning job count	**Type:**	int
	Default value:	0
	Minimum value:	0
	Maximum value:	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

Tuning output level	**Type:**	int
	Default value:	2
	Minimum value:	0
	Maximum value:	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

Numer of improved parameter sets returned	**Type:**	int
	Default value:	-1
	Minimum value:	1
	Maximum value:	MAXINT

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

Tuning tool time limit	**Type:**	double
	Default value:	-1
	Minimum value:	-1
	Maximum value:	Infinity

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

Perform multiple runs on each parameter set to limit the effect of random noise

Type:	int
Default value:	3
Minimum value:	1
Maximum value:	MAXINT

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

Changes the behavior of lazy updates

Type:	int
Default value:	0
Minimum value:	0
Maximum value:	1

Changes the behavior of lazy updates. By default, whenever you add a new variable or constraint to the model, you must call `update` before you can access that new item. For example, you must call `update` before you can build a new constraint that involves that a newly added variable. Setting the new `UpdateMode` parameter to 1 allows you to use new variables and constraints immediately.

Note that it is generally a good idea to add items to your Gurobi model in phases, calling `update` at the end of each phase. This practice allows Gurobi to build the internal representation of your model more efficiently. This new parameter is meant for cases where adding items in phases is inconvenient. It introduces a small amount of additional internal storage, and can introduce a small performance overhead. It may also cause Gurobi to make less aggressive use of warm-start information when modifying models and resolving using simplex.

You should set this parameter as soon as you create your Gurobi environment.

For examples of how to query or modify parameter values from our different APIs, refer to our Parameter Examples.

VarBranch

Branch variable selection strategy

Type:	int
Default value:	-1
Minimum value:	-1
Maximum value:	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

Zero-objective heuristic	**Type:**	int
	Default value:	-1
	Minimum value:	-1
	Maximum value:	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.

10.3 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 GRBEnv::set. 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:

```
GRBModel *m = ...;
m->getEnv().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->getEnv().set("TimeLimit", "100.0");
```

Use GRBEnv::get to query the current value of a parameter:

```
currentlimit = m.getEnv().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, you use GRBEnv.Set. 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:

```
GRBModel m = ...;
m.GetEnv().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.GetEnv().Set("TimeLimit", "100.0");
```

Use GRBEnv.Get to query the current value of a parameter:

```
currentlimit = m.GetEnv().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 GRBEnv.set. 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:

```
GRBModel m = ...;
m.getEnv().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.getEnv().set("TimeLimit", "100.0");
```

Use GRBEnv.get to query the current value of a parameter:

```
currentlimit = m.getEnv().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, you use GRBEnv.Set. 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:

```
GRBModel m = ...;
m.GetEnv().Set(GRB.DoubleParam.TimeLimit, 100.0);
```

Use GRBEnv.Get to query the current value of a parameter:

```
currentlimit = m.GetEnv().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	`GRB_OPTIMAL`
C++	`GRB_OPTIMAL`
Java	`GRB.Status.OPTIMAL`
.NET	`GRB.Status.OPTIMAL`
Python	`GRB.OPTIMAL`

Possible status codes are as follows:

Status code	Value	Description
`LOADED`	1	Model is loaded, but no solution information is available.
`OPTIMAL`	2	Model was solved to optimality (subject to tolerances), and an optimal solution is available.
`INFEASIBLE`	3	Model was proven to be infeasible.
`INF_OR_UNBD`	4	Model was proven to be either infeasible or unbounded. To obtain a more definitive conclusion, set the DualReductions parameter to 0 and reoptimize.
`UNBOUNDED`	5	Model was proven to be unbounded. *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.*
`CUTOFF`	6	Optimal objective for model was proven to be worse than the value specified in the `Cutoff` parameter. No solution information is available.
`ITERATION_LIMIT`	7	Optimization terminated because the total number of simplex iterations performed exceeded the value specified in the `IterationLimit` parameter, or because the total number of barrier iterations exceeded the value specified in the `BarIterLimit` parameter.
`NODE_LIMIT`	8	Optimization terminated because the total number of branch-and-cut nodes explored exceeded the value specified in the `NodeLimit` parameter.
`TIME_LIMIT`	9	Optimization terminated because the time expended exceeded the value specified in the `TimeLimit` parameter.

SOLUTION_LIMIT	10	Optimization terminated because the number of solutions found reached the value specified in the SolutionLimit parameter.
INTERRUPTED	11	Optimization was terminated by the user.
NUMERIC	12	Optimization was terminated due to unrecoverable numerical difficulties.
SUBOPTIMAL	13	Unable to satisfy optimality tolerances; a sub-optimal solution is available.
INPROGRESS	14	An asynchronous optimization call was made, but the associated optimization run is not yet complete.

Callback Codes

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
`POLLING`	0	Periodic polling callback
`PRESOLVE`	1	Currently performing presolve
`SIMPLEX`	2	Currently in simplex
`MIP`	3	Currently in MIP
`MIPSOL`	4	Found a new MIP incumbent
`MIPNODE`	5	Currently exploring a MIP node
`MESSAGE`	6	Printing a log message
`BARRIER`	7	Currently in barrier

Allowable `what` values depend on the value of the `where` argument. Valid combinations are:

`what`	`where`	Result type	Description
`RUNTIME`	Any except `POLLING`	double	Elapsed solver runtime (seconds).
`PRE_COLDEL`	`PRESOLVE`	int	The number of columns removed by presolve to this point.
`PRE_ROWDEL`	`PRESOLVE`	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 GRBcbget should point to an array of doubles that is at least as long as the number of variables in the user model. Use the `getSolution` 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 Status Code 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.

MIPNODE_REL	MIPNODE	double *	Relaxation solution for the current node, when its optimization status is GRB_OPTIMAL (C only). The resultP argument to C routine GRBcbget should point to an array of doubles that is at least as long as the number of variables in the user model. Use the getNodeRel callback method in the object-oriented interfaces.
BARRIER_ITRCNT	BARRIER	int	Current barrier iteration count.
BARRIER_PRIMOBJ	BARRIER	double	Primal objective value for current barrier iterate.
BARRIER_DUALOBJ	BARRIER	double	Dual objective value for current barrier iterate.
BARRIER_PRIMINF	BARRIER	double	Primal infeasibility for current barrier iterate.
BARRIER_DUALINF	BARRIER	double	Dual infeasibility for current barrier iterate.
BARRIER_COMPL	BARRIER	double	Complementarity violation for current barrier iterate.
MSG_STRING	MESSAGE	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 retreived. 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	`GRB_ERROR_OUT_OF_MEMORY`
C++	`GRB_ERROR_OUT_OF_MEMORY`
Java	`GRB.Error.OUT_OF_MEMORY`
.NET	`GRB.Error.OUT_OF_MEMORY`
Python	`GRB.Error.OUT_OF_MEMORY`

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
`OUT_OF_MEMORY`	10001	Available memory was exhausted
`NULL_ARGUMENT`	10002	`NULL` input value provided for a required argument
`INVALID_ARGUMENT`	10003	An invalid value was provided for a routine argument
`UNKNOWN_ATTRIBUTE`	10004	Tried to query or set an unknown attribute
`DATA_NOT_AVAILABLE`	10005	Attempted to query or set an attribute that could not be accessed at that time
`INDEX_OUT_OF_RANGE`	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
`UNKNOWN_PARAMETER`	10007	Tried to query or set an unknown parameter
`VALUE_OUT_OF_RANGE`	10008	Tried to set a parameter to a value that is outside the parameter's valid range
`NO_LICENSE`	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 setPWLObj methods). This error indicates that one of those properties was violated.
NOT_IN_MODEL	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
FAILED_TO_CREATE_MODEL	20002	Failed to create the requested model
INTERNAL	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`.

14.1 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 traditionally used as the objective function, while additional free rows are ignored.

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 $(10X01^2 + 2X01 * X02 + 2X02 * X01 + 2X02^2)/2$ (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 is the optional `QCMATRIX` section, which contains quadratic terms for quadratic constraints. Each quadratic constraint gets it's own header. The header includes the `QCMATRIX` label (starting in column 1), followed by the name of the quadratic constraint (starting in column 12). The lines that follow each represent a single non-zero in the corresponding quadratic constraint. The names of the two participating variables appear first (in columns 5 and 15), followed by the coefficient value (in column 26). Here's an example of a quadratic expression:

```
QCMATRIX   qc0
    X01        X01        10.0
    X01        X02        1.0
    X02        X02        5.0
```

Note that the linear terms, the sense, and the right-hand side value for the quadratic constraint appear in the `COLUMNS`, `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
```

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 of more quadratic terms. Each term is described on one line, which indicates 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   QC0
    X01        X01        10.0
    X01        X02        2.0
    X02        X01        2.0
    X02        X02        2.0
```

These three terms would indicate that quadratic constraint `QC0` contains terms $10X01^2$, $4X01*X02$, and $2X02^2$. Linear terms for constraint `QC0` would appear in the `COLUMNS` section. Note that a `QCMATRIX` block must contain a symmetric matrix, so for example an `X01*X02` term must be accompanied by a matching `X02*X01` term.

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.

14.2 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)`.

14.3 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. The name should be no longer than 255 characters, and to avoid confusing the LP parser, it should not begin with a number, or with 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 headers, on its own line: *minimize*, *maximize*, *minimum*, *maximum*, *min*, or *max*. Capitalization in the header is ignored. The header is then followed by a 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 each variable with a piecewise-linear objective, 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
```

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
```

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.

End statement

The last line in an LP format file should be an `End` statement.

14.4 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)`.

14.5 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.

14.6 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 pseduo-boolean optimization model

$$\begin{array}{ll} \text{minimize} & y - 1.3x(1-z) + (1-z) \\ \text{subject to} & 2y - 3x + 1.7w = 1.7 \\ & -y + x + xz(1-v) \geq 0 \\ & -y \leq 0, \\ & v, w, x, y, z \in \{0, 1\}. \end{array} \tag{1}$$

The corresponding OPB file for this example is given by

```
* This is a dummy pseduo-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 definied by omitting the objective.

Constraint senses `>=`, `=`, and `<=` are supported.

14.7 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.

14.8 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.

14.9 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.

14.10 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.

14.11 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
```

14.12 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.

15.1 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 `dfl001`:

```
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
```

15.2 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 `dfl001`:

```
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:

```
                 Objective                Residual
Iter       Primal          Dual         Primal    Dual     Compl     Time
   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 infeasibilites 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
```

15.3 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.

15.4 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
 203266 12649     cutoff   30        40005.054  39756.344  0.62%   3.9   10s
```

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.

15.5 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.

16.1 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

16.2 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 15 19:28:48 2015
*Replay* Recording captured with Gurobi version 6.5.0 (linux64)
```

For information about recording API calls and replaying them, see the Recording API Calls chapter.

16.3 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.

`--adminpassword`: 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. 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 `--adminpassword` 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 6.5.0) 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 --adminpassword --server=gurobiserver1
> gurobi_cl --joblimit=0 --server=gurobiserver1
```

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.

17.1 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.

17.2 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 15 19:28:48 2015
*Replay* Recording captured with Gurobi version 6.5.0 (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
```

17.3 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.

Parameter Tuning Tool

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), 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 parameters that could produce consistent, reliable improvements on your models. It is not meant to be

a replacement for efficient modeling or careful performance testing.

19.1 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 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 proceeeds 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.

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.

19.2 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

Gurobi Remote Services allow a machine to perform Gurobi computations on behalf of other machines. It is a Windows Service on Windows sytems, 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.

20.1 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;

  binary distributions include the above copyright notice, this list
  of conditions and the following disclaimer in their documentation.

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.
---------------------------------------------------------------------------
```

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.

21.1 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...

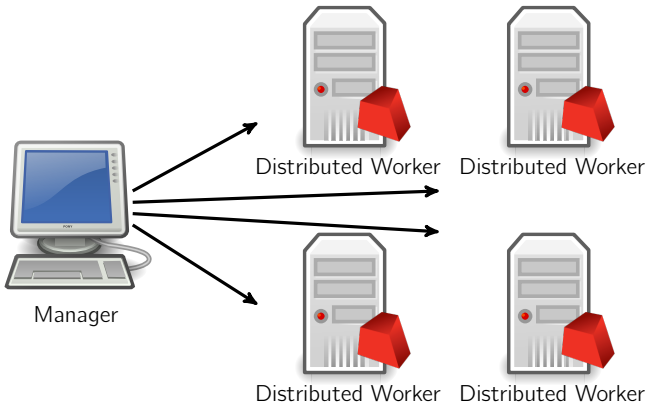
```
Gurobi Remote Services (version 6.5.0) functioning normally
Available services: Distributed Worker
```

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

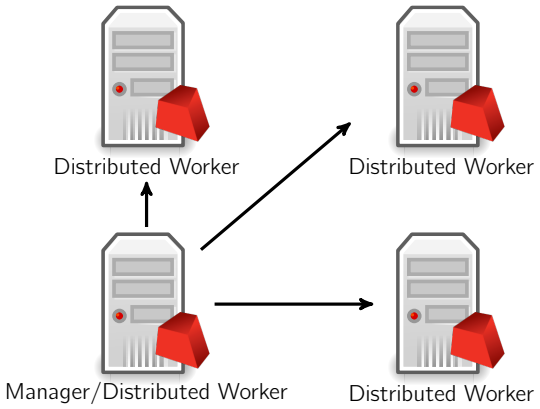
Once you have identified a set of distributed worker machines, you'll need to choose a manager machine. This is the machine where your application actually runs. In addition to building the optimization model, your manager machine will coordinate the efforts of the distributed workers during the execution 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 provides 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.

21.2 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.

21.3 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.

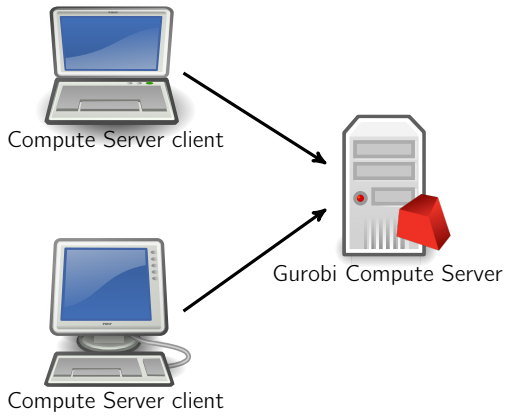
Callbacks

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.

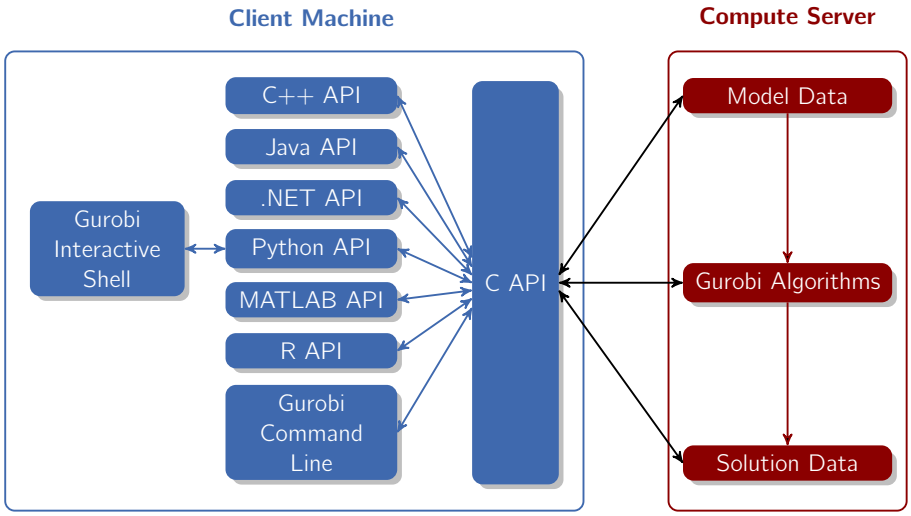
Logging

The distributed algorithms provide slightly different logging information from the standard algorithms. Consult the Distributed MIP Logging section for details.

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:

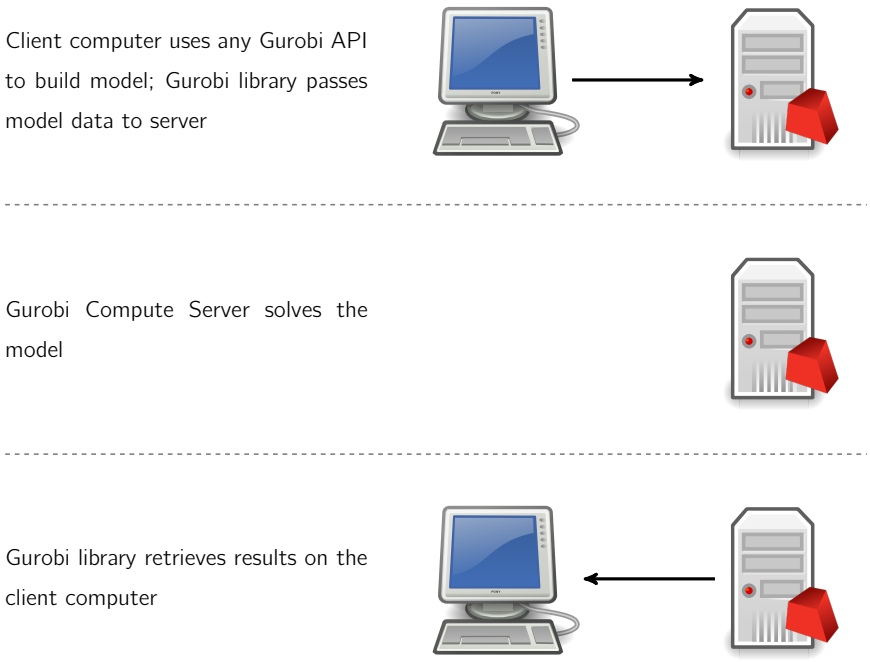


All of our API's sit on top of our C API. The C API is in charge of building the internal model data structures, invoking the Gurobi algorithms, retrieving solution information, etc. When running Gurobi on a single machine, the C API would build the necessary data structures in

memory. The Gurobi algorithms would take the data stored in these data structures as input, and produce solution data as output.

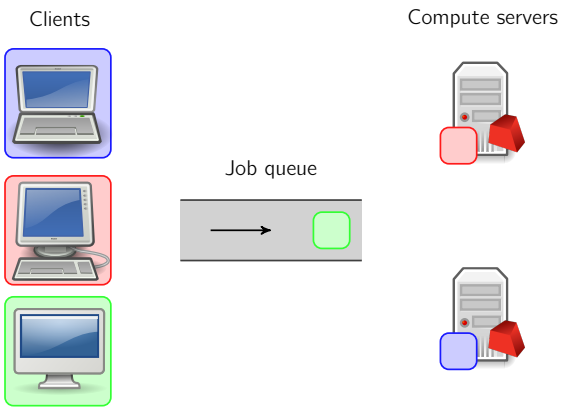
When running on a Compute Server, the C API instead passes model data to the server, where it is stored. When the Gurobi algorithms are invoked, the C API simply passes a message to the server, indicating that optimization should be performed on the stored model data. Solution data is computed and stored 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 proceeed to Compute Server usage for details.

22.1 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 6.5.0) 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.

22.2 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 Computes 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 transfering 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.