1 Introduction

2 Example tour
  2.1 A list of the Gurobi examples .................................................. 10
  2.2 Load and solve a model from a file ............................................. 13
  2.3 Build a model ................................................................. 14
  2.4 Additional modeling elements .................................................. 16
  2.5 Modify a model .......................................................................... 16
  2.6 Change parameters ............................................................... 18
  2.7 Automated parameter tuning ...................................................... 19
  2.8 Diagnose and cope with infeasibility ........................................ 19
  2.9 MIP starts ............................................................... 20
  2.10 Model-data separation in Python ............................................. 21
  2.11 Callbacks ............................................................... 22

3 Example Source Code ................................................................................. 23
  3.1 C Examples ................................................................. 23
     callback_c.c ................................................................. 23
     dense.c ................................................................. 28
     diet.c ................................................................. 30
     facility.c ............................................................. 34
     feasopt.c ............................................................. 39
     fixanddive.c .......................................................... 42
     genconstr.c ............................................................ 45
     lp.c ................................................................. 49
     lpmethod.c ............................................................ 51
     lpmod.c ................................................................. 52
     mip1.c ................................................................. 55
     mip2.c ................................................................. 57
     multiobj.c .............................................................. 60
     params.c ................................................................. 64
     piecewise.c ............................................................ 66
     poolsearch.c ........................................................... 69
     qcp.c ................................................................. 72
     qp.c ................................................................. 75
     sensitivity.c ............................................................ 78
     sos.c ................................................................. 81
     sudoku.c ................................................................. 83
     tsp.c ................................................................. 87
### 3.2 C++ Examples

<table>
<thead>
<tr>
<th>File Name</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>tune_c.c</td>
<td>93</td>
</tr>
<tr>
<td>workforce1_c.c</td>
<td>94</td>
</tr>
<tr>
<td>workforce2_c.c</td>
<td>98</td>
</tr>
<tr>
<td>workforce3_c.c</td>
<td>102</td>
</tr>
<tr>
<td>workforce4_c.c</td>
<td>106</td>
</tr>
<tr>
<td>workforce5_c.c</td>
<td>112</td>
</tr>
<tr>
<td>callback_c++.cpp</td>
<td>118</td>
</tr>
<tr>
<td>dense_c++.cpp</td>
<td>122</td>
</tr>
<tr>
<td>diet_c++.cpp</td>
<td>124</td>
</tr>
<tr>
<td>facility_c++.cpp</td>
<td>126</td>
</tr>
<tr>
<td>feasopt_c++.cpp</td>
<td>130</td>
</tr>
<tr>
<td>fixanddive_c++.cpp</td>
<td>131</td>
</tr>
<tr>
<td>genconstr_c++.cpp</td>
<td>133</td>
</tr>
<tr>
<td>lp_c++.cpp</td>
<td>137</td>
</tr>
<tr>
<td>lpmethod_c++.cpp</td>
<td>138</td>
</tr>
<tr>
<td>lpmod_c++.cpp</td>
<td>139</td>
</tr>
<tr>
<td>mip1_c++.cpp</td>
<td>141</td>
</tr>
<tr>
<td>mip2_c++.cpp</td>
<td>142</td>
</tr>
<tr>
<td>multiobj_c++.cpp</td>
<td>144</td>
</tr>
<tr>
<td>params_c++.cpp</td>
<td>147</td>
</tr>
<tr>
<td>piecewise_c++.cpp</td>
<td>148</td>
</tr>
<tr>
<td>poolsearch_c++.cpp</td>
<td>150</td>
</tr>
<tr>
<td>sensitivity_c++.cpp</td>
<td>153</td>
</tr>
<tr>
<td>qcp_c++.cpp</td>
<td>155</td>
</tr>
<tr>
<td>qp_c++.cpp</td>
<td>156</td>
</tr>
<tr>
<td>sos_c++.cpp</td>
<td>158</td>
</tr>
<tr>
<td>sudoku_c++.cpp</td>
<td>159</td>
</tr>
<tr>
<td>tsp_c++.cpp</td>
<td>162</td>
</tr>
<tr>
<td>tune_c++.cpp</td>
<td>166</td>
</tr>
<tr>
<td>workforce1_c++.cpp</td>
<td>167</td>
</tr>
<tr>
<td>workforce2_c++.cpp</td>
<td>170</td>
</tr>
<tr>
<td>workforce3_c++.cpp</td>
<td>173</td>
</tr>
<tr>
<td>workforce4_c++.cpp</td>
<td>176</td>
</tr>
<tr>
<td>workforce5_c++.cpp</td>
<td>181</td>
</tr>
</tbody>
</table>

### 3.3 Java Examples

<table>
<thead>
<tr>
<th>File Name</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Callback.java</td>
<td>184</td>
</tr>
<tr>
<td>Dense.java</td>
<td>188</td>
</tr>
<tr>
<td>Diet.java</td>
<td>190</td>
</tr>
<tr>
<td>Facility.java</td>
<td>192</td>
</tr>
<tr>
<td>Feasopt.java</td>
<td>195</td>
</tr>
<tr>
<td>Fixanddive.java</td>
<td>196</td>
</tr>
<tr>
<td>Genconstr.java</td>
<td>199</td>
</tr>
<tr>
<td>Lp.java</td>
<td>201</td>
</tr>
<tr>
<td>Lpmethod.java</td>
<td>202</td>
</tr>
</tbody>
</table>
Lpmod.java ................................................................. 204
Mip1.java ................................................................. 205
Mip2.java ................................................................. 206
Multiobj.java ............................................................. 208
Params.java ............................................................... 211
Piecewise.java ......................................................... 212
Poolsearch.java ......................................................... 214
Qep.java ................................................................. 216
Qp.java ................................................................. 218
Sensitivity.java ......................................................... 220
Sos.java ................................................................. 222
Sudoku.java .............................................................. 223
Tsp.java ................................................................. 225
Tune.java ............................................................... 229
Workforce1.java ....................................................... 230
Workforce2.java ....................................................... 232
Workforce3.java ....................................................... 235
Workforce4.java ....................................................... 237
Workforce5.java ....................................................... 241

3.4 C# Examples .................................................................. 244
callback_cs.cs ............................................................ 244
dense_cs.cs ............................................................. 248
diet_cs.cs ............................................................... 250
facility_cs.cs ........................................................... 252
feasopt_cs.cs ............................................................ 255
fixanddive_cs.cs ......................................................... 256
genconstr_cs.cs .......................................................... 258
lp_cs.cs ................................................................. 261
lpmethod_cs.cs .......................................................... 262
lpmod_cs.cs ............................................................. 263
mip1_cs.cs ............................................................... 265
mip2_cs.cs ............................................................... 266
multiobj_cs.cs ........................................................... 268
params_cs.cs ............................................................. 270
piecewise_cs.cs .......................................................... 271
poolsearch_cs.cs ......................................................... 273
qcp_cs.cs ................................................................. 276
qp_cs.cs ................................................................. 277
sensitivity_cs.cs .......................................................... 278
sos_cs.cs ................................................................. 280
sudoku_cs.cs ............................................................. 281
tsp_cs.cs ................................................................. 284
tune_cs.cs ............................................................... 288
workforce1_cs.cs .......................................................... 289
workforce2_cs.cs .......................................................... 291
3.5 Visual Basic Examples

- callback_vb.vb
- dense_vb.vb
- diet_vb.vb
- facility_vb.vb
- feasopt_vb.vb
- fixanddive_vb.vb
- genconstr_vb.vb
- lp_vb.vb
- lpmethod_vb.vb
- lpmode_vb.vb
- mip1_vb.vb
- mip2_vb.vb
- multiobj_vb.vb
- params_vb.vb
- piecewise_vb.vb
- poolsearch_vb.vb
- qcp_vb.vb
- qp_vb.vb
- sensitivity_vb.vb
- sos_vb.vb
- sudoku_vb.vb
- tsp_vb.vb
- tune_vb.vb
- workforce1_vb.vb
- workforce2_vb.vb
- workforce3_vb.vb
- workforce4_vb.vb
- workforce5_vb.vb

3.6 Python Examples

- callback.py
- custom.py
- dense.py
- diet.py
- diet2.py
- diet3.py
- diet4.py
- dietmodel.py
- facility.py
- feasopt.py
- fixanddive.py
- genconstr.py
The Gurobi\textsuperscript{TM} distribution includes an extensive set of examples that illustrate commonly used features of the Gurobi libraries. Most examples have versions for C, C++, C\#, Java, Visual Basic, and Python. A few, however, illustrate features that are specific to the Python interface.

The distribution also includes examples for our MATLAB\textsuperscript{R} and R interfaces. Note, however, that our interfaces to these languages are built around the assumption that you will use the rich matrix-oriented capabilities of the underlying languages to build your optimization models. Thus, our examples for these languages don’t attempt to show you how to build models. We have instead chosen to provide a few simple examples that demonstrate how to pass matrices into our interface.

This document provides a brief tour of these examples. We won’t go through each example in detail. Instead, we’ll start with an Overview of the set of tasks that you are likely to want to perform with the Gurobi Optimizer. Later sections will then describe how specific examples accomplish each of these tasks. Alternatively, we provide a Structured List of all of our examples, which you can use to dive directly into an example of interest to you. In either case, we suggest that you browse the example source code (in a text editor, or in another browser window) while reading this document. This document includes Source Code for all of the examples, in all available languages. Source files are also available in the examples directory of the Gurobi distribution.

If you would like further details on any of the Gurobi routines used in these examples, please consult the Gurobi Reference Manual.
Example tour

This document provides a quick guided tour of the Gurobi examples; we will try to highlight some of the most important features of these examples. Full source code is provided in this document, so you are free to explore the examples in full detail.

Wherever possible, we try to discuss the examples in a manner that is independent of programming languages. We will refer to each example using a brief, language independent name. You will need to map this name to the specific source file name for your language. For example, the facility example corresponds to six different implementations, one in C (facility_c.c), one in C++ (facility_c++.cpp), one in Java (Facility.java), one in C# (facility_cs.cs), one in Visual Basic (facility_vb.vb), and one in Python (facility.py). If you would like to look at the language implementation for a particular example, please refer to the appropriate example source file.

Topics covered in the examples

The easiest place to start your introduction to the Gurobi examples is probably with the examples that load and solve a model from a file. These demonstrate the most basic capabilities of the Gurobi libraries. They also demonstrate the use of model attributes, which are an important concept in the Gurobi optimizer.

Once you are comfortable with these examples, you should move on to the examples that build a model from scratch. These show you how to create variables and constraints, and add them to an optimization model.

The next topic covered in this document is model modification. The Gurobi distribution includes examples that add and remove constraints, add variables, and change variable types, bounds and objective coefficients. You modify a model in much the same way that you build a model from scratch, but there are some important differences involving the use of the solution information.

Next, this document covers parameter changes. The params example shows you how to change parameters, and in particular how to use different parameter settings for different models.

On a related note, the tuning section demonstrates the use of our automated tuning tool. This tool searches for parameter settings that improve performance on a particular model.

The infeasibility section considers a few examples that cope with model infeasibility. Some use an Irreducible Inconsistent Subsystem (IIS) to handle the infeasibility, while others relax constraints.

One useful MIP feature that is worth understanding is MIP starts. A MIP start allows you to specify a known feasible solution to the MIP solver. The solution provides a bound on the objective of the best possible solution, which can help to limit the MIP search. The solution also provides a potential start point for the local search heuristics that are utilized by the Gurobi MIP solver.

It is possible to achieve model-data separation when using our Python interface, as is often done in modeling languages, but you need to make use of Python modules to do so. The model-data separation section provides an example of how this is done. It considers three versions of the diet example. All three use the same function to formulate and solve the actual optimization model, but they obtain model data from very different places.
The final topic we cover in this document is Gurobi callbacks. Callbacks allow the user to obtain periodic progress information related to the optimization.

## 2.1 A list of the Gurobi examples

We recommend that you begin by reading the overview of the examples (which begins in the next section). However, if you'd like to dive directly into a specific example, the following is a list of all of the examples included in the Gurobi distribution, organized by basic function. The source for the examples can be found by following the provided links, or in the examples directory of the Gurobi distribution.

### Read a model from a file

- **lp** - A very simple example that reads a continuous model from a file, optimizes it, and writes the solution to a file. If the model is infeasible, it writes an Irreducible Inconsistent Subsystem (IIS) instead. C, C++, C#, Java, Python, R, VB.

- **mip2** - Reads a MIP model from a file, optimizes it, and then solves the fixed version of the MIP model. C, C++, C#, Java, Python, VB.

### Build a simple model

- **mip1** - Builds a trivial MIP model, solves it, and prints the solution. C, C++, C#, Java, MATLAB, Python, R, VB.

- **qp** - Builds a trivial QP model, solves it, converts it to an MIQP model, and solves it again. C, C++, C#, Java, MATLAB, Python, R, VB.

- **qcp** - Builds and solves a trivial QCP model. C, C++, C#, Java, MATLAB, Python, R, VB.

- **sos** - Builds and solves a trivial SOS model. C, C++, C#, Java, MATLAB, Python, R, VB.

- **dense** - Solves a model stored using dense matrices. We don’t recommend using dense matrices, but this example may be helpful if your data is already in this format. C, C++, C#, Java, Python, VB.

- **genconstr** - Demonstrates the use of general constraints. C, C++, C#, Java, MATLAB, Python, R, VB.

- **multiobj** - Demonstrates the use of multi-objective optimization. C, C++, C#, Java, MATLAB, Python, R, VB.

- **piecewise** - Demonstrates the use of piecewise-linear objective functions. C, C++, C#, Java, MATLAB, Python, R, VB.

- **poolsearch** - Demonstrates the use of solution pools. C, C++, C#, Java, MATLAB, Python, R, VB.
A few simple applications

- **diet** - Builds and solves the classic diet problem. Demonstrates model construction and simple model modification - after the initial model is solved, a constraint is added to limit the number of dairy servings. C, C++, C#, Java, MATLAB, Python, R, VB.

- **diet2, diet3, diet4, dietmodel** - Python-only variants of the diet example that illustrate model-data separation. diet2.py, diet3.py, diet4.py, dietmodel.py.

- **facility** - Simple facility location model: given a set of plants and a set of warehouses, with transportation costs between them, this example finds the least expensive set of plants to open in order to satisfy product demand. This example demonstrates the use of MIP starts — the example computes an initial, heuristic solution and passes that solution to the MIP solver. C, C++, C#, Java, MATLAB, Python, R, VB.

- **netflow** - A Python-only example that solves a multi-commodity network flow model. It demonstrates the use of several Python modeling constructs, including dictionaries, tuples, tupledict, and tuplelist objects. Python.

- **portfolio** - A Python-only example that solves a financial portfolio optimization model, where the historical return data is stored using the pandas package and the result is plotted using the matplotlib package. It demonstrates the use of pandas, NumPy, and Matplotlib in conjunction with Gurobi. Python.

- **sudoku** - Reads a Sudoku puzzle dataset from a file, builds a MIP model to solve that model, solves it, and prints the solution. C, C++, C#, Java, MATLAB, Python, R, VB.

- **workforce1** - Formulates and solves a workforce scheduling model. If the model is infeasible, the example computes and prints an Irreducible Inconsistent Subsystem (IIS). C, C++, C#, Java, MATLAB, Python, R, VB.

- **workforce2** - An enhancement of workforce1. This example solves the same workforce scheduling model, but if the model is infeasible, it computes an IIS, removes one of the associated constraints from the model, and re-solves. This process is repeated until the model becomes feasible. Demonstrates constraint removal. C, C++, C#, Java, MATLAB, Python, R, VB.

- **workforce3** - A different enhancement of workforce1. This example solves the same workforce scheduling model, but if the model is infeasible, it adds artificial variables to each constraint and minimizes the sum of the artificial variables. This corresponds to finding the minimum total change in the right-hand side vector required in order to make the model feasible. Demonstrates variable addition. C, C++, C#, Java, MATLAB, Python, R, VB.

- **workforce4** - An enhancement of workforce3. This example solves the same workforce scheduling model, but it starts with artificial variables in each constraint. It first minimizes the sum of the artificial variables. Then, it introduces a new quadratic objective to balance the workload among the workers. Demonstrates optimization with multiple objective functions. C, C++, C#, Java, MATLAB, Python, R, VB.
• **workforce5** - An alternative enhancement of **workforce3**. This example solves the same workforce scheduling model, but it starts with artificial variables in each constraint. It formulates a multi-objective model where the primary objective is to minimize the sum of the artificial variables (uncovered shifts), and the secondary objective is to minimize the maximum difference in the number of shifts worked between any pair of workers. Demonstrates multi-objective optimization. C, C++, C#, Java, MATLAB, Python, R, VB.

**Illustrating specific features**

• **feasopt** - Reads a MIP model from a file, adds artificial slack variables to relax each constraint, and then minimizes the sum of the artificial variables. It then computes the same relaxation using the *feasibility relaxation* feature. The example demonstrates simple model modification by adding slack variables. It also demonstrates the feasibility relaxation feature. C, C++, C#, Java, MATLAB, Python, R, VB.

• **lpmethod** - Demonstrates the use of different LP algorithms. Reads a continuous model from a file and solves it using multiple algorithms, reporting which is the quickest for that model. C, C++, C#, Java, MATLAB, Python, R, VB.

• **lpmod** - Demonstrates the use of advanced starts in LP. Reads a continuous model from a file, solves it, and then modifies one variable bound. The resulting model is then solved in two different ways: starting from the solution of the original model, or restarting from scratch. C, C++, C#, Java, MATLAB, Python, R, VB.

• **params** - Demonstrates the use of Gurobi parameters. Reads a MIP model from a file, and then spends 5 seconds solving the model with each of four different values of the **MIPFocus** parameter. It compares the optimality gaps for the four different runs, and continues with the **MIPFocus** value that produced the smallest gap. C, C++, C#, Java, MATLAB, Python, R, VB.

• **sensitivity** - MIP sensitivity analysis. Reads a MIP model, solves it, and then computes the objective impact of fixing each binary variable in the model to 0 or 1. Demonstrates simple MIP model modification by changing variable bounds. C, C++, C#, Java, MATLAB, Python, R, VB.

• **tune** - Uses the parameter tuning tool to search for improved parameter settings for a model. C, C++, C#, Java, Python, VB.

• **fixanddive** - Implements a simple MIP heuristic. It reads a MIP model from a file, relaxes the integrality conditions, and then solves the relaxation. It then chooses a set of integer variables that take integer or nearly integer values in the relaxation, fixes them to the nearest integer, and solves the relaxation again. This process is repeated until the relaxation is either integer feasible or linearly infeasible. The example demonstrates different types of model modification (relaxing integrality conditions, changing variable bounds, etc.). C, C++, C#, Java, MATLAB, Python, R, VB.

**More advanced features**

• **tsp** - Solves a traveling salesman problem using lazy constraints. C, C++, C#, Java, Python, VB.
• **callback** - Demonstrates the use of Gurobi callbacks. C, C++, C#, Java, Python, VB.

## 2.2 Load and solve a model from a file

**Examples:** callback, feasopt, fixanddive, lp, lpmethod, lpmod, mip2, params, sensitivity

One of the most basic tasks you can perform with the Gurobi libraries is to read a model from a file, optimize it, and report the result. The `lp` (lp.c, lp_c++.cpp, lp.cs.cs, Lp.java, lp.py, lp_vb.vb) and `mip2` (mip2.c, mip2_c++.cpp, mip2.cs.cs, Mip2.java, mip2.m, mip2.py, mip2.R, mip2_vb.vb) examples are simple illustrations of how this is done in the various supported Gurobi languages. While the specifics vary from one language to another, the basic structure remains the same for all languages.

After initializing the Gurobi environment, the examples begin by reading the model from the specified file. In C, you call the `GRBreadmodel()` function:

```c
error = GRBreadmodel(masterenv, argv[1], &model);
```

In C++, this is done by constructing a `GRBModel` object:

```cpp
GRBModel model = GRBModel(env, argv[1]);
```

In C# and Java, this is also done by constructing a `GRBModel` object:

```cs
GRBModel model = new GRBModel(env, args[0]);
```

In Python, this is done via the `read` global function:

```python
model = read(sys.argv[1])
```

The next step is to invoke the Gurobi optimizer on the model. In C, you call `GRBoptimize()` on the `model` variable:

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

In C++, Java, and Python, this is accomplished by calling the `optimize` method on the `model` object:

```cpp
model.optimize();
```

```java
model.optimize();
```

```python
model.optimize();
```

In C#, the first letter of the method name is capitalized:

```cs
model.Optimize();
```

A successful `optimize` call populates a set of solution attributes in the model. For example, once the call completes, the X variable attribute contains the solution value for each variable. Similarly, for continuous models, the Pi constraint attribute contains the dual value for each constraint.

The examples then retrieve the value of the model `Status` attribute to determine the result of the optimization. In the `lp` example, an optimal solution is written to a solution file (`model.sol`).

There are many other things you can do once you have read and solved the model. For example, `lp` checks the solution status — which is highly recommended. If the model is found to be infeasible, this example computes an Irreducible Inconsistent Subsystem (IIS) to isolate the source of the infeasibility.
2.3 Build a model

Examples: diet, facility, genconstr, mip1, multiobj, piecewise, poolsearch, qcp, qp, sos, sudoku, workforce1, workforce2, workforce3, workforce4, workforce5

Several of the Gurobi examples build models from scratch. We start by focusing on two: *mip1* and *sos*. Both build very simple models to illustrate the basic process.

Typically, the first step in building a model is to create an empty model. This is done using the GRBnewmodel function in C:

```c
error = GRBnewmodel(env, &model, "mip1", 0, NULL, NULL, NULL, NULL);
```

You can optionally create a set of variables when you create the model, as well as specifying bounds, objective coefficients, and names for these variables. These examples add new variables separately.

In C++, C#, and Java, you create a new model using the GRBModel constructor. In Java, this looks like:

```java
GRBModel model = new GRBModel(env);
```

In Python, the class is called Model, and its constructor is similar to the GRBModel constructor for C++ and Java.

Once the model has been created, the typical next step is to add variables. In C, you use the GRBaddvars function to add one or more variables:

```c
error = GRBaddvars(model, 3, 0, NULL, NULL, obj, NULL, NULL, vtype, NULL);
```

In C++, Java, and Python, you use the addVar method on the Model object (AddVar in C#). In Java, this looks like:

```java
GRBVar x = model.addVar(0.0, 1.0, -1.0, GRB.BINARY, "x");
```

The new variable's lower bound, upper bound, objective coefficient, type, and name are specified as arguments. In C++ and Python, you can omit these arguments and use default values; see the Gurobi Reference Manual for details.

The next step is to add constraints to the model. Linear constraints are added through the GRBaddconstr function in C:

```c
error = GRBaddconstr(model, 3, ind, val, GRB_LESS_EQUAL, 4.0, "c0");
```

To add a linear constraint in C, you must specify a list of variable indices and coefficients for the left-hand side, a sense for the constraint (e.g., GRB_LESSEQUAL), and a right-hand side constant. You can also give the constraint a name; if you omit the name, Gurobi will assign a default name for the constraint.

In C++, C#, Java, and Python, you build a linear constraint by first building linear expressions for the left- and right-hand sides. In Java, which doesn’t support operator overloading, you build an expression as follows:

```java
GRBLinExpr expr = new GRBLinExpr();
expr.addTerm(1.0, x); expr.addTerm(2.0, y); expr.addTerm(3.0, z);
```

You then use the addConstr method on the GRBModel object to add a constraint using these linear expressions for the left- and right-hand sides:
model.addConstr(expr, GRB_LESS_EQUAL, 4.0, "c0");

For C++, C#, and Python, the standard mathematical operators such as +, *, <= have been overloaded so that the linear expression resembles a traditional mathematical expression. In C++:

model.addConstr(x + 2 * y + 3 * z <= 4, "c0");

Once the model has been built, the typical next step is to optimize it (using GRB.optimize in C, model.optimize in C++, Java, and Python, or model.Optimize in C#). You can then query the X attribute on the variables to retrieve the solution (and the VarName attribute to retrieve the variable name for each variable). In C, the X attribute is retrieved as follows:

```c
error = GRBgetdblattrarray(model, GRB_DBL_ATTR_X, 0, 3, sol);
```

In C++:

```cpp
cout << x.get(GRB_StringAttr_VarName) << " "
   << x.get(GRB_DoubleAttr_X) << endl;
cout << y.get(GRB_StringAttr_VarName) << " "
   << y.get(GRB_DoubleAttr_X) << endl;
cout << z.get(GRB_StringAttr_VarName) << " "
   << z.get(GRB_DoubleAttr_X) << endl;
```

In Java:

```java
System.out.println(x.get(GRB.StringAttr.VarName) +
   " " + x.get(GRB.DoubleAttr.X));
System.out.println(y.get(GRB.StringAttr.VarName) +
   " " + y.get(GRB.DoubleAttr.X));
System.out.println(z.get(GRB.StringAttr.VarName) +
   " " + z.get(GRB.DoubleAttr.X));
```

In C#:

```csharp
Console.WriteLine(x.Get(GRB.StringAttr.VarName) +
   " " + x.Get(GRB.DoubleAttr.X));
Console.WriteLine(y.Get(GRB.StringAttr.VarName) +
   " " + y.Get(GRB.DoubleAttr.X));
Console.WriteLine(z.Get(GRB.StringAttr.VarName) +
   " " + z.Get(GRB.DoubleAttr.X));
```

In Python:

```python
for v in m.getVars():
    print(v.varName, v.x)
```

When querying or modifying attribute values for an array of constraints or variables, it is generally more efficient to perform the action on the whole array at once. This is quite natural in the C interface, where most of the attribute routines take array arguments. In the C++, C#, Java, and Python interfaces, you can use the get and set methods on the GRBModel object to work directly with arrays of attribute values (getattr/setattr in Python). In the sudoku Java example, this is done as follows:
We should point out one important subtly in our interface. We use a lazy update approach to building and modifying a model. When you make changes, they are added to a queue. The queue is only flushed when you optimize the model (or write it to a file). In the uncommon situation where you want to query information about your model before optimizing it, you should call the update method before making your query.

2.4 Additional modeling elements

Examples: genconstr, multiobj, piecewise, qcp, qp, sos

A mathematical programming model in its traditional form consists of a linear objective, a set of linear constraints, and a set of continuous or integer decision variables. Gurobi supports a number of additional modeling constructs. In addition to linear constraints, Gurobi also supports SOS constraints, quadratic constraints, and general constraints. In addition to a single linear objective, Gurobi also supports quadratic objectives, piecewise-linear objectives, and multiple linear objectives. Consult the corresponding examples from the Gurobi distribution for simple examples of how to use each of these modeling elements.

2.5 Modify a model

Examples: diet, feasopt, fixanddive, lpmod, sensitivity, workforce3, workforce4, workforce5

This section considers model modification. Modification can take many forms, including adding constraints or variables, deleting constraints or variables, modifying constraint and variable attributes, changing constraint coefficients, etc. The Gurobi examples don’t cover all possible modifications, but they cover the most common types.

diet

This example builds a linear model that solves the classic diet problem: to find the minimum cost diet that satisfies a set of daily nutritional requirements. Once the model has been formulated and solved, it adds an additional constraint to limit the number of servings of dairy products and solves the model again. Let’s focus on the model modification.

Adding constraints to a model that has already been solved is no different from adding constraints when constructing an initial model. In Python, we can introduce a limit of 6 dairy servings through the following constraint:

```python
m.addConstr(buy['milk'] + buy['ice cream'] <= 6, "limit_dairy")
```

For linear models, the previously computed solution can be used as an efficient warm start for the modified model. The Gurobi solver retains the previous solution, so the next optimize call automatically starts from the previous solution.

lpmod

Changing a variable bound is also straightforward. The lpmod example changes a single variable bound, then re-solves the model in two different ways. A variable bound can be changed by modifying the UB or LB attribute of the variable. In C:

```c
error = GRBsetdblattrelement(model, GRB_DBL_ATTR_UB, var, 0.0);
```
In Python:

```python
minVar.ub = 0
```

The model is re-solved simply by calling the `optimize` method again. For a continuous model, this starts the optimization from the previous solution. To illustrate the difference when solving the model from an initial, unsolved state, the `lpmod` example calls the `reset` function. In C:

```c
error = GRBreset(model, 0);
```

In C++, Java, and Python:

```c
m.reset(0)
```

In C#:

```c
m.Reset(0)
```

When we call the `optimize` method after resetting the model, optimization starts from scratch. Although the difference in computation time is insignificant for this tiny example, a warm start can make a big difference for larger models.

**fixanddive**

The `fixanddive` example provides another example of bound modification. In this case, we repeatedly modify a set of variable bounds, utilizing warm starts each time. In C, variables are fixed as follows:

```c
for (j = 0; j < nfix; ++j)
{
    fixval = floor(fractional[j].X + 0.5);
    error = GRBsetdblattrelement(model, "LB", fractional[j].index, fixval);
    if (error) goto QUIT;
    error = GRBsetdblattrelement(model, "UB", fractional[j].index, fixval);
    if (error) goto QUIT;
}
```

In Python, they are fixed as follows:

```python
for i in range(nfix):
    v = fractional[i]
    fixval = int(v.x + 0.5)
    v.lb = fixval
    v.ub = fixval
```

Again, the subsequent call to `optimize` starts from the previous solution.

**sensitivity**

The `sensitivity` example computes the amount by which the optimal objective changes if each binary variable is fixed at either 0 or 1. For each binary variable, the example creates and solves a copy of the model with new upper and lower bounds. This example is a MIP, so Gurobi can not make use of advanced start information. As a result, the model is solved from scratch after each bound modification.
The last modification example we consider is `feasopt`, which adds variables to existing constraints and also changes the optimization objective. Setting the objective to zero is straightforward: simply call `setObjective` with a zero argument:

```python
m.setObjective(0)
```

Adding new variables is somewhat more complex. In the example, we want to add artificial variable(s) to each constraint in order to allow the constraint to be relaxed. We use two artificial variables for equality constraints and one for inequality constraints. The Python code for adding a single artificial variable to constraint `c` is:

```python
feasModel.addVar(obj=1.0, name="ArtP_" + c.Constrname, column=Column([1], [c]))
```

We use the `column` argument of the `addVar` method to specify the set of constraints in which the new variable participates, as well as the associated coefficients. In this example, the new variable only participates in the constraint to be relaxed. Default values are used here for all variables attributes except the objective and the variable name.

### 2.6 Change parameters

**Examples:** `callback`, `fixanddive`, `lp`, `lpmethod`, `mip2`, `params`, `sensitivity`

This section illustrates the use of Gurobi parameters. Example `params` reads a MIP model from a file, then solves the model using four different values of the `MIPFocus` parameter, running for five seconds per value (MIPFocus chooses the high-level strategy that the MIP solver uses to solve the problem). It then chooses the parameter value that produced the smallest MIP gap, and continues solving the model until it achieves optimality.

The mechanics of setting a parameter are quite simple. To set the `MIPFocus` parameter in C, do the following:

```c
GRBsetintparam(GRBgetenv(model), GRB_INT_PAR_MIPFOCUS, i);
```

In C++:

```c++
model.set(GRB_IntParam_MIPFocus, i);
```

In Java:

```java
model.set(GRB.IntParam.MIPFocus, i);
```

In C#:

```csharp
model.Parameters.MIPFocus = 1
```

or

```csharp
model.Set(GRB.IntParam.MIPFocus, i);
```

In Python:

```python
model.Params.MIPFocus = i
```
We should add a comment on how parameter settings propagate between different models. When we set the **TimeLimit** parameter on the base model, then make a copy of that model, the parameter setting is carried over to the copy. When we set the **MIPFocus** parameter on the copy, that parameter change has no effect on the other copies, nor on the original model.

### 2.7 Automated parameter tuning

**Example:** `tune`

The next example we consider is **tune**, which demonstrates the use of our automated parameter tuning tool. This tool searches for parameter settings that improve performance on a model. While you would typically invoke the tool through the command line, using our `grbtune` program, it can also be invoked from our APIs. We'll provide only a cursory description of the tool here. We recommend that you consult the *Parameter Tuning Tool* section of the Gurobi Reference Manual for more precise details.

Our tuning example demonstrates a typical use of the tuning tool. You would start by invoking the tool on a model. In C:

```c
error = GRBtunemodel(model);
```

In Java:

```java
model.tune();
```

This routine solves the model multiple times, with different parameter settings, to find settings that improve performance.

Once tuning is complete, you would then use `GetTuneResult` to retrieve the result. In C:

```c
error = GRBgettuneresult(model, 0);
```

In Java:

```java
model.getTuneResult(0);
```

The numerical argument indicates which tuning result to retrieve (0 is the best result, 1 is the second-best, etc.). This routine loads the requested parameter set into the environment associated with the argument model.

Once the tune parameter settings have been loaded into the model, you can then call `Optimize` to use these parameters to solve the model, or you can call `Write` to write these parameters to a `.prm` file.

### 2.8 Diagnose and cope with infeasibility

**Examples:** `feasopt`, `lp`, `workforce1`, `workforce2`, `workforce3`

When solving optimization models, there are some situations where the specified constraints cannot be satisfied. When this happens, you often need to either identify and repair the root cause of the infeasibility, or alternatively find a set of constraints to relax in order to obtain a feasible model. The `workforce1`, `workforce2`, and `workforce3` illustrate these different strategies.

Starting with the simplest of the three examples, `workforce1` formulates a simple workforce scheduling model and solves it. If the model is infeasible, it computes an Irreducible Inconsistent
Subsystem (IIS). The user can then inspect this information to understand and hopefully address the source of the infeasibility in the model.

Example workforce2 is similar, except that if the model is infeasible, the example repeatedly identifies an IIS and removes one of the associated constraints from the model until the model becomes feasible. Note that it is sufficient to remove one constraint from the IIS to address that source of infeasibility, but that one IIS may not capture all sources of infeasibility. It is therefore necessary to repeat the process until the model is feasible.

Example workforce3 takes a different approach to addressing infeasibility. Rather than identifying and removing IIS members, it allows the constraints of the model to be relaxed. Like the feasopt example, an artificial variable is added to each constraint. The example sets the objective on the original variables to zero, and then solves a model that minimizes the total magnitude of the constraint relaxation.

The feasopt example demonstrates another approach to relaxing an infeasible model. It computes a feasibility relaxation for the infeasible model. A 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 is invoked as follows:

In C:
```
error = GRBfeasrelax(feasmodel, GRB_FEASRELAX_LINEAR, 1,
NULL, NULL, rhspen, &feasobj);
```

In C++:
```
feasmodel1.feasRelax(GRB_FEASRELAX_LINEAR, true, false, true);
```

In C#:
```
feasmodel1.FeasRelax(GRB.FEASRELAX_LINEAR, true, false, true);
```

In Java:
```
feasmodel1.feasRelax(GRB.FEASRELAX_LINEAR, true, false, true);
```

In Python:
```
feasmodel1.FeasRelaxS(0, True, False, True);
```

The arguments to this method select the objective function for the relaxed model, the specific set of bounds and constraints that are allowed to be relaxed, and the penalties for relaxing specific bounds and constraints.

2.9 MIP starts

Example: facility

A MIP modeler often knows how to compute a feasible solution to their problem. In cases where the MIP solver is slow in finding an initial feasible solution, it can helpful for the modeler to provide a feasible solution along with the model itself. This is done through the Start attribute on the variables. This is illustrated in the facility example.

The facility example solves a simple facility location problem. The model contains a set of warehouses, and a set of plants that produce the products required in the warehouses. Each
plant has a maximum production capacity and a fixed operating cost. Additionally, there is a cost associated with shipping products from a plant to a warehouse. The goal is to decide which plants should satisfy the demand for the product, given the associated capacities and costs.

The example uses a simple heuristic for choosing an initial solution: it closes the plant with the highest fixed cost. The associated solution may not be optimal, but it could produce a reasonable starting solution for the MIP optimization. The MIP start is passed to the MIP solver by setting the `Start` attribute before the optimization begins. In C, we set the start attribute to open all plants using the following code:

```c
for (p = 0; p < nPlants; ++p)
{
    error = GRBsetdblattrelement(model, "Start", opencol(p), 1.0);
    if (error) goto QUIT;
}
```

In Python:

```python
for p in range(nPlants):
    open[p].start = 1.0
```

When you run the example, the MIP solver reports that the start produced a feasible initial solution:

```
Loaded MIP start with objective 210500
```

This initial solution turns out to be optimal for the sample data. Although the computation difference is insignificant for this tiny example, providing a good starting solution can sometimes help for more difficult models.

Note that the MIP start in this example only specifies values for some of the variables – the variables that determine which plants to leave open and which plants to close. The Gurobi MIP solve uses whatever start information is provided to try to construct a complete solution.

## 2.10 Model-data separation in Python

**Examples:** diet2.py, diet3.py, diet4.py

When building an optimization model in a modeling language, it is typical to separate the optimization model itself from the data used to create an instance of the model. These two model ingredients are often stored in completely different files. We show how a similar result can be achieved in our Python interface with our diet2.py, diet3.py, and diet4.py examples. These examples illustrate alternate approaches to providing data to the optimization model: diet2.py embeds the data in the source file, diet3.py reads the data from an SQL database (using the Python sqlite3 package), and diet4.py reads the data from an Excel spreadsheet (using the Python xlrd package). dietmodel.py contains the optimization model itself. The same model is used by diet2.py, diet3.py, and diet4.py.

The key construct that enables the separation of the model from the data is the Python module. A module is simply a set of functions and variables, stored in a file. You import a module into a program using the `import` statement. diet2.py, diet3.py, and diet4.py all populate a set of variables, and then pass them to the `solve` function of the dietmodel module using the following pair of statements:
import dietmodel
dietmodel.solve(categories, minNutrition, maxNutrition, foods, cost, nutritionValues)

The first statement imports the dietmodel module, which must be stored in file dietmodel.py in the current directory. The second passes the model data to the solve function in the newly imported module.

2.11 Callbacks

Example: callback

The final example we consider is callback, which demonstrates the use of Gurobi callbacks. Callbacks are used to report on the progress of the optimization or to modify the behavior of the Gurobi solver. To use a callback, the user writes a routine that implements the desired behavior. The routine is passed to the Gurobi optimizer when optimization begins, and the routine is called regularly during the optimization process. One argument of the user routine is a where value, which indicates from where in the optimization process the callback is invoked. The user callback routine can call the optimization library to query certain values. We refer the reader to the callback section of the Gurobi Reference Manual for more precise details.

Our callback example implements a simple termination scheme: the user passes a node count into the callback, and the callback asks the optimizer to terminate when that node count is reached. This is implemented in C as follows:

```
GRBcbget(cbdata, where, GRB_CB_MIP_NODCNT, &nodecnt);
if (nodecnt > limit)
    GRBterminate(model);
```

In Python, this is implemented as:

```
nodecnt = model.cbGet(GRB.Callback.MIP_NODCNT)
if nodecnt > model._mynodelimit:
    model.terminate()
```

To obtain the current node count, the user routine calls the cbget routine (the GRBcbget function in C, or the cbGet method on the model object in C++, C#, Java, and Python).

Our callback example also prints progress information. In C:

```
GRBcbget(cbdata, where, GRB_CB_MIP_NODCNT, &nodecnt);
if (nodecnt - mydata->lastmsg >= 100) {
    ...
    printf("%7.0f ...", nodecnt, ...);
}
```

In Python:

```
nodecnt = model.cbGet(GRB.Callback.MIP_NODCNT)
if nodecnt % 100 == 0:
    print(int(nodecnt), "...")
```

Again, the user callback calls the cbGet routine to query the state of the optimization.
We have included source code for all of the distributed examples in this section. The identical example source code is included in the examples directory in the Gurobi distribution.

### 3.1 C Examples

This section includes source code for all of the Gurobi C examples. The same source code can be found in the examples/c directory of the Gurobi distribution.

**callback_c.c**

```c
/* Copyright 2018, Gurobi Optimization, LLC */

/*
 * This example reads a model from a file, sets up a callback that
 * monitors optimization progress and implements a custom
 * termination strategy, and outputs progress information to the
 * screen and to a log file.
 *
 * The termination strategy implemented in this callback stops the
 * optimization of a MIP model once at least one of the following two
 * conditions have been satisfied:
 * 1) The optimality gap is less than 10%
 * 2) At least 10000 nodes have been explored, and an integer feasible
 *    solution has been found.
 * Note that termination is normally handled through Gurobi parameters
 * (MIPGap, NodeLimit, etc.). You should only use a callback for
 * termination if the available parameters don't capture your desired
 * termination criterion.
 */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include "gurobi_c.h"

/* Define structure to pass my data to the callback function */

struct callback_data {
    double lastiter;
    double lastnode;
    double *solution;
    FILE *logfile;
};

/* Define my callback function */
```
int __stdcall mycallback(GRBmodel *model, void *cbdata, int where, void *usrdata)
{
    struct callback_data *mydata = (struct callback_data *) usrdata;

    if (where == GRB_CB_POLLING) {
        /* Ignore polling callback */
    } else if (where == GRB_CB_PRESOLVE) {
        /* Presolve callback */
        int cdels, rdels;
        GRBcbget(cbdata, where, GRB_CB_PRE_COLDEL, &cdels);
        GRBcbget(cbdata, where, GRB_CB_PRE_ROWDEL, &rdels);
        if (cdels || rdels) {
            printf("%7d columns and %7d rows are removed\n", cdels, rdels);
        }
    } else if (where == GRB_CB_SIMPLEX) {
        /* Simplex callback */
        double itcnt, obj, pinf, dinf;
        int ispert;
        char ch;
        GRBcbget(cbdata, where, GRB_CB_SPX_ITRCNT, &itcnt);
        if (itcnt - mydata->lastiter >= 100) {
            mydata->lastiter = itcnt;
            GRBcbget(cbdata, where, GRB_CB_SPX_OBJVAL, &obj);
            GRBcbget(cbdata, where, GRB_CB_SPX_ISPERT, &ispert);
            GRBcbget(cbdata, where, GRB_CB_SPX_PRIMINF, &pinf);
            GRBcbget(cbdata, where, GRB_CB_SPX_DUALINF, &dinf);
            if (ispert == 0) ch = ' ';
            else if (ispert == 1) ch = 'S';
            else ch = 'P';
            printf(" %7.0 f %14.7 e%c %13.6 e %13.6 e\n", itcnt, obj, ch, pinf, dinf);
        }
    } else if (where == GRB_CB_MIP) {
        /* General MIP callback */
        double nodecnt, objbst, objbnd, actnodes, itcnt;
        int solcnt, cutcnt;
        GRBcbget(cbdata, where, GRB_CB_MIP_NODCNT, &nodecnt);
        GRBcbget(cbdata, where, GRB_CB_MIP_OBJBST, &objbst);
        GRBcbget(cbdata, where, GRB_CB_MIP_OBJBND, &objbnd);
        GRBcbget(cbdata, where, GRB_CB_MIP_SOLCNT, &solcnt);
        if (nodecnt - mydata->lastnode >= 100) {
            mydata->lastnode = nodecnt;
            GRBcbget(cbdata, where, GRB_CB_MIP_NODLFT, &actnodes);
            GRBcbget(cbdata, where, GRB_CB_MIP_ITRCNT, &itcnt);
            GRBcbget(cbdata, where, GRB_CB_MIP_CUTCNT, &cutcnt);
            printf("%7.0 f %7.0 f %8.0 f %13.6 e %13.6 e %7d %7d\n",
                   nodecnt, actnodes, itcnt, objbst, objbnd, solcnt, cutcnt);
        }
        if (fabs(objbst - objbnd) < 0.1 * (1.0 + fabs(objbst))) {
            printf("Stop early - 10%% gap achieved\n");
            GRBterminate(model);
        }
    }
printf("Stop early - 10000 nodes explored\n");
GRBterminate(model);
}
}
else if (where == GRB_CB_MIPSOL) {
/* MIP solution callback */
double nodecnt, obj;
int solcnt;
GRBcbget(cbdata, where, GRB_CB_MIPSOL_NODCNT, &nodecnt);
GRBcbget(cbdata, where, GRB_CB_MIPSOL_OBJ, &obj);
GRBcbget(cbdata, where, GRB_CB_MIPSOL_SOLCNT, &solcnt);
GRBcbget(cbdata, where, GRB_CB_MIPSOL_SOL, mydata->solution);
printf("**** New solution at node %.0f, obj %g, sol %d, x[0] = %.2f ****\n",
       nodecnt, obj, solcnt, mydata->solution[0]);
}
else if (where == GRB_CB_MIPNODE) {
int status;
/* MIP node callback */
printf("**** New node ****\n");
GRBcbget(cbdata, where, GRB_CB_MIPNODE_STATUS, &status);
if (status == GRB_OPTIMAL) {
  GRBcbget(cbdata, where, GRB_CB_MIPNODE_REL, mydata->solution);
  GRBcsolution(cbdata, mydata->solution, NULL);
}
}
else if (where == GRB_CB_BARRIER) {
/* Barrier callback */
int itcnt;
double primobj, dualobj, priminf, dualinf, compl;
GRBcbget(cbdata, where, GRB_CB_BARRIER_ITRCNT, &itcnt);
GRBcbget(cbdata, where, GRB_CB_BARRIER_PRIMOBJ, &primobj);
GRBcbget(cbdata, where, GRB_CB_BARRIER_DUALOBJ, &dualobj);
GRBcbget(cbdata, where, GRB_CB_BARRIER_PRIMINF, &priminf);
GRBcbget(cbdata, where, GRB_CB_BARRIER_DUALINF, &dualinf);
GRBcbget(cbdata, where, GRB_CB_BARRIER_COMPL, &compl);
printf("%d %.4e %.4e %.4e %.4e %.4e
",
       itcnt, primobj, dualobj, priminf, dualinf, compl);
}
else if (where == GRB_CB_MESSAGE) {
/* Message callback */
char *msg;
GRBcbget(cbdata, where, GRB_CB_MSG_STRING, &msg);
fprintf(mydata->logfile, "%s", msg);
}
return 0;
}

int main(int argc,
        char *argv[])
{
  GRBenv *env = NULL;
  GRBmodel *model = NULL;
  int error = 0;
  int numvars, solcount, optimstatus, j;
  double objval, x;
  char *varname;
  struct callback_data mydata;

  mydata.lastiter = -GRB_INFINITY;
mydata.lastnode = -GRB_INFINITY;
mydata.solution = NULL;
mydata.logfile = NULL;

if (argc < 2) {
    fprintf(stderr, "Usage: callback_c filename\n");
    goto QUIT;
}

/* Open log file */
mydata.logfile = fopen("cb.log", "w");
if (!mydata.logfile) {
    fprintf(stderr, "Cannot open cb.log for callback message\n");
    goto QUIT;
}

/* Create environment */
error = GRBloadenv(&env, NULL);
if (error) goto QUIT;

/* Turn off display and heuristics */
error = GRBsetintparam(env, GRB_INT_PAR_OUTPUTFLAG, 0);
if (error) goto QUIT;

error = GRBsetdblparam(env, GRB_DBL_PAR_HEURISTICS, 0.0);
if (error) goto QUIT;

/* Read model from file */
error = GRBreadmodel(env, argv[1], &model);
if (error) goto QUIT;

/* Allocate space for solution */
error = GRBgetintattr(model, GRB_INT_ATTR_NUMVARS, &numvars);
if (error) goto QUIT;

mydata.solution = malloc(numvars*sizeof(double));
if (mydata.solution == NULL) {
    fprintf(stderr, "Failed to allocate memory\n");
    exit(1);
}

/* Set callback function */
error = GRBsetcallbackfunc(model, mycallback, (void *)&mydata);
if (error) goto QUIT;

/* Solve model */
error = GRBoptimize(model);
if (error) goto QUIT;

/* Capture solution information */
printf("\nOptimization complete\n");

error = GRBgetintattr(model, GRB_INT_ATTR_SOLCOUNT, &solcount);
if (error) goto QUIT;

error = GRBgetintattr(model, GRB_INT_ATTR_STATUS, &optimstatus);
if (error) goto QUIT;

if (solcount == 0) {
    printf("No solution found, optimization status = %d\n", optimstatus);
    goto QUIT;
}

error = GRBgetdblattr(model, GRB_DBL_ATTR_OBJVAL, &objval);
if (error) goto QUIT;

printf("Solution found, objective = %.4e\n", objval);

for ( j = 0; j < numvars; ++j ) {
    error = GRBgetstrattrelement(model, GRB_STR_ATTR_VARNAME, j, &varname);
    if (error) goto QUIT;
    error = GRBgetdblattrelement(model, GRB_DBL_ATTR_X, j, &x);
    if (error) goto QUIT;
    if (x != 0.0) {
        printf("%s %f\n", varname, x);
    }
}

QUIT:

/* Error reporting */

if (error) {
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Close log file */

if (mydata.logfile)
    fclose(mydata.logfile);

/* Free solution */

if (mydata.solution)
    free(mydata.solution);

/* Free model */

GRBfreemodel(model);

/* Free environment */

GRBfreeenv(env);
/* Copyright 2018, Gurobi Optimization, LLC */

/* This example formulates and solves the following simple QP model:
minimize x + y + x^2 + x*y + y^2 + y*z + z^2
subject to x + 2 y + 3 z >= 4
x + y >= 1

The example illustrates the use of dense matrices to store A and Q
(and dense vectors for the other relevant data). We don’t recommend
that you use dense matrices, but this example may be helpful if you
already have your data in this format. */

#include <stdlib.h>
#include <stdio.h>
#include "gurobi_c.h"

/* Solve an LP/QP/MILP/MIQP represented using dense matrices. This
routine assumes that A and Q are both stored in row-major order.
It returns 1 if the optimization succeeds. When successful,
it returns the optimal objective value in 'objvalP', and the
optimal solution vector in 'solution'. */

static int dense_optimize(GRBenv *env,
    int rows,
    int cols,
    double *c, /* linear portion of objective function */
    double *Q, /* quadratic portion of objective function */
    double *A, /* constraint matrix */
    char *sense, /* constraint senses */
    double *rhs, /* RHS vector */
    double *lb, /* variable lower bounds */
    double *ub, /* variable upper bounds */
    char *vtype, /* variable types (continuous, binary, etc.) */
    double *solution,
    double *objvalP)
{
    GRBmodel *model = NULL;
    int i, j, optimstatus;
    int error = 0;
    int success = 0;

    /* Create an empty model */
    error = GRBnewmodel(env, &model, "dense", cols, c, lb, ub, vtype, NULL);
    if (error) goto QUIT;

    // ... (remaining code) ...

    /* Finish and print the solution */
    GRBoptimize(model);
    optimstatus = GRBgetintAttr(model, GRB_INT_ATTR_STATUS);
    if (optimstatus == GRB_OPTIMAL)
        success = 1;
    else
        success = 0;

    /* Print solution */
    GRBgetdblattrarray(model, GRB_DBL_ATTR_X, 0, cols, solution);
    GRBfree(model);
    return 0;
}
error = GRBaddconstrs(model, rows, 0, NULL, NULL, NULL, sense, rhs, NULL);
if (error) goto QUIT;

/* Populate A matrix */
for (i = 0; i < rows; i++) {
    for (j = 0; j < cols; j++) {
        if (A[i*cols+j] != 0) {
            error = GRBchgcoeffs(model, 1, &i, &j, &A[i*cols+j]);
            if (error) goto QUIT;
        }
    }
}

/* Populate Q matrix */
if (Q) {
    for (i = 0; i < cols; i++) {
        for (j = 0; j < cols; j++) {
            if (Q[i*cols+j] != 0) {
                error = GRBaddqpterms(model, 1, &i, &j, &Q[i*cols+j]);
                if (error) goto QUIT;
            }
        }
    }
}

/* Optimize model */
error = GRBoptimize(model);
if (error) goto QUIT;

/* Write model to 'dense.lp' */
error = GRBwrite(model, "dense.lp");
if (error) goto QUIT;

/* Capture solution information */
error = GRBgetintattr(model, GRB_INT_ATTR_STATUS, &optimstatus);
if (error) goto QUIT;
if (optimstatus == GRB_OPTIMAL) {
    error = GRBgetdblattr(model, GRB_DBL_ATTR_OBJVAL, objvalP);
    if (error) goto QUIT;
    error = GRBgetdblattrarray(model, GRB_DBL_ATTR_X, 0, cols, solution);
    if (error) goto QUIT;
    success = 1;
}
QUIT:
/* Error reporting */
if (error) {
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free model */
GRBfreemodel(model);

return success;
}

int main(int argc, char *argv[])
{
    GRBenv *env = NULL;
    int error = 0;
    double c[] = {1, 1, 0};
    double Q[3][3] = {{1, 1, 0}, {0, 1, 1}, {0, 0, 1}};
    double A[2][3] = {{1, 2, 3}, {1, 1, 0}};
    char sense[] = {'>', '>'};
    double rhs[] = {4, 1};
    double lb[] = {0, 0, 0};
    double sol[3];
    int solved;
    double objval;

    /* Create environment */
    error = GRBloadenv(&env, "dense.log");
    if (error) goto QUIT;

    /* Solve the model */
    solved = dense_optimize(env, 2, 3, c, &Q[0][0], &A[0][0], sense, rhs, lb,
                             NULL, NULL, sol, &objval);

    if (solved)
        printf("Solved: x=%.4f, y=%.4f, z=%.4f\n", sol[0], sol[1], sol[2]);

QUIT:
    /* Free environment */
    GRBfreenv(env);

    return 0;
}

diet_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* Solve the classic diet model, showing how to add constraints */
int printSolution(GRBmodel * model, int nCategories, int nFoods);

int main(int argc, char *argv[])
{
    GRBenv *env = NULL;
    GRBmodel *model = NULL;
    int error = 0;
    int i, j;
    int *cbeg, *cind, idx;
    double *cval, *rhs;
    char *sense;

    /* Nutrition guidelines, based on
    USDA Dietary Guidelines for Americans, 2005

    const int nCategories = 4;
    char *Categories[] =
        { "calories", "protein", "fat", "sodium" };
    double minNutrition[] = { 1800, 91, 0, 0 };
    double maxNutrition[] = { 2200, GRB_INFINITY, 65, 1779 };

    /* Set of foods */
    const int nFoods = 9;
    char* Foods[] =
        { "hamburger", "chicken", "hot dog", "fries", "macaroni", "pizza", "salad", "milk", "ice cream" };
    double cost[] =
        { 2.49, 2.89, 1.60, 1.89, 2.09, 1.99, 2.49, 0.89, 1.59 };

    /* Nutrition values for the foods */
    double nutritionValues[][4] = {
        { 410, 24, 26, 730 },
        { 420, 32, 10, 1190 },
        { 560, 20, 32, 1800 },
        { 380, 4, 19, 270 },
        { 320, 12, 10, 930 },
        { 320, 15, 12, 820 },
        { 320, 31, 12, 1230 },
        { 100, 8, 2.5, 125 },
        { 330, 8, 10, 180 }
    };

    /* Create environment */
    error = GRBloadenv(&env, "diet.log");
    if (error) goto QUIT;
/* Create initial model */
error = GRBnewmodel(env, &model, "diet", nFoods + nCategories,
NULL, NULL, NULL, NULL, NULL);
if (error) goto QUIT;

/* Initialize decision variables for the foods to buy */
for (j = 0; j < nFoods; ++j)
{
    error = GRBsetdblattrelement(model, "Obj", j, cost[j]);
    if (error) goto QUIT;
    error = GRBsetstrattrelement(model, "VarName", j, Foods[j]);
    if (error) goto QUIT;
}

/* Initialize decision variables for the nutrition information,
 which we limit via bounds */
for (j = 0; j < nCategories; ++j)
{
    error = GRBsetdblattrelement(model, "LB", j + nFoods, minNutrition[j]);
    if (error) goto QUIT;
    error = GRBsetdblattrelement(model, "UB", j + nFoods, maxNutrition[j]);
    if (error) goto QUIT;
    error = GRBsetstrattrelement(model, "VarName", j + nFoods, Categories[j]);
    if (error) goto QUIT;
}

/* The objective is to minimize the costs */
error = GRBsetintattr(model, "ModelSense", GRB_MINIMIZE);
if (error) goto QUIT;

/* Nutrition constraints */
cbeg = malloc(sizeof(int) * nCategories);
if (!cbeg) goto QUIT;
cind = malloc(sizeof(int) * nCategories * (nFoods + 1));
if (!cind) goto QUIT;
cval = malloc(sizeof(double) * nCategories * (nFoods + 1));
if (!cval) goto QUIT;
rhs = malloc(sizeof(double) * nCategories);
if (!rhs) goto QUIT;
sense = malloc(sizeof(char) * nCategories);
if (!sense) goto QUIT;
idx = 0;
for (i = 0; i < nCategories; ++i)
{
    cbeg[i] = idx;
    rhs[i] = 0.0;
    sense[i] = GRB_EQUAL;
    for (j = 0; j < nFoods; ++j)
    {
        cind[idx] = j;
        cval[idx++] = nutritionValues[j][i];
    }
    cind[idx] = nFoods + i;
    cval[idx++] = -1.0;
}
error = GRBaddconstrs(model, nCategories, idx, cbeg, cind, cval, sense, 
    rhs, Categories);
if (error) goto QUIT;

/* Solve */
error = GRBoptimize(model);
if (error) goto QUIT;
error = printSolution(model, nCategories, nFoods);
if (error) goto QUIT;

printf("\nAdding constraint: at most 6 servings of dairy\n");
cind[0] = 7;
cval[0] = 1.0;
cind[1] = 8;
cval[1] = 1.0;
error = GRBaddconstr(model, 2, cind, cval, GRB_LESS_EQUAL, 6.0, 
    "limit_dairy");
if (error) goto QUIT;

/* Solve */
error = GRBoptimize(model);
if (error) goto QUIT;
error = printSolution(model, nCategories, nFoods);
if (error) goto QUIT;

QUIT:

/* Error reporting */
if (error)
{
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free data */
free(cbeg);
free(cind);
free(cval);
free(rhs);
free(sense);

/* Free model */
GRBfreemodel(model);

/* Free environment */
GRBfreeenv(env);

return 0;
}
int printSolution (GRBmodel * model, int nCategories, int nFoods)
{
    int error, status, i, j;
    double obj, x;
    char* vname;

    error = GRBgetintattr(model, "Status", &status);
    if (error) return error;
    if (status == GRB_OPTIMAL)
    {
        error = GRBgetdblattr(model, "ObjVal", &obj);
        if (error) return error;
        printf("\nCost : %f\nBuy :\n", obj);
        for (j = 0; j < nFoods; ++j)
        {
            error = GRBgetdblattrelement(model, "X", j, &x);
            if (error) return error;
            if (x > 0.0001)
            {
                error = GRBgetstrattrelement(model, "VarName", j, &vname);
                if (error) return error;
                printf("%s %f\n", vname, x);
            }
        }
        printf("\nNutrition:\n");
        for (i = 0; i < nCategories; ++i)
        {
            error = GRBgetdblattrelement(model, "X", i + nFoods, &x);
            if (error) return error;
            error = GRBgetstrattrelement(model, "VarName", i + nFoods, &vname);
            if (error) return error;
            printf("%s %f\n", vname, x);
        }
    }
    else
    {
        printf("No solution\n");
    }

    return 0;
}

facility.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* Facility location: a company currently ships its product from 5 plants to 4 warehouses. It is considering closing some plants to reduce costs. What plant(s) should the company close, in order to minimize transportation and fixed costs?

Based on an example from Frontline Systems:
http://www.solver.com/disfacility.htm
Used with permission. */
```c
#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include "gurobi_c.h"

#define opencol(p) p
#define transportcol(w, p) nPlants*(w+1)+p
#define MAXSTR 128

int main(int argc, char *argv[])
{
    GRBenv *env = NULL;
    GRBmodel *model = NULL;
    int error = 0;
    int p, w, col;
    int *cbeg = NULL;
    int *cind = NULL;
    int idx, rowct;
    double *cval = NULL;
    double *rhs = NULL;
    char *sense = NULL;
    char vname[MAXSTR];
    int cnamect = 0;
    char **cname = NULL;
    double maxFixed = -GRB_INFINITY, sol, obj;

    /* Number of plants and warehouses */
    const int nPlants = 5;
    const int nWarehouses = 4;

    /* Warehouse demand in thousands of units */
    double Demand[] = { 15, 18, 14, 20 }; 

    /* Plant capacity in thousands of units */
    double Capacity[] = { 20, 22, 17, 19, 18 }; 

    /* Fixed costs for each plant */
    double FixedCosts[] =
    { 12000, 15000, 17000, 13000, 16000 }; 

    /* Transportation costs per thousand units */
    double TransCosts[4][5] =
    { 
        { 4000, 2000, 3000, 2500, 4500 },
        { 2500, 2600, 3400, 3000, 4000 },
        { 1200, 1800, 2600, 4100, 3000 },
        { 2200, 2600, 3100, 3700, 3200 }
    };

    /* Create environment */
    error = GRBloadenv(&env, "facility.log");
    if (error) goto QUIT;
```
/ Create initial model */
error = GRBnewmodel(env, &model, "facility", nPlants * (nWarehouses + 1),
NULL, NULL, NULL, NULL, NULL);
if (error) goto QUIT;

/* Initialize decision variables for plant open variables */
for (p = 0; p < nPlants; ++p)
{
    col = opencol(p);
    error = GRBsetcharattrelement(model, "VType", col, GRB_BINARY);
    if (error) goto QUIT;
    error = GRBsetdblattrelement(model, "Obj", col, FixedCosts[p]);
    if (error) goto QUIT;
    sprintf(vname, "Open%i", p);
    error = GRBsetstrattrelement(model, "VarName", col, vname);
    if (error) goto QUIT;
}

/* Initialize decision variables for transportation decision variables:
how much to transport from a plant p to a warehouse w */
for (w = 0; w < nWarehouses; ++w)
{
    for (p = 0; p < nPlants; ++p)
    {
        col = transportcol(w, p);
        error = GRBsetdblattrelement(model, "Obj", col, TransCosts[w][p]);
        if (error) goto QUIT;
        sprintf(vname, "Trans%i.%i", p, w);
        error = GRBsetstrattrelement(model, "VarName", col, vname);
        if (error) goto QUIT;
    }
}

/* The objective is to minimize the total fixed and variable costs */
error = GRBsetintattr(model, "ModelSense", GRB_MINIMIZE);
if (error) goto QUIT;

/* Make space for constraint data */
rowct = (nPlants > nWarehouses) ? nPlants : nWarehouses;

cbeg = malloc(sizeof(int) * rowct);
if (!cbeg) goto QUIT;

cind = malloc(sizeof(int) * (nPlants * (nWarehouses + 1)));
if (!cind) goto QUIT;
cval = malloc(sizeof(double) * (nPlants * (nWarehouses + 1)));
if (!cval) goto QUIT;
rhs = malloc(sizeof(double) * rowct);
if (!rhs) goto QUIT;
sense = malloc(sizeof(char) * rowct);
if (!sense) goto QUIT;
cname = calloc(rowct, sizeof(char*));
if (!cname) goto QUIT;

/* Production constraints
Note that the limit sets the production to zero if
the plant is closed */
idx = 0;
for (p = 0; p < nPlants; ++p)
{
cbeg[p] = idx;
rhs[p] = 0.0;
sense[p] = GRB_LESS_EQUAL;
cname[p] = malloc(sizeof(char) * MAXSTR);
if (!cname[p]) goto QUIT;
cnamect++;
sprintf(cname[p], "Capacity %i", p);
for (w = 0; w < nWarehouses; ++w)
{
cind[idx] = transportcol(w, p);
cval[idx++] = 1.0;
}
cind[idx] = opencol(p);
cval[idx++] = -Capacity[p];
}
error = GRBaddconstrs(model, nPlants, idx, cbeg, cind, cval, sense, rhs, cname);
if (error) goto QUIT;

/* Demand constraints */
dx = 0;
for (w = 0; w < nWarehouses; ++w)
{
cbeg[w] = idx;
sense[w] = GRB_EQUAL;
sprintf(cname[w], "Demand %i", w);
for (p = 0; p < nPlants; ++p)
{
cind[idx] = transportcol(w, p);
cval[idx++] = 1.0;
}
}
error = GRBaddconstrs(model, nWarehouses, idx, cbeg, cind, cval, sense, Demand, cname);
if (error) goto QUIT;

/* Guess at the starting point: close the plant with the highest fixed costs; open all others */

/* First, open all plants */
for (p = 0; p < nPlants; ++p)
{
    error = GRBsetdblattrelement(model, "Start", opencol(p), 1.0);
    if (error) goto QUIT;
}

/* Now close the plant with the highest fixed cost */
printf("Initial guess:\n");
for (p = 0; p < nPlants; ++p)
{
    if (FixedCosts[p] > maxFixed)
    {
        maxFixed = FixedCosts[p];
    }
for (p = 0; p < nPlants; ++p) {
    if (FixedCosts[p] == maxFixed) {
        error = GRBsetdblattrelement(model, "Start", opencol(p), 0.0);
        if (error) goto QUIT;
        printf("Closing plant %i\n\n", p);
        break;
    }
}

/* Use barrier to solve root relaxation */
error = GRBsetintparam(GRBgetenv(model),
                        GRB_INT_PAR_METHOD,
                        GRB_METHOD_BARRIER);
if (error) goto QUIT;

/* Solve */
error = GRBoptimize(model);
if (error) goto QUIT;

/* Print solution */
error = GRBgetdblattr(model, "ObjVal", &obj);
if (error) goto QUIT;
printf("\nTOTAL COSTS: %f\n", obj);
printf("SOLUTION:\n");
for (p = 0; p < nPlants; ++p) {
    error = GRBgetdblattrelement(model, "X", opencol(p), &sol);
    if (error) goto QUIT;
    if (sol > 0.99) {
        printf("Plant %i open: \n", p);
        for (w = 0; w < nWarehouses; ++w) {
            error = GRBgetdblattrelement(model, "X", transportcol(w, p), &sol);
            if (error) goto QUIT;
            if (sol > 0.0001) {
                printf("Transport %f units to warehouse %i\n", sol, w);
            }
        }
    } else {
        printf("Plant %i closed!\n", p);
    }
}
QUIT:

/* Error reporting */
if (error)
{  
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free data */
free(cbeg);
free(cind);
free(cval);
free(rhs);
free(sense);
for (p = 0; p < cnamect; ++p) {
    free(cname[p]);
}
free(cname);

/* Free model */
GRBfreemodel(model);

/* Free environment */
GRBfreenv(env);

return 0;
}

feasopt_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads a MIP model from a file, adds artificial variables to each constraint, and then minimizes the sum of the artificial variables. A solution with objective zero corresponds to a feasible solution to the input model. We can also use FeasRelax feature to do it. In this example, we use minrelax=1, i.e. optimizing the returned model finds a solution that minimizes the original objective, but only from among those solutions that minimize the sum of the artificial variables. */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include <string.h>
#include "gurobi_c.h"

int main(int argc,
    char *argv[])
{
    GRBenv  *env = NULL;
    GRBmodel *model = NULL;
    GRBmodel *feasmodel = NULL;
    double  *rhspen  = NULL;
    int      error  = 0;

int i, j;
int numvars, numconstrs;
char sense;
int vind[1];
double vval[1];
double feasobj;
char *cname, *vname;

if (argc < 2)
{
    fprintf(stderr, "Usage: feasopt_c filename\n");
    exit(1);
}

error = GRBloadenv(&env, "feasopt.log");
if (error) goto QUIT;

error = GRBreadmodel(env, argv[1], &model);
if (error) goto QUIT;

/* Create a copy to use FeasRelax feature later */
feasmodel = GRBcopymodel(model);
if (error) goto QUIT;

/* clear objective */
error = GRBgetintattr(model, "NumVars", &numvars);
if (error) goto QUIT;
for (j = 0; j < numvars; ++j)
{
    error = GRBsetdblattrelement(model, "Obj", j, 0.0);
    if (error) goto QUIT;
}

/* add slack variables */
error = GRBgetintattr(model, "NumConstrs", &numconstrs);
if (error) goto QUIT;
for (i = 0; i < numconstrs; ++i)
{
    error = GRBgetcharattrelement(model, "Sense", i, &sense);
    if (error) goto QUIT;
    if (sense != '>
    
    error = GRBgetstrattrelement(model, "ConstrName", i, &cname);
    if (error) goto QUIT;
    vname = malloc(sizeof(char) * (6 + strlen(cname)));
    if (!vname) goto QUIT;
    strcpy(vname, "ArtN_");
    strcat(vname, cname);
    vind[0] = i;
    vval[0] = -1.0;
    error = GRBaddvar(model, 1, vind, vval, 1.0, 0.0, GRB_INFINITY,
                        GRB_CONTINUOUS, vname);
    if (error) goto QUIT;
    free(vname);
}
if (sense != '<') {
    error = GRBgetstrattrelement(model, "ConstrName", i, &cname);
    if (error) goto QUIT;
    vname = malloc(sizeof(char) * (6 + strlen(cname)));
    if (!vname) goto QUIT;
    strcpy(vname, "ArtP_"); strcat(vname, cname);
    vind[0] = i; vval[0] = 1.0;
    error = GRBaddvar(model, 1, vind, vval, 1.0, 0.0, GRB_INFINITY,
                      GRB_CONTINUOUS, vname);
    if (error) goto QUIT;
    free(vname);
}

/* Optimize modified model */
error = GRBoptimize(model);
if (error) goto QUIT;
error = GRBwrite(model, "feasopt.lp");
if (error) goto QUIT;

/* Use FeasRelax feature */
rhspen = (double *) malloc(numconstrs*strlen(double));
if (rhspen == NULL) {
    printf("ERROR: out of memory\n");
    goto QUIT;
}

/* set penalties for artificial variables */
for (i = 0; i < numconstrs; i++) rhspen[i] = 1;

/* create a FeasRelax model with the original objective recovered
   and enforcement on minimum of aretificial variables */
error = GRBfeasrelax(feasmodel, GRB_FEASRELAX_LINEAR, 1,
                      NULL, NULL, rhspen, &feasobj);
if (error) goto QUIT;

/* optimize FeasRelax model */
error = GRBwrite(feasmodel, "feasopt1.lp");
if (error) goto QUIT;
error = GRBoptimize(feasmodel);
if (error) goto QUIT;

QUIT:

/* Error reporting */
if (error) {

```c
printf("ERROR: %s\n", GRBgeterrormsg(env));
exit(1);
}
/* Free models, env and etc. */
if (rhspen) free(rhspen);
GRBfreemodel(model);
GRBfreemodel(feasmodel);
GRBfreeenv(env);
return 0;
}

fixanddive_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* Implement a simple MIP heuristic. Relax the model,
sort variables based on fractionality, and fix the 25% of
the fractional variables that are closest to integer variables.
Repeat until either the relaxation is integer feasible or
linearly infeasible. */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include "gurobi_c.h"

typedef struct
{
    int index;
    double X;
}
var_t;

int vcomp(const void* v1, const void* v2);

int main(int argc, char *argv[])
{
    GRBenv *env = NULL, *modelenv = NULL;
    GRBmodel *model = NULL;
    int error = 0;
    int j, iter, nfix;
    int numvars, numintvars, numfractional;
    int *intvars = NULL;
    int status;
    char vtype, *vname;
    double sol, obj, fixval;
    var_t *fractional = NULL;
    ```
if (argc < 2) {
    fprintf(stderr, "Usage: fixanddive_c filename\n");
    exit(1);
}

error = GRBloadenv(&env, "fixanddive.log");
if (error) goto QUIT;

/* Read model */
error = GRBreadmodel(env, argv[1], &model);
if (error) goto QUIT;

/* Collect integer variables and relax them */
error = GRBgetintattr(model, "NumVars", &numvars);
if (error) goto QUIT;
error = GRBgetintattr(model, "NumIntVars", &numintvars);
if (error) goto QUIT;
intvars = malloc(sizeof(int) * numintvars);
if (!intvars) goto QUIT;
fractional = malloc(sizeof(var_t) * numintvars);
if (!fractional) goto QUIT;
numfractional = 0;
for (j = 0; j < numvars; j++) {
    error = GRBgetcharattrelement(model, "VType", j, &vtype);
    if (error) goto QUIT;
    if (vtype != GRB_CONTINUOUS)
    { intvars[numfractional++] = j;
        error = GRBsetcharattrelement(model, "VType", j, GRB_CONTINUOUS);
        if (error) goto QUIT;
    }
}

modelenv = GRBgetenv(model);
if (!modelenv) goto QUIT;
error = GRBsetintparam(modelenv, "OutputFlag", 0);
if (error) goto QUIT;
error = GRBoptimize(model);
if (error) goto QUIT;

/* Perform multiple iterations. In each iteration, identify the first quartile of integer variables that are closest to an integer value in the relaxation, fix them to the nearest integer, and repeat. */
for (iter = 0; iter < 1000; ++iter) {
    /* create a list of fractional variables, sorted in order of increasing distance from the relaxation solution to the nearest integer value */
    numfractional = 0;
    for (j = 0; j < numintvars; ++j) {
        
}
error = GRBgetdblattrelement(model, "X", intvars[j], &sol);
if (error) goto QUIT;
if (fabs(sol - floor(sol + 0.5)) > 1e-5)
{
    fractional[numfractional].index = intvars[j];
    fractional[numfractional++].X = sol;
}
}

error = GRBgetdblattr(model, "ObjVal", &obj);
if (error) goto QUIT;
printf("Iteration %i, obj %f, fractional %i\n", iter, obj, numfractional);

if (numfractional == 0)
{
    printf("Found feasible solution - objective %f\n", obj);
    break;
}

/* Fix the first quartile to the nearest integer value */
qsort(fractional, numfractional, sizeof(var_t), vcomp);
nfix = numfractional / 4;
nfix = (nfix > 1) ? nfix : 1;
for (j = 0; j < nfix; ++j)
{
    fixval = floor(fractional[j].X + 0.5);
    error = GRBsetdblattrelement(model, "LB", fractional[j].index, fixval);
    if (error) goto QUIT;
    error = GRBsetdblattrelement(model, "UB", fractional[j].index, fixval);
    if (error) goto QUIT;
    error = GRBgetstrattrelement(model, "VarName",
                                 fractional[j].index, &vname);
    if (error) goto QUIT;
    printf(" Fix %s to %f ( rel %f )\n", vname, fixval, fractional[j].X);
}

error = GRBoptimize(model);
if (error) goto QUIT;

/* Check optimization result */
error = GRBgetintattr(model, "Status", &status);
if (error) goto QUIT;
if (status != GRB_OPTIMAL)
{
    printf("Relaxation is infeasible\n");
    break;
}
}

QUIT:

/* Error reporting */
if ( error )
{
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free data */
free(intvars);
free(fractional);

/* Free model */
GRBfreemodel(model);

/* Free environment */
GRBfreeenv(env);

return 0;

int vcomp(const void* v1, const void* v2)
{
    double sol1, sol2, frac1, frac2;
    sol1 = fabs(((var_t *)v1)->X);
    sol2 = fabs(((var_t *)v2)->X);
    frac1 = fabs(sol1 - floor(sol1 + 0.5));
    frac2 = fabs(sol2 - floor(sol2 + 0.5));
    return (frac1 < frac2) ? -1 : ((frac1 == frac2) ? 0 : 1);
}

genconstr_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* In this example we show the use of general constraints for modeling
* some common expressions. We use as an example a SAT-problem where we
* want to see if it is possible to satisfy at least four (or all) clauses
* of the logical for
* * L = (x0 or -x1 or x2) and (x1 or -x2 or x3) and
*   (x2 or -x3 or x0) and (x3 or -x0 or x1) and
*   (-x0 or -x1 or x2) and (-x1 or -x2 or x3) and
*   (-x2 or -x3 or x0) and (-x3 or -x0 or x1)
* * We do this by introducing two variables for each literal (itself and its
*   negated value), a variable for each clause, and then two
* variables for indicating if we can satisfy four, and another to identify
* the minimum of the clauses (so if it one, we can satisfy all clauses)
* and put these two variables in the objective.
* i.e. the Objective function will be
* * maximize Obj0 + Obj1
* */
* Obj0 = MIN(Clause1, ..., Clause8)
* Obj1 = 1 -> Clause1 + ... + Clause8 >= 4
*
* thus, the objective value will be two if and only if we can satisfy all
* clauses; one if and only if at least four clauses can be satisfied, and
* zero otherwise.
*/

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include <string.h>
#include "gurobi_c.h"

#define MAXSTR 128
#define NLITERALS 4
#define NCLAUSES 8
#define NOBJ 2
#define NVARS (2 * NLITERALS + NCLAUSES + NOBJ)
#define LIT(n) (n)
#define NOTLIT(n) (NLITERALS + n)
#define CLA(n) (2 * NLITERALS + n)
#define OBJ(n) (2 * NLITERALS + NCLAUSES + n)

int main(void)
{
    GRBenv *env = NULL;
    GRBmodel *model = NULL;
    int error = 0;
    int cind[NVARS];
    double cval[NVARS];
    char buffer[MAXSTR];
    int col, i, status, nSolutions;
    double objval;

    /* Example data */
    const int Clauses[][3] = {{LIT(0), NOTLIT(1), LIT(2)},
                              {LIT(1), NOTLIT(2), LIT(3)},
                              {LIT(2), NOTLIT(3), LIT(0)},
                              {LIT(3), NOTLIT(0), LIT(1)},
                              {NOTLIT(0), NOTLIT(1), LIT(2)},
                              {NOTLIT(1), NOTLIT(2), LIT(3)},
                              {NOTLIT(2), NOTLIT(3), LIT(0)},
                              {NOTLIT(3), NOTLIT(0), LIT(1)};

    /* Create environment */
    error = GRBloadenv(&env, "genconstr_c.log");
    if (error) goto QUIT;

    /* Create initial model */
    error = GRBnewmodel(env, &model, "genconstr_c", NVARS, NULL,
                         NULL, NULL, NULL, NULL);
    if (error) goto QUIT;
/* Initialize decision variables and objective */
for (i = 0; i < NLITERALS; i++) {
    col = LIT(i);
    sprintf(buffer, "X%d", i);
    error = GRBsetcharattrelement(model, "VType", col, GRB_BINARY);
    if (error) goto QUIT;

    error = GRBsetstrattrelement(model, "VarName", col, buffer);
    if (error) goto QUIT;

    col = NOTLIT(i);
    sprintf(buffer, "notX%d", i);
    error = GRBsetcharattrelement(model, "VType", col, GRB_BINARY);
    if (error) goto QUIT;

    error = GRBsetstrattrelement(model, "VarName", col, buffer);
    if (error) goto QUIT;
}

for (i = 0; i < NCLAUSES; i++) {
    col = CLA(i);
    sprintf(buffer, "Clause%d", i);
    error = GRBsetcharattrelement(model, "VType", col, GRB_BINARY);
    if (error) goto QUIT;

    error = GRBsetstrattrelement(model, "VarName", col, buffer);
    if (error) goto QUIT;
}

for (i = 0; i < NOBJ; i++) {
    col = OBJ(i);
    sprintf(buffer, "Obj%d", i);
    error = GRBsetcharattrelement(model, "VType", col, GRB_BINARY);
    if (error) goto QUIT;

    error = GRBsetstrattrelement(model, "VarName", col, buffer);
    if (error) goto QUIT;

    error = GRBsetdblattrelement(model, "Obj", col, 1.0);
    if (error) goto QUIT;
}

/* Link Xi and notXi */
for (i = 0; i < NLITERALS; i++) {
    sprintf(buffer,"CNSTR_X%d",i);
    cind[0] = LIT(i);
    cind[1] = NOTLIT(i);
    cval[0] = cval[1] = 1;
    error = GRBaddconstr(model, 2, cind, cval, GRB_EQUAL, 1.0, buffer);
    if (error) goto QUIT;
}

/* Link clauses and literals */
for (i = 0; i < NCLAUSES; i++) {
    sprintf(buffer,"CNSTR_Clause%d",i);
    error = GRBaddgenconstrOr(model, buffer, CLA(i), 3, Clauses[i]);
if (error) goto QUIT;
}

/* Link objs with clauses */
for (i = 0; i < NCLAUSES; i++) {
  cind[i] = CLA(i);
  cval[i] = 1;
}  
error = GRBaddgenconstrMin(model, "CNSTR_Obj0", OBJ(0), NCLAUSES, cind, GRB_INFINITY);
if (error) goto QUIT;

/* note that passing 4 instead of 4.0 will produce undefined behavior */
error = GRBaddgenconstrIndicator(model, "CNSTR_Obj1",
  OBJ(1), 1, NCLAUSES, cind, cval,
  GRB_GREATER_EQUAL, 4.0);
if (error) goto QUIT;

/* Set global objective sense */
error = GRBsetintattr(model, GRB_INT_ATTR_MODELSENSE, GRB_MAXIMIZE);
if (error) goto QUIT;

/* Save problem */
error = GRBwrite(model, "genconstr_c.mps");
if (error) goto QUIT;

error = GRBwrite(model, "genconstr_c.lp");
if (error) goto QUIT;

/* Optimize */
error = GRBoptimize(model);
if (error) goto QUIT;

/* Status checking */
error = GRBgetintattr(model, "Status", &status);
if (error) goto QUIT;

if (status == GRB_INF_OR_UNBD ||
    status == GRB_INFEASIBLE ||
    status == GRB_UNBOUNDED ) {
  printf("The model cannot be solved "
    "because it is infeasible or unbounded\n");
  goto QUIT;
}
if (status != GRB_OPTIMAL) {
  printf("Optimization was stopped with status %i\n", status);
  goto QUIT;
}

/* Print result */
error = GRBgetdblattr(model, GRB_DBL_ATTR_OBJVAL, &objval);
if (error) goto QUIT;

if (objval > 1.9)  
  printf("Logical expression is satisfiable\n");
else if (objval > 0.9)
  printf("At least four clauses can be satisfied\n");
else
    printf("At most three clauses may be satisfied\n");
QUIT:
    if (model != NULL) GRBfreemodel(model);
    if (env != NULL) GRBfreeenv(env);
    return error;
}

lp_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads an LP model from a file and solves it. 
   If the model is infeasible or unbounded, the example turns off 
   presolve and solves the model again. If the model is infeasible, 
   the example computes an Irreducible Inconsistent Subsystem (IIS), 
   and writes it to a file */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include "gurobi_c.h"

int main(int argc, char *argv[])
{
    GRBenv *masterenv = NULL;
    GRBmodel *model = NULL;
    GRBenv *modelenv = NULL;
    int error = 0;
    int optimstatus;
    double objval;

    if (argc < 2) {
        fprintf(stderr, "Usage: lp_c filename\n");
        exit(1);
    }

    /* Create environment */
    error = GRBloadenv(&masterenv, "lp.log");
    if (error) goto QUIT;

    /* Read model from file */
    error = GRBreadmodel(masterenv, argv[1], &model);
    if (error) goto QUIT;

    /* Solve model */
    error = GRBoptimize(model);
    if (error) goto QUIT;
/* Capture solution information */
error = GRBgetintattr(model, GRB_INT_ATTR_STATUS, &optimstatus);
if (error) goto QUIT;

/* If model is infeasible or unbounded, turn off presolve and resolve */

if (optimstatus == GRB_INF_OR_UNBD) {
    modelenv = GRBgetenv(model);
    if (!modelenv) {
        fprintf(stderr, "Error: could not get model environment\n");
        goto QUIT;
    }

    /* Change parameter on model environment. The model now has
    a copy of the master environment, so changing the master will
    no longer affect the model. */
    error = GRBsetintparam(modelenv, "PRESOLVE", 0);
    if (error) goto QUIT;

    error = GRBoptimize(model);
    if (error) goto QUIT;

    error = GRBgetintattr(model, GRB_INT_ATTR_STATUS, &optimstatus);
    if (error) goto QUIT;
}

if (optimstatus == GRB_OPTIMAL) {
    error = GRBgetdblattr(model, GRB_DBL_ATTR_OBJVAL, &objval);
    if (error) goto QUIT;
    printf("Optimal objective: %.4e\n", objval);
} else if (optimstatus == GRB_INFEASIBLE) {
    printf("Model is infeasible\n");
}

QUIT:
/* Error reporting */

if (error) {
    printf("ERROR: %s\n", GRBgeterrormsg(masterenv));
    exit(1);
}
/* Free model */
GRBfreemodel(model);
/* Free environment */
GRBfreeenv(masterenv);
return 0;
}

lpmethod_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* Solve a model with different values of the Method parameter;
show which value gives the shortest solve time. */

#include <stdlib.h>
#include <stdio.h>
#include "gurobi_c.h"

int main(int argc, char *argv[])
{
  GRBenv *env = NULL, *menv;
  GRBmodel *m = NULL;
  int error = 0;
  int i;
  int optimstatus;
  int bestMethod = -1;
  double bestTime;

  if (argc < 2)
  {
    fprintf(stderr, "Usage: lpmethod_c filename\n");
    exit(1);
  }

  error = GRBloadenv(&env, "lpmethod.log");
  if (error) goto QUIT;

  /* Read model */
  error = GRBreadmodel(env, argv[1], &m);
  if (error) goto QUIT;
  menv = GRBgetenv(m);
  error = GRBgetdblparam(menv, "TimeLimit", &bestTime);
  if (error) goto QUIT;

  /* Solve the model with different values of Method */
  for (i = 0; i <= 2; ++i)
  {
    error = GRBreset(m, 0);
    if (error) goto QUIT;
    error = GRBsetintparam(menv, "Method", i);
if (error) goto QUIT;
error = GRBoptimize(m);
if (error) goto QUIT;
error = GRBgetintattr(m, "Status", &optimstatus);
if (error) goto QUIT;
if (optimstatus == GRB_OPTIMAL) {
    error = GRBgetdblattr(m, "Runtime", &bestTime);
    bestMethod = i;
    /* Reduce the TimeLimit parameter to save time
     with other methods */
    error = GRBsetdblparam(menv, "TimeLimit", bestTime);
    if (error) goto QUIT;
}
/* Report which method was fastest */
if (bestMethod == -1) {
    printf("Unable to solve this model\n");
} else {
    printf("Solved in %f seconds with Method: %i\n", bestTime, bestMethod);
}
QUIT:
/* Error reporting */
if (error)
{
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}
/* Free model */
GRBfreemodel(m);
/* Free environment */
GRBfreeenv(env);
return 0;
}

lpmod_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads an LP model from a file and solves it. 
   If the model can be solved, then it finds the smallest positive variable,
   sets its upper bound to zero, and resolves the model two ways:
   first with an advanced start, then without an advanced start
   (i.e. 'from scratch'). */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include <string.h>
#include "gurobi_c.h"

int main(int argc, char *argv[])
{
GRBenv *env = NULL;
GRBmodel *model = NULL;
int error = 0;
int j;
int numvars, isMIP, status, minVar = 0;
double minVal = GRB_INFINITY, sol, lb;
char *varname;
double warmCount, warmTime, coldCount, coldTime;

if (argc < 2)
{
    fprintf(stderr, "Usage: lpmo_c filename\n");
    exit(1);
}

error = GRBloadenv(&env, "lpmo.log");
if (error) goto QUIT;

/* Read model and determine whether it is an LP */
error = GRBreadmodel(env, argv[1], &model);
if (error) goto QUIT;
error = GRBgetintattr(model, "IsMIP", &isMIP);
if (error) goto QUIT;
if (isMIP)
{
    printf("The model is not a linear program\n");
    goto QUIT;
}

error = GRBoptimize(model);
if (error) goto QUIT;

error = GRBgetintattr(model, "Status", &status);
if (error) goto QUIT;

if ((status == GRB_INF_OR_UNBD) || (status == GRB_INFEASIBLE) ||
    (status == GRB_UNBOUNDED))
{
    printf("The model cannot be solved because it is ");
    printf("infeasible or unbounded\n");
    goto QUIT;
}

if (status != GRB_OPTIMAL)
{
    printf("Optimization was stopped with status %i\n", status);
    goto QUIT;
}
/* Find the smallest variable value */
error = GRBgetintattr(model, "NumVars", &numvars);
if (error) goto QUIT;
for (j = 0; j < numvars; ++j)
{
    error = GRBgetdblattrelement(model, "X", j, &sol);
    if (error) goto QUIT;
    error = GRBgetdblattrelement(model, "LB", j, &lb);
    if (error) goto QUIT;
    if ((sol > 0.0001) && (sol < minVal) &&
        (lb == 0.0))
    {
        minVal = sol;
        minVar = j;
    }
}
error = GRBgetstrattrelement(model, "VarName", minVar, &varname);
if (error) goto QUIT;
printf(" *** Setting %s from %.6f to zero ***\n", varname, minVal);
error = GRBsetdblattrelement(model, "UB", minVar, 0.0);
if (error) goto QUIT;

/* Solve from this starting point */
error = GRBoptimize(model);
if (error) goto QUIT;

/* Save iteration & time info */
error = GRBgetblattr(model, "IterCount", &warmCount);
if (error) goto QUIT;
error = GRBgetblattr(model, "Runtime", &warmTime);
if (error) goto QUIT;

/* Reset the model and resolve */
printf(" *** Resetting and solving ");
printf(" without an advanced start ***\n\n");
error = GRBreset(model, 0);
if (error) goto QUIT;
error = GRBoptimize(model);
if (error) goto QUIT;

/* Save iteration & time info */
error = GRBgetblattr(model, "IterCount", &coldCount);
if (error) goto QUIT;
error = GRBgetblattr(model, "Runtime", &coldTime);
if (error) goto QUIT;

printf(" *** Warm start: %.0f iterations, %.6f seconds\n", warmCount, warmTime);
printf(" *** Cold start: %.0f iterations, %.6f seconds\n", coldCount, coldTime);

QUIT:
/* Error reporting */

if (error)
{
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free model */
GRBfreemodel(model);

/* Free environment */
GRBfreeenv(env);

return 0;

mip1_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example formulates and solves the following simple MIP model:

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

*/

#include <stdlib.h>
#include <stdio.h>
#include "gurobi_c.h"

int main(int argc, char *argv[])
{
    GRBenv *env = NULL;
    GRBmodel *model = NULL;
    int error = 0;
    double sol[3];
    int ind[3];
    double val[3];
    double obj[3];
    char vtype[3];
    int optimstatus;
    double objval;
    
    /* Create environment */
    
    error = GRBloadenv(&env, "mip1.log");
    if (error) goto QUIT;

QUIT:
/* Create an empty model */

error = GRBnewmodel(env, &model, "mip1", 0, NULL, NULL, NULL, NULL, NULL);
if (error) goto QUIT;

/* Add variables */

obj[0] = 1; obj[1] = 1; obj[2] = 2;
error = GRBaddvars(model, 3, 0, NULL, NULL, NULL, obj, NULL, NULL, vtype, NULL);
if (error) goto QUIT;

/* Change objective sense to maximization */

error = GRBsetintattr(model, GRB_INT_ATTR_MODELSENSE, GRB_MAXIMIZE);
if (error) goto QUIT;

/* First constraint: x + 2 y + 3 z <= 4 */

ind[0] = 0; ind[1] = 1; ind[2] = 2;
val[0] = 1; val[1] = 2; val[2] = 3;
error = GRBaddconstr(model, 3, ind, val, GRB_LESS_EQUAL, 4.0, "c0");
if (error) goto QUIT;

/* Second constraint: x + y >= 1 */

ind[0] = 0; ind[1] = 1;
val[0] = 1; val[1] = 1;
error = GRBaddconstr(model, 2, ind, val, GRB_GREATER_EQUAL, 1.0, "c1");
if (error) goto QUIT;

/* Optimize model */

error = GRBoptimize(model);
if (error) goto QUIT;

/* Write model to 'mip1.lp' */

error = GRBwrite(model, "mip1.lp");
if (error) goto QUIT;

/* Capture solution information */

error = GRBgetintattr(model, GRB_INT_ATTR_STATUS, &optimstatus);
if (error) goto QUIT;

error = GRBgetdblattr(model, GRB_DBL_ATTR_OBJVAL, &objval);
if (error) goto QUIT;

error = GRBgetdblattrarray(model, GRB_DBL_ATTR_X, 0, 3, sol);
if (error) goto QUIT;
printf("\nOptimization complete\n");
if (optimstatus == GRB_OPTIMAL) {
    printf("Optimal objective: %.4e\n", objval);
    printf(" x=%.0f, y=%.0f, z=%.0f\n", sol[0], sol[1], sol[2]);
} else if (optimstatus == GRB_INF_OR_UNBD) {
    printf("Model is infeasible or unbounded\n");
} else {
    printf("Optimization was stopped early\n");
}
QUIT:

/* Error reporting */
if (error) {
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}
/* Free model */
GRBfreemodel(model);
/* Free environment */
GRBfreeenv(env);
return 0;
}

mip2_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads a MIP model from a file, solves it and
prints the objective values from all feasible solutions
generated while solving the MIP. Then it creates the fixed
model and solves that model. */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include "gurobi_c.h"

int main(int argc, char *argv[])
{
    GRBenv *env = NULL;
    GRBmodel *model = NULL;
    GRBmodel *fixed = NULL;
    int error = 0;
    int ismip;
    int j, k, solcount, numvars;
    double objn, vobj, xn;
int optimstatus, foptimstatus;
double objval, fobjval;
char *varname;
double x;

/* To change settings for a loaded model, we need to get
the model environment, which will be freed when the model
is freed. */

GRBenv *menv, *fenv;

if (argc < 2) {
    fprintf(stderr, "Usage: mip2_c filename\n");
    exit(1);
}

/* Create environment */

error = GRBloadenv(&env, "mip2.log");
if (error) goto QUIT;

/* Read model from file */

error = GRBreadmodel(env, argv[1], &model);
if (error) goto QUIT;

error = GRBgetintattr(model, "IsMIP", &ismip);
if (error) goto QUIT;

if (ismip == 0) {
    printf("Model is not a MIP\n");
    goto QUIT;
}

/* Get model environment */

menv = GRBgetenv(model);
if (!menv) {
    fprintf(stderr, "Error: could not get model environment\n");
    goto QUIT;
}

/* Solve model */

error = GRBoptimize(model);
if (error) goto QUIT;

/* Capture solution information */

error = GRBgetintattr(model, GRB_INT_ATTR_STATUS, &optimstatus);
if (error) goto QUIT;

printf("\nOptimization complete\n");
if (optimstatus == GRB_OPTIMAL) {
    error = GRBgetdblattr(model, GRB_DBL_ATTR_OBJVAL, &objval);
    if (error) goto QUIT;
printf("Optimal objective: %4.2e\n", objval);
} else if (optimstatus == GRB_INF_OR_UNBD) {
    printf("Model is infeasible or unbounded\n\n");
    goto QUIT;
} else if (optimstatus == GRB_INFEASIBLE) {
    printf("Model is infeasible\n\n");
    goto QUIT;
} else if (optimstatus == GRB_UNBOUNDED) {
    printf("Model is unbounded\n\n");
    goto QUIT;
} else {
    printf("Optimization was stopped with status = %d\n\n", optimstatus);
    goto QUIT;
}

/* Iterate over the solutions and compute the objectives */

error = GRBsetintparam(menv, "OutputFlag", 0);
if (error) goto QUIT;
error = GRBgetintattr(model, "SolCount", &solcount);
if (error) goto QUIT;
error = GRBgetintattr(model, "NumVars", &numvars);
if (error) goto QUIT;
printf("\n");
for ( k = 0; k < solcount; ++k ) {
    error = GRBsetintparam(menv, "SolutionNumber", k);
    objn = 0.0;
    for ( j = 0; j < numvars; ++j ) {
        error = GRBgetdblattrelement(model, "Obj", j, &vobj);
        if (error) goto QUIT;
        error = GRBgetdblattrelement(model, "Xn", j, &xn);
        if (error) goto QUIT;
        objn += vobj * xn;
    }
    printf("Solution %i has objective: %f\n", k, objn);
}
printf("\n");
error = GRBsetintparam(menv, "OutputFlag", 1);
if (error) goto QUIT;

/* Create a fixed model, turn off presolve and solve */

fixed = GRBfixedmodel(model);
if (!fixed) {
    fprintf(stderr, "Error: could not create fixed model\n\n");
    goto QUIT;
}

fenv = GRBgetenv(fixed);
if (!fenv) {
    fprintf(stderr, "Error: could not get fixed model environment\n\n");
    goto QUIT;
}
error = GRBsetintparam(fenv, "PRESOLVE", 0);
if (error) goto QUIT;

error = GRBoptimize(fixed);
if (error) goto QUIT;

error = GRBgetintattr(fixed, GRB_INT_ATTR_STATUS, &foptimstatus);
if (error) goto QUIT;

if (foptimstatus != GRB_OPTIMAL) {
    fprintf(stderr, "Error: fixed model isn’t optimal\n");
    goto QUIT;
}

error = GRBgetdblattr(fixed, GRB_DBL_ATTR_OBJVAL, &fobjval);
if (error) goto QUIT;

if (fabs(fobjval - objval) > 1.0e-6 * (1.0 + fabs(objval))) {
    fprintf(stderr, "Error: objective values are different\n");
}

/* Print values of nonzero variables */
for (j = 0; j < numvars; ++j) {
    error = GRBgetstrattrelement(fixed, "VarName", j, &varname);
    if (error) goto QUIT;
    error = GRBgetdblattrelement(fixed, "X", j, &x);
    if (error) goto QUIT;
    if (x != 0.0) {
        printf("%s %f\n", varname, x);
    }
}

QUIT:

/* Error reporting */
if (error) {
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free models */
GRBfreemodel(model);
GRBfreemodel(fixed);

/* Free environment */
GRBfreeenv(env);

return 0;
}
/* Copyright 2018, Gurobi Optimization, LLC */

/* Want to cover three different sets but subject to a common budget of
* elements allowed to be used. However, the sets have different priorities to
* be covered; and we tackle this by using multi-objective optimization. */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include <string.h>
#include "gurobi_c.h"

#define MAXSTR 128

int main(void) {
    GRBenv *env = NULL;
    GRBenv *menv = NULL;
    GRBmodel *model = NULL;
    int error = 0;
    int *cbeg = NULL;
    int *cind = NULL;
    double *cval = NULL;
    char buffer[MAXSTR];
    int e, i, status, nSolutions;
    double objn;

    /* Sample data */
    const int groundSetSize = 20;
    const int nSubsets = 4;
    const int Budget = 12;
    double Set[20][20] =
        { { 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 },
         { 0, 0, 0, 0, 0, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1 },
         { 0, 0, 0, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 0 },
         { 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 1, 1, 0 } };
    int SetObjPriority[] = {3, 2, 2, 1};
    double SetObjWeight[] = {1.0, 0.25, 1.25, 1.0};

    /* Create environment */
    error = GRBloadenv(&env, "multiobj_c.log");
    if (error) goto QUIT;

    /* Create initial model */
    error = GRBnewmodel(env, &model, "multiobj_c", groundSetSize, NULL,
        NULL, NULL, NULL, NULL);
    if (error) goto QUIT;

    /* get model environment */
    menv = GRBgetenv(model);
    if (!menv) {
        fprintf(stderr, "Error: could not get model environment\n");
        goto QUIT;
    }

QUIT:
/* Initialize decision variables for ground set:
* x[e] == 1 if element e is chosen for the covering. */
for (e = 0; e < groundSetSize; e++) {
    sprintf(buffer, "El%d", e);
    error = GRBsetcharattrelement(model, "VType", e, GRB_BINARY);
    if (error) goto QUIT;

    error = GRBsetstrattrelement(model, "VarName", e, buffer);
    if (error) goto QUIT;
}

/* Make space for constraint data */
cind = malloc(sizeof(int) * groundSetSize);
if (!cind) goto QUIT;
cval = malloc(sizeof(double) * groundSetSize);
if (!cval) goto QUIT;

/* Constraint: limit total number of elements to be picked to be at most
* Budget */
for (e = 0; e < groundSetSize; e++) {
    cind[e] = e;
    cval[e] = 1.0;
}

sprintf(buffer, "Budget");
error = GRBaddconstr(model, groundSetSize, cind, cval, GRB_LESS_EQUAL,
        (double)Budget, buffer);
if (error) goto QUIT;

/* Set global sense for ALL objectives */
error = GRBsetintattr(model, GRB_INT_ATTR_MODELSENSE, GRB_MAXIMIZE);
if (error) goto QUIT;

/* Limit how many solutions to collect */
error = GRBsetintparam(menv, GRB_INT_PAR_POOLSOLUTIONS, 100);
if (error) goto QUIT;

/* Set and configure i-th objective */
for (i = 0; i < nSubsets; i++) {
    sprintf(buffer, "Set%d", i + 1);

    error = GRBsetobjectiven(model, i, SetObjPriority[i], SetObjWeight[i],
        1.0 + i, 0.01, buffer, 0.0, groundSetSize, cind, Set[i]);
    if (error) goto QUIT;
}

/* Save problem */
error = GRBwrite(model, "multiobj_c.lp");
if (error) goto QUIT;
error = GRBwrite(model, "multiobj_c.mps");
if (error) goto QUIT;

/* Optimize */
error = GRBoptimize(model);
if (error) goto QUIT;
/* Status checking */
error = GRBgetintattr(model, "Status", &status);
if (error) goto QUIT;

if (status == GRB_INF_OR_UNBD ||
    status == GRB_INFEASIBLE ||
    status == GRB_UNBOUNDED ) {
    printf("The model cannot be solved 
"    "because it is infeasible or unbounded\n");
    goto QUIT;
}
if (status != GRB_OPTIMAL) {
    printf("Optimization was stopped with status %i\n", status);
    goto QUIT;
}

/* Print best selected set */
error = GRBgetdblattrarray(model, GRB_DBL_ATTR_X, 0, groundSetSize, cval);
if (error) goto QUIT;
printf("Selected elements in best solution:\n\t");
for (e = 0; e < groundSetSize ; e++) {
    if (cval[e] < .9) continue;
    printf("El%d ", e);
}

/* Print number of solutions stored */
error = GRBgetintattr(model, GRB_INT_ATTR_SOLCOUNT, &nSolutions);
if (error) goto QUIT;
printf("Number of solutions found: %d\n", nSolutions);

/* Print objective values of solutions */
if (nSolutions > 10) nSolutions = 10;
printf("Objective values for first %d solutions:\n", nSolutions);
for (i = 0; i < nSubsets; i++) {
    error = GRBsetintparam(menv, GRB_INT_PAR_OBJNUMBER, i);
    if (error) goto QUIT;
    printf("\tSet %d:", i);
    for (e = 0; e < nSolutions; e++) {
        error = GRBsetintparam(menv, GRB_INT_PAR_SOLUTIONNUMBER, e);
        if (error) goto QUIT;
        error = GRBgetdblattr(model, GRB_DBL_ATTR_OBJNVAL, &objn);
        if (error) goto QUIT;
        printf(" %6g", objn);
    }
    printf("\n");
}

QUIT:
if (cind != NULL) free(cind);
if (cval != NULL) free(cval);
if (model != NULL) GRBfreemodel(model);
if (env != NULL) GRBfreeenv(env);

return error;
}

params_c.c

/* Copyright 2018, Gurobi Optimization, LLC */
/* Use parameters that are associated with a model. 
A MIP is solved for a few seconds with different sets of parameters. 
The one with the smallest MIP gap is selected, and the optimization 
resumed until the optimal solution is found. */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include "gurobi_c.h"

int main(int argc, char * argv[])
{
    GRBenv * env = NULL, * modelenv = NULL, * bestenv = NULL;
    GRBmodel * model = NULL, * bestmodel = NULL;
    int error = 0;
    int ismip, i, mipfocus;
    double bestgap, gap;

    if (argc < 2)
    {
        fprintf(stderr, "Usage: params_c filename\n");
        exit(1);
    }

    error = GRBloadenv(& env, "params.log");
    if (error) goto QUIT;

    /* Read model and verify that it is a MIP */
    error = GRBreadmodel(env, argv[1], & model);
    if (error) goto QUIT;
    error = GRBgetintattr(model, "IsMIP", & ismip);
    if (error) goto QUIT;
    if (ismip == 0)
    {
        printf("The model is not an integer program\n");
        exit(1);
    }

    /* Set a 2 second time limit */
    modelenv = GRBgetenv(model);
    if (! modelenv) {
        printf("Cannot retrieve model environment\n");
        exit(1);
    }

QUIT:
exit(1);
}
error = GRBsetdblparam(modelenv, "TimeLimit", 2);
if (error) goto QUIT;

/* Now solve the model with different values of MIPFocus */
bestmodel = GRBcopymodel(model);
if (!bestmodel) {
    printf("Cannot copy model\n");
    exit(1);
}
error = GRBoptimize(bestmodel);
if (error) goto QUIT;
error = GRBgetdblattr(bestmodel, "MIPGap", &bestgap);
if (error) goto QUIT;
for (i = 1; i <= 3; ++i)
{
    error = GRBreset(model, 0);
    if (error) goto QUIT;
    modelenv = GRBgetenv(model);
    if (!modelenv) {
        printf("Cannot retrieve model environment\n");
        exit(1);
    }
    error = GRBsetintparam(modelenv, "MIPFocus", i);
    if (error) goto QUIT;
    error = GRBoptimize(model);
    if (error) goto QUIT;
    error = GRBgetdblattr(model, "MIPGap", &gap);
    if (error) goto QUIT;
    if (bestgap > gap)
    {
        GRBmodel *tmp = bestmodel;
        bestmodel = model;
        model = tmp;
        bestgap = gap;
    }
}

/* Finally, free the extra model, reset the time limit and
 continue to solve the best model to optimality */
GRBfreemodel(model);
bestenv = GRBgetenv(bestmodel);
if (!bestenv) {
    printf("Cannot retrieve best model environment\n");
    exit(1);
}
error = GRBsetdblparam(bestenv, "TimeLimit", GRB_INFINITY);
if (error) goto QUIT;
error = GRBoptimize(bestmodel);
if (error) goto QUIT;
error = GRBsetintparam(bestenv, "MIPFocus", &mipfocus);
if (error) goto QUIT;
printf("Solved with MIPFocus: %i\n", mipfocus);
QUIT:

/* Error reporting */

if ( error )
{
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free best model */
GRBfreemodel(bestmodel);

/* Free environment */
GRBfreeenv(env);

return 0;
}

piecewise_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example considers the following separable, convex problem:

  minimize   f(x) - y + g(z)
  subject to x + 2 y + 3 z <= 4
             x + y      >= 1
             x, y, z <= 1

  where f(u) = exp(-u) and g(u) = 2 u^2 - 4 u, for all real u. It
  formulates and solves a simpler LP model by approximating f and
  g with piecewise-linear functions. Then it transforms the model
  into a MIP by negating the approximation for f, which corresponds
  to a non-convex piecewise-linear function, and solves it again. */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include "gurobi_c.h"

double f(double u) { return exp(-u); }
double g(double u) { return 2 * u * u - 4 * u; }

int main(int argc, char * argv[])
{
    GRBenv * env = NULL;
    GRBmodel * model = NULL;
    int error = 0;
    double lb, ub;
    int npts, i;
double *ptu = NULL;
double *ptf = NULL;
double *ptg = NULL;
int ind[3];
double val[3];
int ismip;
double objval;
double sol[3];

/* Create environment */

error = GRBloadenv(&env, NULL);
if (error) goto QUIT;

/* Create a new model */

error = GRBnewmodel(env, &model, NULL, 0, NULL, NULL, NULL, NULL, NULL);
if (error) goto QUIT;

/* Add variables */

lb = 0.0; ub = 1.0;

error = GRBaddvar(model, 0, NULL, NULL, 0.0, lb, ub, GRB_CONTINUOUS, "x");
if (error) goto QUIT;
error = GRBaddvar(model, 0, NULL, NULL, 0.0, lb, ub, GRB_CONTINUOUS, "y");
if (error) goto QUIT;
error = GRBaddvar(model, 0, NULL, NULL, 0.0, lb, ub, GRB_CONTINUOUS, "z");
if (error) goto QUIT;

/* Set objective for y */

error = GRBsetdblattrelement(model, GRB_DBL_ATTR_OBJ, 1, -1.0);
if (error) goto QUIT;

/* Add piecewise-linear objective functions for x and z */

npts = 101;
ptu = (double *) malloc(npts * sizeof(double));
ptf = (double *) malloc(npts * sizeof(double));
ptg = (double *) malloc(npts * sizeof(double));

for (i = 0; i < npts; i++) {
    ptu[i] = lb + (ub - lb) * i / (npts - 1);
    ptf[i] = f(ptu[i]);
    ptg[i] = g(ptu[i]);
}

error = GRBsetpwlobj(model, 0, npts, ptu, ptf);
if (error) goto QUIT;
error = GRBsetpwlobj(model, 2, npts, ptu, ptg);
if (error) goto QUIT;

/* Add constraint: x + 2 y + 3 z <= 4 */

ind[0] = 0; ind[1] = 1; ind[2] = 2;
val[0] = 1; val[1] = 2; val[2] = 3;

error = GRBaddconstr(model, 3, ind, val, GRB_LESS_EQUAL, 4.0, "c0");
if (error) goto QUIT;

/* Add constraint: x + y >= 1 */
ind[0] = 0; ind[1] = 1;
val[0] = 1; val[1] = 1;

error = GRBaddconstr(model, 2, ind, val, GRB_GREATER_EQUAL, 1.0, "c1");
if (error) goto QUIT;

/* Optimize model as an LP */
error = GRBoptimize(model);
if (error) goto QUIT;

error = GRBgetintattr(model, "IsMIP", &ismip);
if (error) goto QUIT;
error = GRBgetdblattr(model, "ObjVal", &objval);
if (error) goto QUIT;
error = GRBgetdblattrarray(model, "X", 0, 3, sol);
if (error) goto QUIT;

printf(" IsMIP: %d\n", ismip);
printf("x %g\ny %g\nz %g\n", sol[0], sol[1], sol[2]);
printf("Obj: %g\n", objval);
printf("\n");

/* Negate piecewise-linear objective function for x */
for (i = 0; i < npts; i++) {
    ptf[i] = -ptf[i];
}

error = GRBsetpwlobj(model, 0, npts, ptu, ptf);
if (error) goto QUIT;

/* Optimize model as a MIP */
error = GRBoptimize(model);
if (error) goto QUIT;

error = GRBgetintattr(model, "IsMIP", &ismip);
if (error) goto QUIT;
error = GRBgetdblattr(model, "ObjVal", &objval);
if (error) goto QUIT;
error = GRBgetdblattrarray(model, "X", 0, 3, sol);
if (error) goto QUIT;

printf(" IsMIP: %d\n", ismip);
printf("x %g\ny %g\nz %g\n", sol[0], sol[1], sol[2]);
printf("Obj: %g\n", objval);

QUIT:
/* Error reporting */

if (error) {
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free data */

free(ptu);
free(ptf);
free(ptg);

/* Free model */

GRBfreemodel(model);

/* Free environment */

GRBfreeenv(env);

return 0;

poolsearch_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* We find alternative epsilon-optimal solutions to a given knapsack problem by using PoolSearchMode */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include <string.h>
#include "gurobi_c.h"

#define MAXSTR 128

int main(void)
{
    GRBenv *env = NULL;
    GRBenv *menv = NULL;
    GRBmodel *model = NULL;
    int error = 0;
    char buffer[MAXSTR];
    int e, status, nSolutions, prlen;
    double objval, *cval = NULL;
    int *cind = NULL;

    /* Sample data */
    const int groundSetSize = 10;
    double objCoef[10] =
        {32, 32, 15, 15, 6, 6, 1, 1, 1, 1};
double knapsackCoef[10] =
    {16, 16, 8, 8, 4, 4, 2, 2, 1, 1};
double Budget = 33;

/* Create environment */
error = GRBloadenv(env, "poolsearch_c.log");
if (error) goto QUIT;

/* Create initial model */
error = GRBnewmodel(env, &model, "poolsearch_c", groundSetSize, NULL,
    NULL, NULL, NULL, NULL);
if (error) goto QUIT;

/* get model environment */
menv = GRBgetenv(model);
if (!menv) {
    fprintf(stderr, "Error: could not get model environment\n");
    goto QUIT;
}

/* set objective function */
error = GRBsetdblattrarray(model, "Obj", 0, groundSetSize, objCoef);
if (error) goto QUIT;

/* set variable types and names */
for (e = 0; e < groundSetSize; e++) {
    sprintf(buffer, "El%d", e);
    error = GRBsetcharattrelement(model, "VType", e, GRB_BINARY);
    if (error) goto QUIT;

    error = GRBsetstrattrelement(model, "VarName", e, buffer);
    if (error) goto QUIT;
}

/* Make space for constraint data */
cind = malloc(sizeof(int) * groundSetSize);
if (!cind) goto QUIT;
for (e = 0; e < groundSetSize; e++)
    cind[e] = e;

/* Constraint: limit total number of elements to be picked to be at most
 * Budget */
sprintf(buffer, "Budget");
error = GRBaddconstr(model, groundSetSize, cind, knapsackCoef,
    GRB_LESS_EQUAL, Budget, buffer);
if (error) goto QUIT;

/* set global sense for ALL objectives */
error = GRBsetintattr(model, GRB_INT_ATTR_MODELSENSE, GRB_MAXIMIZE);
if (error) goto QUIT;

/* Limit how many solutions to collect */
error = GRBsetintparam(menv, GRB_INT_PAR_POOLSOLUTIONS, 1024);
if (error) goto QUIT;

/* Limit the search space by setting a gap for the worst possible solution that will be accepted */

QUIT:;
exit(1);
error = GRBsetdblparam(menv, GRB_DBL_PAR_POOLGAP, 0.10);
if (error) goto QUIT;

/* do a systematic search for the k-best solutions */
error = GRBsetintparam(menv, GRB_INT_PAR_POOLSEARCHMODE, 2);
if (error) goto QUIT;

/* save problem */
error = GRBwrite(model, "poolsearch_c.lp");
if (error) goto QUIT;
error = GRBwrite(model, "poolsearch_c.mps");
if (error) goto QUIT;

/* Optimize */
error = GRBoptimize(model);
if (error) goto QUIT;

/* Status checking */
error = GRBgetintattr(model, "Status", &status);
if (error) goto QUIT;

if (status == GRB_INF_OR_UNBD ||
    status == GRB_INFEASIBLE ||
    status == GRB_UNBOUNDED ) {
    printf("The model cannot be solved 
"      "because it is infeasible or unbounded
");
    goto QUIT;
}
if (status != GRB_OPTIMAL) {
    printf("Optimization was stopped with status %d
", status);
    goto QUIT;
}

/* make space for optimal solution */
cval = malloc(sizeof(double) * groundSetSize);
if (!cval) goto QUIT;

/* Print best selected set */
error = GRBgetdblattrarray(model, GRB_DBL_ATTR_X, 0, groundSetSize, cval);
if (error) goto QUIT;

printf("Selected elements in best solution:
	");
for (e = 0; e < groundSetSize; e++) {
    if (cval[e] < .9) continue;
    printf("El%d", e);
}

/* print number of solutions stored */
error = GRBgetintattr(model, GRB_INT_ATTR_SOLCOUNT, &nSolutions);
if (error) goto QUIT;
printf("\nNumber of solutions found: %d\nValues:", nSolutions);

/* print objective values of alternative solutions */
prlen = 0;
for (e = 0; e < nSolutions; e++) {
    error = GRBsetintparam(menv, GRB_INT_PAR_SOLUTIONNUMBER, e);

if (error) goto QUIT;

error = GRBgetdblattr(model, GRB_DBL_ATTR_POOLOBJVAL, &objval);
if (error) goto QUIT;

prlen += printf(" %g", objval);
if (prlen >= 75 && e+1 < nSolutions) {
    prlen = printf("\n   ");
}
printf("\n");

/* print fourth best set if available */
if (nSolutions >= 4) {
    error = GRBsetintparam(menv, GRB_INT_PAR_SOLUTIONNUMBER, 3);
    if (error) goto QUIT;

    /* get the solution vector */
    error = GRBgetdblattrarray(model, GRB_DBL_ATTR_XN, 0, groundSetSize, cval);
    if (error) goto QUIT;

    printf("Selected elements in fourth best solution:\n\t");
    for (e = 0; e < groundSetSize ; e++) {
        if (cval[e] < .9) continue;
        printf("El%d ", e);
    }
    printf("\n");
}

QUIT:
if (model != NULL) GRBfreemodel(model);
if (env != NULL) GRBfreeenv(env);
if (cind != NULL) free(cind);
if (cval != NULL) free(cval);
return error;
}

qcp_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example formulates and solves the following simple QCP model:

    maximize     x
    subject to   x + y + z = 1
                x^2 + y^2 <= z^2 (second-order cone)
                x^2 <= yz     (rotated second-order cone)

*/

#include <stdlib.h>
#include <stdio.h>
#include "gurobi_c.h"

int main(int argc, char *argv[])
{
    GRBenv *env = NULL;
    GRBmodel *model = NULL;
    int    error = 0;
    double sol[3];
    int    ind[3];
    double val[3];
    double obj[] = {1, 0, 0};
    int    qrow[3];
    int    qcol[3];
    double qval[3];
    int    optimstatus;
    double objval;

    /* Create environment */
    error = GRBloadenv(&env, "qcp.log");
    if (error) goto QUIT;

    /* Create an empty model */
    error = GRBnewmodel(env, &model, "qcp", 0, NULL, NULL, NULL, NULL, NULL);
    if (error) goto QUIT;

    /* Add variables */
    error = GRBaddvars(model, 3, 0, NULL, NULL, NULL, obj, NULL, NULL, NULL);
    if (error) goto QUIT;

    /* Change sense to maximization */
    error = GRBsetintattr(model, GRB_INT_ATTR_MODELSENSE, GRB_MAXIMIZE);
    if (error) goto QUIT;

    /* Linear constraint: x + y + z = 1 */
    ind[0] = 0; ind[1] = 1; ind[2] = 2;
    val[0] = 1; val[1] = 1; val[2] = 1;
    error = GRBaddconstr(model, 3, ind, val, GRB_EQUAL, 1.0, "c0");
    if (error) goto QUIT;

    /* Cone: x^2 + y^2 <= z^2 */
    qrow[0] = 0; qcol[0] = 0; qval[0] = 1.0;
    error = GRBaddqconstr(model, 0, NULL, NULL, 3, qrow, qcol, qval,
                           GRB_LESS_EQUAL, 0.0, "qc0");
    if (error) goto QUIT;

    /* Rotated cone: x^2 <= yz */
qrow[0] = 0; qcol[0] = 0; qval[0] = 1.0;
qrow[1] = 1; qcol[1] = 2; qval[1] = -1.0;

error = GRBaddqconstr(model, 0, NULL, NULL, 2, qrow, qcol, qval,
                      GRB_LESS_EQUAL, 0.0, "qc1");
if (error) goto QUIT;

/* Optimize model */
error = GRBoptimize(model);
if (error) goto QUIT;

/* Write model to 'qcp.lp' */
error = GRBwrite(model, "qcp.lp");
if (error) goto QUIT;

/* Capture solution information */
error = GRBgetintattr(model, GRB_INT_ATTR_STATUS, &optimstatus);
if (error) goto QUIT;

error = GRBgetdblattr(model, GRB_DBL_ATTR_OBJVAL, &objval);
if (error) goto QUIT;

error = GRBgetdblattrarray(model, GRB_DBL_ATTR_X, 0, 3, sol);
if (error) goto QUIT;

printf ("Optimization complete\n");
if (optimstatus == GRB_OPTIMAL) {
    printf("Optimal objective: %.4e\n", objval);
    printf(" x=%.2f, y=%.2f, z=%.2f\n", sol[0], sol[1], sol[2]);
} else if (optimstatus == GRB_INF_OR_UNBD) {
    printf("Model is infeasible or unbounded\n");
} else {
    printf("Optimization was stopped early\n");
}

QUIT:

/* Error reporting */
if (error) {
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free model */
GRBfreemodel(model);

/* Free environment */
GRBfreeenv(env);
qp_c.c

/* Copyright 2018, Gurobi Optimization, LLC */
/* This example formulates and solves the following simple QP model:

minimize    x^2 + x*y + y^2 + y*z + z^2 + 2 x
subject to  x + 2 y + 3 z >= 4
            x + y       >= 1

It solves it once as a continuous model, and once as an integer model. */

#include <stdlib.h>
#include <stdio.h>
#include "gurobi_c.h"

int main(int argc, char *argv[])
{
    GRBenv *env = NULL;
    GRBmodel *model = NULL;
    int error = 0;
    double sol[3];
    int ind[3];
    double val[3];
    int qrow[5];
    int qcol[5];
    double qval[5];
    char vtype[3];
    int optimstatus;
    double objval;

    /* Create environment */
    error = GRBloadenv(&env, "qp.log");
    if (error) goto QUIT;

    /* Create an empty model */
    error = GRBnewmodel(env, &model, "qp", 0, NULL, NULL, NULL, NULL, NULL);
    if (error) goto QUIT;

    /* Add variables */
    error = GRBaddvars(model, 3, 0, NULL, NULL, NULL, NULL, NULL, NULL, NULL);
    if (error) goto QUIT;

    /* Quadratic objective terms */

error = GRBaddqpterms(model, 5, qrow, qcol, qval);
if (error) goto QUIT;

/* Linear objective term */
error = GRBsetdblattrelement(model, GRB_DBL_ATTR_OBJ, 0, 2.0);
if (error) goto QUIT;

/* First constraint: x + 2 y + 3 z <= 4 */
ind[0] = 0; ind[1] = 1; ind[2] = 2;
val[0] = 1; val[1] = 2; val[2] = 3;
error = GRBaddconstr(model, 3, ind, val, GRB_GREATER_EQUAL, 4.0, "c0");
if (error) goto QUIT;

/* Second constraint: x + y >= 1 */
ind[0] = 0; ind[1] = 1;
val[0] = 1; val[1] = 1;
error = GRBaddconstr(model, 2, ind, val, GRB_GREATER_EQUAL, 1.0, "c1");
if (error) goto QUIT;

/* Optimize model */
error = GRBoptimize(model);
if (error) goto QUIT;

/* Write model to ‘qp.lp’ */
error = GRBwrite(model, "qp.lp");
if (error) goto QUIT;

/* Capture solution information */
error = GRBgetintattr(model, GRB_INT_ATTR_STATUS, &optimstatus);
if (error) goto QUIT;
error = GRBgetdblattr(model, GRB_DBL_ATTR_OBJVAL, &objval);
if (error) goto QUIT;
error = GRBgetdblattarray(model, GRB_DBL_ATTR_X, 0, 3, sol);
if (error) goto QUIT;
printf("\nOptimization complete\n");
if (optimstatus == GRB_OPTIMAL) {
    printf("Optimal objective: %.4e\n", objval);
    printf(" x=%.4f, y=%.4f, z=%.4f\n", sol[0], sol[1], sol[2]);
} else if (optimstatus == GRB_INF_OR_UNBD) {
    printf("Model is infeasible or unbounded\n");
} else {

76
printf("Optimization was stopped early\n");
}

/* Modify variable types */

error = GRBsetcharattrarray(model, GRB_CHAR_ATTR_VTYPE, 0, 3, vtype);
if (error) goto QUIT;

/* Optimize model */
error = GRBoptimize(model);
if (error) goto QUIT;

/* Write model to 'qp2.lp' */
error = GRBwrite(model, "qp2.lp");
if (error) goto QUIT;

/* Capture solution information */
error = GRBgetintattr(model, GRB_INT_ATTR_STATUS, &optimstatus);
if (error) goto QUIT;

error = GRBgetdblattr(model, GRB_DBL_ATTR_OBJVAL, &objval);
if (error) goto QUIT;

error = GRBgetdblattrarray(model, GRB_DBL_ATTR_X, 0, 3, sol);
if (error) goto QUIT;

printf("Optimization complete\n");
if (optimstatus == GRB_OPTIMAL) {
    printf("Optimal objective: %.4e\n", objval);
    printf("x=%.4f, y=%.4f, z=%.4f\n", sol[0], sol[1], sol[2]);
} else if (optimstatus == GRB_INF_OR_UNBD) {
    printf("Model is infeasible or unbounded\n");
} else {
    printf("Optimization was stopped early\n");
}

QUIT:

/* Error reporting */
if (error) {
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free model */
GRBfreemodel(model);
/* Free environment */

GRBfreeenv(env);

return 0;
}

sensitivity_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* A simple sensitivity analysis example which reads a MIP model
   from a file and solves it. Then each binary variable is set
to 1-X, where X is its value in the optimal solution, and
the impact on the objective function value is reported. */

#include <stdlib.h>
#include <stdio.h>
#include "gurobi_c.h"

int main(int argc, char *argv[])
{
    GRBenv *env = NULL, *modelenv = NULL;
    GRBmodel *model = NULL;
    int error = 0;
    int ismip, status, numvars, i, j;
    double origobjval, lb, ub, objval;
    double *origx = NULL;
    char vtype, *vname;

    if (argc < 2)
    {
        fprintf(stderr, "Usage: sensitivity_c filename\n");
        exit(1);
    }

    /* Create environment */

    error = GRBloadenv(env, "sensitivity.log");
    if (error) goto QUIT;

    /* Read and solve model */

    error = GRBreadmodel(env, argv[1], &model);
    if (error) goto QUIT;

    error = GRBgetintattr(model, "IsMIP", &ismip);
    if (error) goto QUIT;
    if (ismip == 0) {
        printf("Model is not a MIP\n");
        exit(1);
    }
error = GRBoptimize(model);
if (error) goto QUIT;

error = GRBgetintattr(model, "Status", &status);
if (error) goto QUIT;
if (status != GRB_OPTIMAL) {
    printf("Optimization ended with status %d\n", status);
    exit(1);
}

/* Store the optimal solution */

error = GRBgetdblattr(model, "ObjVal", &origobjval);
if (error) goto QUIT;
error = GRBgetintattr(model, "NumVars", &numvars);
if (error) goto QUIT;
origx = (double*) malloc(numvars * sizeof(double));
if (origx == NULL) {
    printf("Out of memory\n");
    exit(1);
}
error = GRBgetdblattrelement(model, "X", 0, numvars, origx);
if (error) goto QUIT;

/* Disable solver output for subsequent solves */

modelenv = GRBgetenv(model);
if (!modelenv) {
    printf("Cannot retrieve model environment\n");
    exit(1);
}
error = GRBsetintparam(modelenv, "OutputFlag", 0);
if (error) goto QUIT;

/* Iterate through unfixed, binary variables in model */

for (i = 0; i < numvars; i++) {
    error = GRBgetdblattrelement(model, "LB", i, &lb);
    if (error) goto QUIT;
    error = GRBgetdblattrelement(model, "UB", i, &ub);
    if (error) goto QUIT;
    error = GRBgetcharattrelement(model, "VType", i, &vtype);
    if (error) goto QUIT;
    if (lb == 0 && ub == 1
        && (vtype == GRB_BINARY || vtype == GRB_INTEGER)) {
        /* Set variable to 1-X, where X is its value in optimal solution */

        if (origx[i] < 0.5) {
            error = GRBsetdblattrelement(model, "LB", i, 1.0);
            if (error) goto QUIT;
            error = GRBsetdblattrelement(model, "Start", i, 1.0);
            if (error) goto QUIT;
        } else {
            error = GRBsetdblattrelement(model, "UB", i, 0.0);
        }
    }
}
if (error) goto QUIT;
error = GRBsetdblattrelement(model, "Start", i, 0.0);
if (error) goto QUIT;
}

/* Update MIP start for the other variables */
for (j = 0; j < numvars; j++) {
    if (j != i) {
        error = GRBsetdblattrelement(model, "Start", j, origx[j]);
        if (error) goto QUIT;
    }
}

/* Solve for new value and capture sensitivity information */
error = GRBoptimize(model);
if (error) goto QUIT;

error = GRBgetintattr(model, "Status", &status);
if (error) goto QUIT;
error = GRBgetstrattrelement(model, "VarName", i, &vname);
if (error) goto QUIT;
if (status == GRB_OPTIMAL) {
    error = GRBgetdblattrelement(model, "ObjVal", &objval);
    if (error) goto QUIT;
    printf("Objective sensitivity for variable %s is %g
", vname, objval - origobjval);
} else {
    printf("Objective sensitivity for variable %s is infinite
", vname);
}

/* Restore the original variable bounds */
error = GRBsetdblattrelement(model, "LB", i, 0.0);
if (error) goto QUIT;
error = GRBsetdblattrelement(model, "UB", i, 1.0);
if (error) goto QUIT;
}

QUIT:

/* Error reporting */

if (error)
{
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free data */
free(origx);
/* Free model */
GRBfreemodel(model);
/* Free environment */
GRBfreeenv(env);
return 0;
}

SOS_C.C

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example creates a very simple Special Ordered Set (SOS) model. The model consists of 3 continuous variables, no linear constraints, and a pair of SOS constraints of type 1. */

#include <stdlib.h>
#include <stdio.h>
#include "gurobi_c.h"

int main(int argc, char *argv[])
{
    GRBenv *env = NULL;
    GRBmodel *model = NULL;
    int error = 0;
    double x[3];
    double obj[3];
    double ub[3];
    int sostype[2];
    int sosbeg[2];
    int sosind[4];
    double soswt[4];
    int optimstatus;
    double objval;

    /* Create environment */

    error = GRBloadenv(&env, "sos.log");
    if (error) goto QUIT;

    /* Create an empty model */

    error = GRBnewmodel(env, &model, "sos", 0, NULL, NULL, NULL, NULL, NULL); 
    if (error) goto QUIT;

    /* Add variables */

    obj[0] = -2; obj[1] = -1; obj[2] = -1;
    ub[0] = 1.0; ub[1] = 1.0; ub[2] = 2.0;
error = GRBaddvars(model, 3, 0, NULL, NULL, NULL, obj, NULL, ub, NULL, NULL);
if (error) goto QUIT;

/* Build first SOS1: x0=0 or x1 =0 */
sosind[0] = 0; sosind[1] = 1;
soswt[0] = 1.0; soswt[1] = 2.0;
sosbeg[0] = 0; sostype[0] = GRB_SOS_TYPE1;

/* Build second SOS1: x0 =0 or x2 =0 */
sosbeg[1] = 2; sostype[1] = GRB_SOS_TYPE1;

/* Add SOSs to model */
error = GRBaddsos(model, 2, 4, sostype, sosbeg, sosind, soswt);
if (error) goto QUIT;

/* Optimize model */
error = GRBoptimize(model);
if (error) goto QUIT;

/* Write model to 'sos.lp' */
error = GRBwrite(model, "sos.lp");
if (error) goto QUIT;

/* Capture solution information */
error = GRBgetintattr(model, GRB_INT_ATTR_STATUS, &optimstatus);
if (error) goto QUIT;

error = GRBgetdblattr(model, GRB_DBL_ATTR_OBJVAL, &objval);
if (error) goto QUIT;

error = GRBgetdblattrarray(model, GRB_DBL_ATTR_X, 0, 3, x);
if (error) goto QUIT;

printf("Optimization complete\n");
if (optimstatus == GRB_OPTIMAL) {
    printf("Optimal objective: %.4e\n", objval);
    printf(" x=%.4f, y=%.4f, z=%.4f\n", x[0], x[1], x[2]);
} else if (optimstatus == GRB_INF_OR_UNBD) {
    printf("Model is infeasible or unbounded\n");
} else {
    printf("Optimization was stopped early\n");
}

QUIT:

/* Error reporting */
if (error) {
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free model */
GRBfreemodel(model);

/* Free environment */
GRBfreeenv(env);

return 0;

*/

sudoku_c.c

/* Copyright 2018, Gurobi Optimization, LLC */
/*
Sudoku example.
The Sudoku board is a 9x9 grid, which is further divided into a 3x3 grid of 3x3 grids. Each cell in the grid must take a value from 0 to 9. No two grid cells in the same row, column, or 3x3 subgrid may take the same value.

In the MIP formulation, binary variables x[i,j,v] indicate whether cell <i,j> takes value 'v'. The constraints are as follows:
1. Each cell must take exactly one value (sum_v x[i,j,v] = 1)
2. Each value is used exactly once per row (sum_i x[i,j,v] = 1)
3. Each value is used exactly once per column (sum_j x[i,j,v] = 1)
4. Each value is used exactly once per 3x3 subgrid (sum_grid x[i,j,v] = 1)

Input datasets for this example can be found in examples/data/sudoku*. */

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include "gurobi_c.h"

#define SUBDIM 3
#define DIM (SUBDIM*SUBDIM)

int main(int argc, char *argv[])
{
    FILE *fp = NULL;
    GRBenv *env = NULL;
    GRBmodel *model = NULL;
    int board[DIM][DIM];
    int inputline[100];
    int ind[DIM];
double val[DIM];
double lb[DIM*DIM*DIM];
char vtype[DIM*DIM*DIM];
char *names[DIM*DIM*DIM];
char namestorage[10*DIM*DIM*DIM];
char *cursor;
int optimstatus;
double objval;
int zero = 0;
int i, j, v, ig, jg, count;
int error = 0;

if (argc < 2) {
    fprintf(stderr, "Usage: sudoku_c datafile\n");
    exit(1);
}

fp = fopen(argv[1], "r");
if (fp == NULL) {
    fprintf(stderr, "Error: unable to open input file %s\n", argv[1]);
    exit(1);
}

for (i = 0; i < DIM; i++) {
    fgets(inputline, 100, fp);
    if (strlen(inputline) < 9) {
        fprintf(stderr, "Error: not enough board positions specified\n");
        exit(1);
    }
    for (j = 0; j < DIM; j++) {
        board[i][j] = (int) inputline[j] - (int) '1';
        if (board[i][j] < 0 || board[i][j] >= DIM)
            board[i][j] = -1;
    }
}

/* Create an empty model */
cursor = namestorage;
for (i = 0; i < DIM; i++) {
    for (j = 0; j < DIM; j++) {
        for (v = 0; v < DIM; v++) {
            if (board[i][j] == v)
                lb[i*DIM*DIM+j*DIM+v] = 1;
            else
                lb[i*DIM*DIM+j*DIM+v] = 0;
            vtype[i*DIM*DIM+j*DIM+v] = GRB_BINARY;

            names[i*DIM*DIM+j*DIM+v] = cursor;
            sprintf(names[i*DIM*DIM+j*DIM+v], "x[%d,%d,%d]", i, j, v+1);
            cursor += strlen(names[i*DIM*DIM+j*DIM+v]) + 1;
        }
    }
}

/* Create environment */
error = GRBloadenv(&env, "sudoku.log");
if (error) goto QUIT;

/* Create new model */

error = GRBnewmodel(env, &model, "sudoku", DIM*DIM*DIM, NULL, lb, NULL, vtype, names);
if (error) goto QUIT;

/* Each cell gets a value */

for (i = 0; i < DIM; i++) {
  for (j = 0; j < DIM; j++) {
    for (v = 0; v < DIM; v++) {
      ind[v] = i*DIM*DIM + j*DIM + v;
      val[v] = 1.0;
    }

    error = GRBaddconstr(model, DIM, ind, val, GRB_EQUAL, 1.0, NULL);
    if (error) goto QUIT;
  }
}

/* Each value must appear once in each row */

for (v = 0; v < DIM; v++) {
  for (j = 0; j < DIM; j++) {
    for (i = 0; i < DIM; i++) {
      ind[i] = i*DIM*DIM + j*DIM + v;
      val[i] = 1.0;
    }

    error = GRBaddconstr(model, DIM, ind, val, GRB_EQUAL, 1.0, NULL);
    if (error) goto QUIT;
  }
}

/* Each value must appear once in each column */

for (v = 0; v < DIM; v++) {
  for (i = 0; i < DIM; i++) {
    for (j = 0; j < DIM; j++) {
      ind[j] = i*DIM*DIM + j*DIM + v;
      val[j] = 1.0;
    }

    error = GRBaddconstr(model, DIM, ind, val, GRB_EQUAL, 1.0, NULL);
    if (error) goto QUIT;
  }
}

/* Each value must appear once in each subgrid */

for (v = 0; v < DIM; v++) {
  for (ig = 0; ig < SUBDIM; ig++) {
for (jg = 0; jg < SUBDIM; jg++) {
    count = 0;
    for (i = ig*SUBDIM; i < (ig+1)*SUBDIM; i++) {
        for (j = jg*SUBDIM; j < (jg+1)*SUBDIM; j++) {
            ind[count] = i*DIM*DIM + j*DIM + v;
            val[count] = 1.0;
            count++;
        }
    }
    error = GRBaddconstr(model, DIM, ind, val, GRB_EQUAL, 1.0, NULL);
    if (error) goto QUIT;
}

/* Optimize model */
error = GRBoptimize(model);
if (error) goto QUIT;

/* Write model to 'sudoku.lp' */
error = GRBwrite(model, "sudoku.lp");
if (error) goto QUIT;

/* Capture solution information */
error = GRBgetintattr(model, GRB_INT_ATTR_STATUS, &optimstatus);
if (error) goto QUIT;
error = GRBgetdblattr(model, GRB_DBL_ATTR_OBJVAL, &objval);
if (error) goto QUIT;

printf("\nOptimization complete\n");
if (optimstatus == GRB_OPTIMAL)
    printf("Optimal objective: %.4e\n", objval);
else if (optimstatus == GRB_INF_OR_UNBD)
    printf("Model is infeasible or unbounded\n");
else
    printf("Optimization was stopped early\n");
printf("\n");

QUIT:

/* Error reporting */
if (error) {
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}
fclose(fp);
/* Free model */
GRBfreemodel(model);
/* Free environment */
GRBfreeenv(env);
return 0;
}
tsp_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* Solve a traveling salesman problem on a randomly generated set of points using lazy constraints. The base MIP model only includes 'degree-2' constraints, requiring each node to have exactly two incident edges. Solutions to this model may contain subtours - tours that don't visit every node. The lazy constraint callback adds new constraints to cut them off. */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include "gurobi_c.h"

/* Define structure to pass data to the callback function */

struct callback_data {
    int n;
};

/* Given an integer-feasible solution 'sol', find the smallest sub-tour. Result is returned in 'tour', and length is returned in 'tourlenP'. */

static void findsubtour(int n, double *sol, int *tourlenP, int *tour)
{
    int i, node, len, start;
    int bestind, bestlen;
    int *seen = NULL;

    seen = (int *) malloc(n*sizeof(int));
    if (seen == NULL) {
        fprintf(stderr, "Out of memory\n");
        exit(1);
    }

    for (i = 0; i < n; i++)
seen[i] = 0;

start = 0;
bestlen = n+1;
bestind = -1;
while (start < n) {
    for (node = 0; node < n; node++)
        if (seen[node] == 0)
            break;
    if (node == n)
        break;
    for (len = 0; len < n; len++) {
        tour[start+len] = node;
        seen[node] = 1;
        for (i = 0; i < n; i++)
            if (sol[node*n+i] > 0.5 && !seen[i]) {
                node = i;
                break;
            }
    }
    if (i == n) {
        len++;
        if (len < bestlen) {
            bestlen = len;
            bestind = start;
        }
        start += len;
        break;
    }
}
for (i = 0; i < bestlen; i++)
    tour[i] = tour[bestind+i];
*tourlenP = bestlen;
free(seen);

/* Subtour elimination callback. Whenever a feasible solution is found, 
   find the shortest subtour, and add a subtour elimination constraint 
   if that tour doesn’t visit every node. */

int __stdcall subtourelim(GRBmodel *model, 
    void *cbdata, 
    int where, 
    void *usrdata)
{
    struct callback_data *mydata = (struct callback_data *) usrdata;
    int n = mydata->n;
    int *tour = NULL;
    double *sol = NULL;
    int i, j, len, nz;
    int error = 0;
if (where == GRB_CB_MIPSOL) {
    sol = (double *) malloc(n*n*sizeof(double));
    tour = (int *) malloc(n*sizeof(int));
    if (sol == NULL || tour == NULL) {
        fprintf(stderr, "Out of memory\n");
        exit(1);
    }
    GRBcbget(cbdata, where, GRB_CB_MIPSOL_SOL, sol);
    findsubtour(n, sol, &len, tour);
    if (len < n) {
        int *ind = NULL;
        double *val = NULL;
        ind = (int *) malloc(len*(len-1)/2*sizeof(int));
        val = (double *) malloc(len*(len-1)/2*sizeof(double));
        if (ind == NULL || val == NULL) {
            fprintf(stderr, "Out of memory\n");
            exit(1);
        }
        /* Add subtour elimination constraint */
        nz = 0;
        for (i = 0; i < len; i++)
            for (j = i+1; j < len; j++)
                ind[nz++] = tour[i]*n+tour[j];
        for (i = 0; i < nz; i++)
            val[i] = 1.0;
        error = GRBcblazy(cbdata, nz, ind, val, GRB_LESS_EQUAL, len-1);
        free(ind);
        free(val);
    }
    free(sol);
    free(tour);
}
return error;
}
/* Euclidean distance between points 'i' and 'j'. */
static double
distance(double *x, double *y, int i, int j) {
    double dx = x[i] - x[j];
}
double dy = y[i] - y[j];

    return sqrt(dx*dx + dy*dy);
}

int main(int argc,
    char *argv[])
{
    GRBenv *env = NULL;
    GRBmodel *model = NULL;
    int i, j, len, n, solcount;
    int error = 0;
    char name[100];
    double *x = NULL;
    double *y = NULL;
    int *ind = NULL;
    double *val = NULL;
    struct callback_data mydata;

    if (argc < 2) {
        fprintf(stderr, "Usage: tsp_c size\n");
        exit(1);
    }

    n = atoi(argv[1]);
    if (n == 0) {
        fprintf(stderr, "Argument must be a positive integer.\n");
    } else if (n > 100) {
        printf("It will be a challenge to solve a TSP this large.\n");
    }

    x = (double *) malloc(n*sizeof(double));
    y = (double *) malloc(n*sizeof(double));
    ind = (int *) malloc(n*sizeof(int));
    val = (double *) malloc(n*sizeof(double));

    if (x == NULL || y == NULL || ind == NULL || val == NULL) {
        fprintf(stderr, "Out of memory\n");
        exit(1);
    }

    /* Create random points */
    for (i = 0; i < n; i++) {
        x[i] = ((double) rand())/RAND_MAX;
        y[i] = ((double) rand())/RAND_MAX;
    }

    /* Create environment */
    error = GRBloadenv(&env, "tsp.log");
    if (error) goto QUIT;

    /* Create an empty model */
error = GRBnewmodel(env, &model, "tsp", 0, NULL, NULL, NULL, NULL, NULL);
if (error) goto QUIT;

/* Add variables - one for every pair of nodes */
/* Note: If edge from i to j is chosen, then x[i*n+j] = x[j*n+i] = 1. */
/* The cost is split between the two variables. */

for (i = 0; i < n; i++) {
    for (j = 0; j < n; j++) {
        sprintf(name, "x_%d_%d", i, j);
        error = GRBaddvar(model, 0, NULL, NULL, distance(x, y, i, j)/2,
                          0.0, 1.0, GRB_BINARY, name);
        if (error) goto QUIT;
    }
}

/* Degree-2 constraints */

for (i = 0; i < n; i++) {
    for (j = 0; j < n; j++) {
        ind[j] = i*n+j;
        val[j] = 1.0;
    }

    sprintf(name, "deg2_%d", i);
    error = GRBaddconstr(model, n, ind, val, GRB_EQUAL, 2, name);
    if (error) goto QUIT;
}

/* Forbid edge from node back to itself */

for (i = 0; i < n; i++) {
    error = GRBsetdblattrelement(model, GRB_DBL_ATTR_UB, i*n+i, 0);
    if (error) goto QUIT;
}

/* Symmetric TSP */

for (i = 0; i < n; i++) {
    for (j = 0; j < i; j++) {
        ind[0] = i*n+j;
        ind[1] = i+j*n;
        val[0] = 1;
        val[1] = -1;
        error = GRBaddconstr(model, 2, ind, val, GRB_EQUAL, 0, NULL);
        if (error) goto QUIT;
    }
}

/* Set callback function */

mydata.n = n;
error = GRBsetcallbackfunc(model, subtourelim, (void *) &mydata);
if (error) goto QUIT;

/* Must set LazyConstraints parameter when using lazy constraints */
error = GRBsetintparam (GRBgetenv(model), GRB_INT_PAR_LAZYCONSTRAINTS, 1);
if (error) goto QUIT;

/* Optimize model */
error = GRBoptimize(model);
if (error) goto QUIT;

/* Extract solution */
error = GRBgetintattr(model, GRB_INT_ATTR_SOLCOUNT, &solcount);
if (error) goto QUIT;
if (solcount > 0) {
    int *tour = NULL;
    double *sol = NULL;
    sol = (double *) malloc(n*n*sizeof(double));
    tour = (int *) malloc(n*sizeof(int));
    if (sol == NULL || tour == NULL) {
        fprintf(stderr, "Out of memory\n");
        exit(1);
    }
    error = GRBgetdblattrarray(model, GRB_DBL_ATTR_X, 0, n*n, sol);
    if (error) goto QUIT;

    /* Print tour */
    findsubtour(n, sol, &len, tour);

    printf("Tour: ");
    for (i = 0; i < len; i++)
        printf("%d ", tour[i]);
    printf("\n");
    free(tour);
    free(sol);
}
QUIT:

/* Free data */
free(x);
free(y);
free(ind);
free(val);

/* Error reporting */
if (error) {
printf("ERROR: %s\n", GRBgeterrormsg(env));
exit(1);
}

/* Free model */
GRBfreemodel(model);
/* Free environment */
GRBfreeenv(env);
return 0;
}

tune_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads a model from a file and tunes it. It then writes the best parameter settings to a file and solves the model using these parameters. */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include "gurobi_c.h"

int main(int argc, char *argv[])
{
    GRBenv *env = NULL;
    GRBmodel *model = NULL;
    int tuneresultcount;
    int error = 0;

    if (argc < 2) {
        fprintf(stderr, "Usage: tune_c filename
");
        exit(1);
    }

    /* Create environment */

    error = GRBloadenv(&env, "tune_c.log");
    if (error) goto QUIT;

    /* Read model from file */

    error = GRBreadmodel(env, argv[1], &model);
    if (error) goto QUIT;

    /* Set the TuneResults parameter to 1 */

    error = GRBsetintparam(GRBgetenv(model), GRB_INT_PAR_TUNERESULTS, 1);
    if (error) goto QUIT;
/* Tune the model */

error = GRBtunemodel(model);
if (error) goto QUIT;

/* Get the number of tuning results */

error = GRBgetintattr(model, GRB_INT_ATTR_TUNE_RESULTCOUNT, &tuneresultcount);
if (error) goto QUIT;

if (tuneresultcount > 0) {
    /* Load the best tuned parameters into the model's environment */
    error = GRBgettuneresult(model, 0);
    if (error) goto QUIT;

    /* Write tuned parameters to a file */
    error = GRBwrite(model, "tune.prm");
    if (error) goto QUIT;

    /* Solve the model using the tuned parameters */
    error = GRBoptimize(model);
    if (error) goto QUIT;
}

QUIT:

/* Error reporting */

if (error) {
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free model */

GRBfreemodel(model);

/* Free environment */

GRBfreeenv(env);

return 0;

workforce1_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a particular day. If the problem cannot be solved, use IIS to find a set of conflicting constraints. Note that there may be additional conflicts */
besides what is reported via IIS. */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include "gurobi_c.h"

#define xcol(w,s) nShifts*w+s
#define MAXSTR 128

int
main(int argc, char *argv[])
{
  GRBenv *env = NULL;
  GRBmodel *model = NULL;
  int error = 0, status;
  int s, w, col;
  int *cbeg = NULL;
  int *cind = NULL;
  int idx;
  double *cval = NULL;
  char *sense = NULL;
  char vname[MAXSTR];
  double obj;
  int i, iis, numconstrs;
  char *cname;

  /* Sample data */
  const int nShifts = 14;
  const int nWorkers = 7;

  /* Sets of days and workers */
  char* Shifts[] =
  char* Workers[] =

  /* Number of workers required for each shift */
  double shiftRequirements[] =
  { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

  /* Amount each worker is paid to work one shift */
  double pay[] = { 10, 12, 10, 8, 8, 9, 11 };

  /* Worker availability: 0 if the worker is unavailable for a shift */
  double availability[][14] =
  { { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
    { 1, 1, 0, 0, 1, 0, 1, 0, 1, 0, 1, 0, 0 },
    { 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
    { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
    { 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 0, 1 },
    { 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 0, 1 };

  /* Sample data */
  const int nShifts = 14;
  const int nWorkers = 7;

  /* Sets of days and workers */
  char* Shifts[] =
  char* Workers[] =

  /* Number of workers required for each shift */
  double shiftRequirements[] =
  { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

  /* Amount each worker is paid to work one shift */
  double pay[] = { 10, 12, 10, 8, 8, 9, 11 };

  /* Worker availability: 0 if the worker is unavailable for a shift */
  double availability[][14] =
  { { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
    { 1, 1, 0, 0, 1, 0, 1, 0, 1, 0, 1, 0, 0 },
    { 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
    { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
    { 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 0, 1 },
    { 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 0, 1 },
/* Create environment */
error = GRBloadenv(&env, "workforce1.log");
if (error) goto QUIT;

/* Create initial model */
error = GRBnewmodel(env, &model, "workforce1", nWorkers * nShifts,
NULL, NULL, NULL, NULL, NULL);
if (error) goto QUIT;

/* Initialize assignment decision variables:
x[w][s] == 1 if worker w is assigned
    to shift s. Since an assignment model always produces integer
    solutions, we use continuous variables and solve as an LP. */
for (w = 0; w < nWorkers; ++w)
{
    for (s = 0; s < nShifts; ++s)
    {
        col = xcol(w, s);
        sprintf(vname, "%s.%s", Workers[w], Shifts[s]);
        error = GRBsetdblattrelement(model, "UB", col, availability[w][s]);
        if (error) goto QUIT;
        error = GRBsetdblattrelement(model, "Obj", col, pay[w]);
        if (error) goto QUIT;
        error = GRBsetstrattrelement(model, "VarName", col, vname);
        if (error) goto QUIT;
    }
}

/* The objective is to minimize the total pay costs */
error = GRBsetintattr(model, "ModelSense", GRB_MINIMIZE);
if (error) goto QUIT;

/* Make space for constraint data */
cbeg = malloc(sizeof(int) * nShifts);
if (!cbeg) goto QUIT;
cind = malloc(sizeof(int) * nShifts * nWorkers);
if (!cind) goto QUIT;
cval = malloc(sizeof(double) * nShifts * nWorkers);
if (!cval) goto QUIT;
sense = malloc(sizeof(char) * nShifts);
if (!sense) goto QUIT;

/* Constraint: assign exactly shiftRequirements[s] workers
    to each shift s */
idx = 0;
for (s = 0; s < nShifts; ++s)
{
    cbeg[s] = idx;
    sense[s] = GRB_EQUAL;
    for (w = 0; w < nWorkers; ++w)
    {
        cind[idx] = xcol(w, s);
        cval[idx++] = 1.0;
    }
}
error = GRBaddconstrs(model, nShifts, idx, cbeg, cind, cval, sense, shiftRequirements, Shifts);
if (error) goto QUIT;

/* Optimize */
error = GRBoptimize(model);
if (error) goto QUIT;
error = GRBgetintattr(model, "Status", &status);
if (error) goto QUIT;
if (status == GRB_UNBOUNDED)
{
    printf("The model cannot be solved because it is unbounded\n");
    goto QUIT;
}
if (status == GRB_OPTIMAL)
{
    error = GRBgetdblattr(model, "ObjVal", &obj);
    if (error) goto QUIT;
    printf("The optimal objective is %f\n", obj);
    goto QUIT;
}
if ((status != GRB_INF_OR_UNBD) && (status != GRB_INFEASIBLE))
{
    printf("Optimization was stopped with status %i\n", status);
    goto QUIT;
}

/* do IIS */
printf("The model is infeasible; computing IIS\n");
error = GRBcomputeIIS(model);
if (error) goto QUIT;
printf("\nThe following constraint(s) cannot be satisfied: \n");
error = GRBgetintattr(model, "NumConstrs", &numconstrs);
if (error) goto QUIT;
for (i = 0; i < numconstrs; ++i)
{
    error = GRBgetintattrelement(model, "IISConstr", i, &iis);
    if (error) goto QUIT;
    if (iis)
    {
        error = GRBgetstrattrelement(model, "ConstrName", i, &cname);
        if (error) goto QUIT;
        printf("%s\n", cname);
    }
}
QUIT:

/* Error reporting */
if (error)
{
printf("ERROR: %s\n", GRBgeterrormsg(env));
exit(1);
}

/* Free data */
free(cbeg);
free(cind);
free(cval);
free(sense);

/* Free model */
GRBfreemodel(model);

/* Free environment */
GRBfreeenv(env);

return 0;
}

workforce2_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a
particular day. If the problem cannot be solved, use IIS iteratively to
find all conflicting constraints. */

#include "stdlib.h"
#include "stdio.h"
#include "math.h"
#include "string.h"
#include "gurobi_c.h"

#define xcol(w,s) nShifts*w+s
#define MAXSTR 128

int
main(int argc,
     char *argv[])
{
  GRBenv *env = NULL;
  GRBmodel *model = NULL;
  int error = 0, status;
  int s, w, col;
  int *cbeg = NULL;
  int *cind = NULL;
  int idx;
  double *cval = NULL;
  char *sense = NULL;
  char vname[MAXSTR];
  double obj;
int i, iis, numconstrs, numremoved = 0;
char *cname;
char **removed = NULL;

/* Sample data */
const int nShifts = 14;
const int nWorkers = 7;

/* Sets of days and workers */
char* Shifts[] =
{ "Mon1", "Tue2", "Wed3", "Thu4", "Fri5", "Sat6",
  "Sun7", "Mon8", "Tue9", "Wed10", "Thu11", "Fri12", "Sat13",
  "Sun14" };
char* Workers[] =

/* Number of workers required for each shift */
double shiftRequirements[] =
{ 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

/* Amount each worker is paid to work one shift */
double pay[] = { 10, 12, 10, 8, 8, 9, 11 };

/* Worker availability: 0 if the worker is unavailable for a shift */
double availability[][14] =
{ { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
  { 1, 1, 0, 0, 1, 0, 1, 0, 0, 0, 1, 0, 1, 0 },
  { 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1 },
  { 0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1 },
  { 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
  { 1, 1, 1, 1, 0, 1, 0, 1, 1, 0, 1, 0, 1, 1 },
  { 0, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1 },
  { 1, 1, 1, 0, 0, 1, 0, 1, 1, 0, 1, 0, 1, 1 },
  { 1, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 } };

/* Create environment */
error = GRBloadenv(&env, "workforce2.log");
if (error) goto QUIT;

/* Create initial model */
error = GRBnewmodel(env, &model, "workforce2", nWorkers * nShifts,
  NULL, NULL, NULL, NULL, NULL);
if (error) goto QUIT;

/* Initialize assignment decision variables:
x[w][s] == 1 if worker w is assigned
to shift s. Since an assignment model always produces integer
solutions, we use continuous variables and solve as an LP. */
for (w = 0; w < nWorkers; ++w)
{
  for (s = 0; s < nShifts; ++s)
  {
    col = xcol(w, s);
sprintf(vname, "%s.%s", Workers[w], Shifts[s]);
error = GRBsetdblattrelement(model, "UB", col, availability[w][s]);
if (error) goto QUIT;
error = GRBsetdblattrelement(model, "Obj", col, pay[w]);
if (error) goto QUIT;
error = GRBsetstrattrelement(model, "VarName", col, vname);
if (error) goto QUIT;
}

/* The objective is to minimize the total pay costs */
error = GRBsetintattr(model, "ModelSense", GRB_MINIMIZE);
if (error) goto QUIT;

/* Make space for constraint data */
cbeg = malloc(sizeof(int) * nShifts);
if (!cbeg) goto QUIT;
cind = malloc(sizeof(int) * nShifts * nWorkers);
if (!cind) goto QUIT;
cval = malloc(sizeof(double) * nShifts * nWorkers);
if (!cval) goto QUIT;
sense = malloc(sizeof(char) * nShifts);
if (!sense) goto QUIT;

/* Constraint: assign exactly shiftRequirements[s] workers to each shift s */
idx = 0;
for (s = 0; s < nShifts; ++s)
{
    cbeg[s] = idx;
    sense[s] = GRB_EQUAL;
    for (w = 0; w < nWorkers; ++w)
    {
        cind[idx] = xcol(w, s);
        cval[idx++] = 1.0;
    }
}
error = GRBaddconstrs(model, nShifts, idx, cbeg, cind, cval, sense,
                       shiftRequirements, Shifts);
if (error) goto QUIT;

/* Optimize */
error = GRBoptimize(model);
if (error) goto QUIT;
error = GRBgetintattr(model, "Status", &status);
if (error) goto QUIT;
if (status == GRB_UNBOUNDED)
{
    printf("The model cannot be solved because it is unbounded\n");
    goto QUIT;
}
if (status == GRB_OPTIMAL)
{
    error = GRBgetdblattr(model, "ObjVal", &obj);
    if (error) goto QUIT;
    printf("The optimal objective is %f\n", obj);
    goto QUIT;
}
if ((status != GRB_INF_OR_UNBD) && (status != GRB_INFEASIBLE))
{
    printf("Optimization was stopped with status %i\n", status);
}
goto QUIT;
}

/* do IIS */
printf("The model is infeasible; computing IIS\n");

/* Loop until we reduce to a model that can be solved */
error = GRBgetintattr(model, "NumConstrs", &numconstrs);
if (error) goto QUIT;
removed = calloc(numconstrs, sizeof(char*));
if (!removed) goto QUIT;
while (1)
{
    error = GRBcomputeIIS(model);
    if (error) goto QUIT;
    printf("\nThe following constraint cannot be satisfied:\n");
    for (i = 0; i < numconstrs; ++i)
    {
        error = GRBgetintattrelement(model, "IISConstr", i, &iis);
        if (error) goto QUIT;
        if (iis)
        {
            error = GRBgetstrattrelement(model, "ConstrName", i, &cname);
            if (error) goto QUIT;
            printf("%s\n", cname);
            /* Remove a single constraint from the model */
            removed[numremoved] = malloc(sizeof(char) * (1+strlen(cname)));
            if (!removed[numremoved]) goto QUIT;
            strcpy(removed[numremoved++], cname);
            cind[0] = i;
            error = GRBdelconstrs(model, 1, cind);
            if (error) goto QUIT;
            break;
        }
    }
    printf("\n");
    error = GRBoptimize(model);
    if (error) goto QUIT;
    error = GRBgetintattr(model, "Status", &status);
    if (error) goto QUIT;
    if (status == GRB_UNBOUNDED)
    {
        printf("The model cannot be solved because it is unbounded\n");
        goto QUIT;
    }
    if (status == GRB_OPTIMAL)
    {
        break;
    }
    if ((status != GRB_INF_OR_UNBD) && (status != GRB_INFEASIBLE))
    {
        printf("Optimization was stopped with status %i\n", status);
        goto QUIT;
    }
}
printf("The following constraints were removed to get a feasible LP:\n");
for (i = 0; i < numremoved; ++i)
{
    printf("%s ", removed[i]);
}
printf("\n");

QUIT:

    /* Error reporting */
    if (error)
    {
        printf("ERROR: %s\n", GRBgeterrormsg(env));
        exit(1);
    }

    /* Free data */
    free(cbeg);
    free(cind);
    free(cval);
    free(sense);
    for (i=0; i<numremoved; ++i)
    {
        free(removed[i]);
    }
    free(removed);

    /* Free model */
    GRBfreemodel(model);

    /* Free environment */
    GRBfreeenv(env);

    return 0;
}

workforce3_c.c

    /* Copyright 2018, Gurobi Optimization, LLC */

    /* Assign workers to shifts; each worker may or may not be available on a
     * particular day. If the problem cannot be solved, relax the model
     * to determine which constraints cannot be satisfied, and how much
     * they need to be relaxed. */

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include <string.h>
# include "gurobi_c.h"

#define xcol(w,s) nShifts*w+s
#define MAXSTR 128

int main(int argc, char *argv[])
{
    GRBenv *env = NULL;
    GRBmodel *model = NULL;
    int error = 0, status;
    int s, w, col;
    int *cbeg = NULL;
    int *cind = NULL;
    int idx;
    double *cval = NULL;
    char *sense = NULL;
    char vname[MAXSTR];
    double obj;
    int i, j, orignumvars , numvars , numconstrs;
    double *rhspen = NULL;
    double sol;
    char *sname;

    /* Sample data */
    const int nShifts = 14;
    const int nWorkers = 7;

    /* Sets of days and workers */
    char* Shifts[] =
    { "Mon1", "Tue2", "Wed3", "Thu4", "Fri5", "Sat6",
      "Sun7", "Mon8", "Tue9", "Wed10", "Thu11", "Fri12", "Sat13",
      "Sun14" };
    char* Workers[] =

    /* Number of workers required for each shift */
    double shiftRequirements[] =
    { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

    /* Amount each worker is paid to work one shift */
    double pay[] = { 10, 12, 10, 8, 8, 9, 11 };

    /* Worker availability: 0 if the worker is unavailable for a shift */
    double availability[][14] =
    { { 0, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1 },
      { 0, 0, 0, 1, 1, 1, 0, 0, 1, 0, 0, 1, 0 },
      { 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
      { 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1 },
      { 1, 1, 1, 1, 0, 1, 0, 1, 1, 0, 1, 0, 1 },
      { 1, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
      { 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1 } };
/* Create environment */
error = GRBloadenv(&env, "workforce3.log");
if (error) goto QUIT;

/* Create initial model */
error = GRBnewmodel(env, &model, "workforce3", nWorkers * nShifts,
NULL, NULL, NULL, NULL, NULL);
if (error) goto QUIT;

/* Initialize assignment decision variables:
x[w][s] == 1 if worker w is assigned
to shift s. Since an assignment model always produces integer
solutions, we use continuous variables and solve as an LP. */
for (w = 0; w < nWorkers; ++w)
{
    for (s = 0; s < nShifts; ++s)
    {
        col = xcol(w, s);
        sprintf(vname, "%s.%s", Workers[w], Shifts[s]);
        error = GRBsetdblattrelement(model, "UB", col, availability[w][s]);
        if (error) goto QUIT;
        error = GRBsetdblattrelement(model, "Obj", col, pay[w]);
        if (error) goto QUIT;
        error = GRBsetstrattrelement(model, "VarName", col, vname);
        if (error) goto QUIT;
    }
}

/* The objective is to minimize the total pay costs */
error = GRBsetintattr(model, "ModelSense", GRB_MINIMIZE);
if (error) goto QUIT;

/* Make space for constraint data */
cbeg = malloc(sizeof(int) * nShifts);
if (!cbeg) goto QUIT;
cind = malloc(sizeof(int) * nShifts * nWorkers);
if (!cind) goto QUIT;
cval = malloc(sizeof(double) * nShifts * nWorkers);
if (!cval) goto QUIT;
sense = malloc(sizeof(char) * nShifts);
if (!sense) goto QUIT;

/* Constraint: assign exactly shiftRequirements[s] workers
to each shift s */
idx = 0;
for (s = 0; s < nShifts; ++s)
{
    cbeg[s] = idx;
    sense[s] = GRB_EQUAL;
    for (w = 0; w < nWorkers; ++w)
    {
        cind[idx] = xcol(w, s);
        cval[idx++] = 1.0;
    }
}
error = GRBaddconstrs(model, nShifts, idx, cbeg, cind, cval, sense,
shiftRequirements, Shifts);

if (error) goto QUIT;

/* Optimize */
error = GRBoptimize(model);
if (error) goto QUIT;
error = GRBgetintattr(model, "Status", &status);
if (error) goto QUIT;
if (status == GRB_UNBOUNDED)
{
    printf("The model cannot be solved because it is unbounded\n");
goTo QUIT;
}
if (status == GRB_OPTIMAL)
{
    error = GRBgetdblattr(model, "ObjVal", &obj);
    if (error) goto QUIT;
    printf("The optimal objective is %f\n", obj);
goTo QUIT;
}
if ((status != GRB_INF_OR_UNBD) && (status != GRB_INFEASIBLE))
{
    printf("Optimization was stopped with status %i\n", status);
goTo QUIT;
}

/* Relax the constraints to make the model feasible */
printf("The model is infeasible; relaxing the constraints\n");

/* Determine the matrix size before relaxing the constraints */
error = GRBgetintattr(model, "NumVars", &orignumvars);
if (error) goto QUIT;
error = GRBgetintattr(model, "NumConstrs", &numconstrs);
if (error) goto QUIT;

/* Use FeasRelax feature with penalties for constraint violations */
rhspen = malloc(sizeof(double) * numconstrs);
if (!rhspen) goto QUIT;
for (i = 0; i < numconstrs; i++) rhspen[i] = 1;
error = GRBfeasrelax(model, GRB_FEASRELAX_LINEAR, 0,
    NULL, NULL, rhspen, NULL);
if (error) goto QUIT;
error = GRBoptimize(model);
if (error) goto QUIT;
error = GRBgetintattr(model, "Status", &status);
if (error) goto QUIT;
if ((status == GRB_INF_OR_UNBD) || (status == GRB_INFEASIBLE) ||
    (status == GRB_UNBOUNDED))
{
    printf("The relaxed model cannot be solved "
        "because it is infeasible or unbounded\n");
goTo QUIT;
}
if (status != GRB_OPTIMAL)
{
    printf("Optimization was stopped with status %i\n", status);
goto QUIT;
}

printf("\nSlack values:\n");
error = GRBgetintattr(model, "NumVars", &numvars);
if (error) goto QUIT;
for (j = orignumvars; j < numvars; ++j)
{
    error = GRBgetdblattrelement(model, "X", j, &sol);
    if (error) goto QUIT;
    if (sol > 1e-6)
    {
        error = GRBgetstrattrelement(model, "VarName", j, &sname);
        if (error) goto QUIT;
        printf("%s = %f\n", sname, sol);
    }
}
QUIT:

/* Error reporting */
if (error)
{
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free data */
free(cbeg);
free(cind);
free(cval);
free(sense);
free(rhspen);

/* Free model */
GRBfreemodel(model);

/* Free environment */
GRBfreeenv(env);

return 0;
}

workforce4_c.c

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a particular day. We use Pareto optimization to solve the model: first, we minimize the linear sum of the slacks. Then, we constrain the sum of the slacks, and we minimize a quadratic objective that tries to balance the workload among the workers. */
#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include <string.h>
#include "gurobi_c.h"

int solveAndPrint(GRBmodel * model,
                  int nShifts, int nWorkers, char ** Workers,
                  int* status);

#define xcol(w,s) nShifts*w+s
#define slackcol(s) nShifts*nWorkers+s
#define totSlackcol nShifts*(nWorkers+1)
#define totShiftscol(w) nShifts*(nWorkers+1)+1+w
#define avgShiftscol (nShifts+1)*(nWorkers+1)
#define diffShiftscol(w) (nShifts+1)*(nWorkers+1)+1+w
#define MAXSTR 128

int main(int argc,
         char * argv[])
{
    GRBenv * env = NULL;
    GRBmodel * model = NULL;
    int error = 0, status;
    int s, w, col;
    int * cbeg = NULL;
    int * cind = NULL;
    int idx;
    double * cval = NULL;
    char * sense = NULL;
    char vname[MAXSTR], cname[MAXSTR];
    double val;

    /* Sample data */
    const int nShifts = 14;
    const int nWorkers = 7;

    /* Sets of days and workers */
    char* Shifts[] =
    char* Workers[] =

    /* Number of workers required for each shift */
    double shiftRequirements[] =
        { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5};

    /* Worker availability: 0 if the worker is unavailable for a shift */
    double availability[][14] =
        { { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
/* Create environment */
error = GRBloadenv(&env, "workforce4.log");
if (error) goto QUIT;

/* Create initial model */
error = GRBnewmodel(env, &model, "workforce4",
(nShifts + 1) * (nWorkers + 1),
NULL, NULL, NULL, NULL, NULL);
if (error) goto QUIT;

/* Initialize assignment decision variables:
x[w][s] == 1 if worker w is assigned to shift s.
This is no longer a pure assignment model, so we must
use binary variables. */
for (w = 0; w < nWorkers; ++w)
{
    for (s = 0; s < nShifts; ++s)
    {
        col = xcol(w, s);
        sprintf(vname, "%s.%s", Workers[w], Shifts[s]);
        error = GRBsetcharattrelement(model, "VType", col, GRB_BINARY);
        if (error) goto QUIT;
        error = GRBsetdblattrelement(model, "UB", col, availability[w][s]);
        if (error) goto QUIT;
        error = GRBsetstrattrelement(model, "VarName", col, vname);
        if (error) goto QUIT;
    }
}

/* Initialize slack decision variables */
for (s = 0; s < nShifts; ++s)
{
    sprintf(vname, "%sSlack", Shifts[s]);
    error = GRBsetstrattrelement(model, "VarName", slackcol(s), vname);
    if (error) goto QUIT;
}

/* Initialize total slack decision variable */
error = GRBsetstrattrelement(model, "VarName", totSlackcol, "totSlack");
if (error) goto QUIT;

/* Initialize variables to count the total shifts worked by each worker */
for (w = 0; w < nWorkers; ++w)
{
    sprintf(vname, "%sTotShifts", Workers[w]);
    error = GRBsetstrattrelement(model, "VarName", totShiftscol(w), vname);
    if (error) goto QUIT;
}
/* The objective is to minimize the sum of the slacks */
error = GRBsetintattr(model, "ModelSense", GRB_MINIMIZE);
if (error) goto QUIT;
error = GRBsetdblattrelement(model, "Obj", totSlackcol, 1.0);
if (error) goto QUIT;

/* Make space for constraint data */
cbeg = malloc(sizeof(int) * nShifts);
if (!cbeg) goto QUIT;
cind = malloc(sizeof(int) * nShifts * (nWorkers + 1));
if (!cind) goto QUIT;
cval = malloc(sizeof(double) * nShifts * (nWorkers + 1));
if (!cval) goto QUIT;
sense = malloc(sizeof(char) * nShifts);
if (!sense) goto QUIT;

/* Constraint: assign exactly shiftRequirements[s] workers to each shift s, plus the slack */
idx = 0;
for (s = 0; s < nShifts; ++s)
{
    cbeg[s] = idx;
    sense[s] = GRB_EQUAL;
    for (w = 0; w < nWorkers; ++w)
    {
        cind[idx] = xcol(w, s);
        cval[idx++] = 1.0;
    }
    cind[idx] = slackcol(s);
    cval[idx++] = 1.0;
}
error = GRBaddconstrs(model, nShifts, idx, cbeg, cind, cval, sense, shiftRequirements, Shifts);
if (error) goto QUIT;

/* Constraint: set totSlack column equal to the total slack */
idx = 0;
for (s = 0; s < nShifts; ++s)
{
    cind[idx] = slackcol(s);
    cval[idx++] = 1.0;
}
cind[idx] = totSlackcol;
cval[idx++] = -1.0;
error = GRBaddconstr(model, idx, cind, cval, GRB_EQUAL, 0.0, "totSlack");
if (error) goto QUIT;

/* Constraint: compute the total number of shifts for each worker */
for (w = 0; w < nWorkers; ++w)
{
    idx = 0;
    for (s = 0; s < nShifts; ++s)
    {
        cind[idx] = xcol(w,s);
        cval[idx++] = 1.0;
    }
}
sprintf (cname, "totShifts_s", Workers[w]);
cind[idx] = totShiftscol(w);
cval[idx++] = -1.0;
error = GRBaddconstr(model, idx, cind, cval, GRB_EQUAL, 0.0, cname);
if (error) goto QUIT;
}

/* Optimize */
error = solveAndPrint(model, nShifts, nWorkers, Workers, &status);
if (error) goto QUIT;
if (status != GRB_OPTIMAL) goto QUIT;

/* Constrain the slack by setting its upper and lower bounds */
error = GRBgetdblattrelement(model, "X", totSlackcol, &val);
if (error) goto QUIT;
error = GRBsetdblattrelement(model, "UB", totSlackcol, val);
if (error) goto QUIT;
error = GRBsetdblattrelement(model, "LB", totSlackcol, val);
if (error) goto QUIT;

/* Variable to count the average number of shifts worked */
error = GRBaddvar(model, 0, NULL, NULL, 0, 0, GRB_INFINITY, GRB_CONTINUOUS, "avgShifts");
if (error) goto QUIT;

/* Variables to count the difference from average for each worker; 
   note that these variables can take negative values. */
error = GRBaddvars(model, nWorkers, 0, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL);
if (error) goto QUIT;

for (w = 0; w < nWorkers; ++w)
{
    sprintf(vname, "%sDiff", Workers[w]);
    error = GRBsetstrattrelement(model, "VarName", diffShiftscol(w), vname);
    if (error) goto QUIT;
    error = GRBsetdblattrelement(model, "LB", diffShiftscol(w), -GRB_INFINITY);
    if (error) goto QUIT;
}

/* Constraint: compute the average number of shifts worked */
idx = 0;
for (w = 0; w < nWorkers; ++w)
{
    cind[idx] = totShiftscol(w);
    cval[idx++] = 1.0;
}
cind[idx] = avgShiftscol;
cval[idx++] = -nWorkers;
error = GRBaddconstr(model, idx, cind, cval, GRB_EQUAL, 0.0, "avgShifts");
if (error) goto QUIT;

/* Constraint: compute the difference from the average number of shifts */
for (w = 0; w < nWorkers; ++w)
{
cind[0] = totShiftscol(w);
cval[0] = 1.0;
cind[1] = avgShiftscol;
cval[1] = -1.0;
cind[2] = diffShiftscol(w);
cval[2] = -1.0;
sprintf(cname, "%sDiff", Workers[w]);
error = GRBaddconstr(model, 3, cind, cval, GRB_EQUAL, 0.0, cname);
if (error) goto QUIT;
}

/* Objective: minimize the sum of the square of the difference from the average number of shifts worked */
error = GRBsetdblattrelement(model, "Obj", totSlackcol, 0.0);
if (error) goto QUIT;

for (w = 0; w < nWorkers; ++w)
{
    cind[w] = diffShiftscol(w);
cval[w] = 1.0;
}
error = GRBaddqpterms(model, nWorkers, cind, cind, cval);
if (error) goto QUIT;

/* Optimize */
error = solveAndPrint(model, nShifts, nWorkers, Workers, &status);
if (error) goto QUIT;
if (status != GRB_OPTIMAL) goto QUIT;

QUIT:

/* Error reporting */
if (error)
{
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free data */
free(cbeg);
free(cind);
free(cval);
free(sense);

/* Free model */
GRBfreemodel(model);

/* Free environment */
GRBfreeenv(env);
return 0;
```c
int solveAndPrint ( GRBmodel * model,
                   int nShifts, int nWorkers, char** Workers,
                   int* status)
{
    int error, w;
    double val;

    error = GRBoptimize(model);
    if (error) return error;

    error = GRBgetintattr(model, "Status", status);
    if (error) return error;

    if ((*status == GRB_INF_OR_UNBD) || (*status == GRB_INFEASIBLE) ||
     (*status == GRB_UNBOUNDED))
    {
        printf("The model cannot be solved 
"          "because it is infeasible or unbounded\n");
        return 0;
    }
    if (*status != GRB_OPTIMAL)
    {
        printf("Optimization was stopped with status %i\n", *status);
        return 0;
    }

    /* Print total slack and the number of shifts worked for each worker */
    error = GRBgetdblattrelement(model, "X", totSlackcol, &val);
    if (error) return error;

    printf("\nTotal slack required: %f\n", val);
    for (w = 0; w < nWorkers; ++w)
    {
        error = GRBgetdblattrelement(model, "X", totShiftscol(w), &val);
        if (error) return error;
        printf("%s worked %f shifts\n", Workers[w], val);
    }
    printf("\n");
    return 0;
}
```

```c
/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a 
   particular day. We use multi-objective optimization to solve the model. 
The highest-priority objective minimizes the sum of the slacks 
(i.e., the total number of uncovered shifts). The secondary objective 
minimizes the difference between the maximum and minimum number of 
shifts worked among all workers. The second optimization is allowed 
to degrade the first objective by up to the smaller value of 10% and 2 */
```
```c
#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include <string.h>
#include "gurobi_c.h"

int solveAndPrint(GRBmodel * model,
        int nShifts, int nWorkers, char ** Workers,
        int* status);

#define xcol(w,s) nShifts*w+s
#define slackcol(s) nShifts*nWorkers+s
#define totSlackcol nShifts*(nWorkers+1)
#define totShiftscol(w) nShifts*(nWorkers+1)+1+w
#define minShiftcol (nShifts+1)*(nWorkers+1)
#define maxShiftcol (nShifts+1)*(nWorkers+1)+1
#define MAXSTR 128

int main(int argc, char *argv[])
{
    GRBenv * env = NULL;
    GRBenv * menv = NULL;
    GRBmodel * model = NULL;
    int error = 0, status = 0;
    int s, w, col;
    int *cbeg = NULL;  // Column beginnings
    int *cind = NULL;  // Column indices
    int idx;
    double *cval = NULL;  // Column values
    char *sense = NULL;
    char vname[MAXSTR], cname[MAXSTR];

    /* Sample data */
    const int nShifts = 14;
    const int nWorkers = 8;

    /* Sets of days and workers */
    char *Shifts[] =
    { "Mon1", "Tue2", "Wed3", "Thu4", "Fri5", "Sat6",
      "Sun7", "Mon8", "Tue9", "Wed10", "Thu11", "Fri12", "Sat13",
      "Sun14" ];
    char *Workers[] =

    /* Number of workers required for each shift */
    double shiftRequirements[] =
    { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

    /* Worker availability: 0 if the worker is unavailable for a shift */
    double availability[][14] =
    { { 0, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1 },
      { 1, 1, 0, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1 } },
```

---

113
/* Create environment */
error = GRBloadenv(& env , "workforce5.log");
if (error) goto QUIT;

/* Create initial model */
error = GRBnewmodel(env , & model , "workforce5",
 (nShifts + 1) * (nWorkers + 1) + 2,
 NULL , NULL , NULL , NULL , NULL);
if (error) goto QUIT;

/* get model environment */
menv = GRBgetenv(model);
if (!menv) {
 fprintf(stderr , " Error : could not get model environment \n");
goto QUIT;
}

/* Initialize assignment decision variables :
 x[w][s] == 1 if worker w is assigned to shift s.
 This is no longer a pure assignment model, so we must
 use binary variables. */
for (w = 0; w < nWorkers ; ++w)
{
 for (s = 0; s < nShifts ; ++s)
 { 
   col = xcol(w, s);
   sprintf(vname , "%s.%s", Workers[w], Shifts[s]);
   error = GRBsetcharattrelement(model , "VType", col , GRB_BINARY);
   if (error) goto QUIT;
   error = GRBsetdblattrelement(model , "UB", col , availability[w][s]);
   if (error) goto QUIT;
   error = GRBsetstrattrelement(model , "VarName", col , vname);
   if (error) goto QUIT;
 }
 }

/* Initialize slack decision variables */
for (s = 0; s < nShifts; ++s)
{
  sprintf(vname , "%sSlack", Shifts[s]);
  error = GRBsetstrattrelement(model , "VarName", slackcol(s), vname);
  if (error) goto QUIT;
}

/* Initialize total slack decision variable */
error = GRBsetstrattrelement(model , "VarName", totSlackcol, "totSlack");
if (error) goto QUIT;
/* Initialize variables to count the total shifts worked by each worker */
for (w = 0; w < nWorkers; ++w)
{
    sprintf(vname, "%sTotShifts", Workers[w]);
    error = GRBsetstrattrelement(model, "VarName", totShiftscol(w), vname);
    if (error) goto QUIT;
}

/* Initialize max and min # shifts variables */
sprintf(vname, " minShifts ");
error = GRBsetstrattrelement(model, "VarName", minShiftcol, vname);
sprintf(vname, " maxShifts ");
error = GRBsetstrattrelement(model, "VarName", maxShiftcol, vname);

/* Make space for constraint data */
  cbeg = malloc(sizeof(int) * nShifts);
  if (! cbeg) goto QUIT;
  cind = malloc(sizeof(int) * nShifts * (nWorkers + 1));
  if (! cind) goto QUIT;
  cval = malloc(sizeof(double) * nShifts * (nWorkers + 1));
  if (! cval) goto QUIT;
  sense = malloc(sizeof(char) * (nShifts + nWorkers));
  if (! sense) goto QUIT;

/* Constraint: assign exactly shiftRequirements[s] workers to each shift s, plus the slack */
idx = 0;
for (s = 0; s < nShifts; ++s)
{
    cbeg[s] = idx;
    sense[s] = GRB_EQUAL;
    for (w = 0; w < nWorkers; ++w)
    {
        cind[idx] = xcol(w, s);
        cval[idx++] = 1.0;
    }
    cind[idx] = slackcol(s);
    cval[idx++] = 1.0;
}
error = GRBaddconstrs(model, nShifts, idx, cbeg, cind, cval, sense, shiftRequirements, Shifts);
if (error) goto QUIT;

/* Constraint: set totSlack column equal to the total slack */
idx = 0;
for (s = 0; s < nShifts; ++s)
{
    cind[idx] = slackcol(s);
    cval[idx++] = 1.0;
}
  cind[idx] = totSlackcol;
  cval[idx++] = -1.0;
error = GRBaddconstr(model, idx, cind, cval, GRB_EQUAL, 0.0, "totSlack");
if (error) goto QUIT;
/* Constraint: compute the total number of shifts for each worker */
for (w = 0; w < nWorkers; ++w)
{
    idx = 0;
    for (s = 0; s < nShifts; ++s)
    {
        cind[idx] = xcol(w,s);
        cval[idx++] = 1.0;
    }
    sprintf(cname, "totShifts%s", Workers[w]);
    cind[idx] = totShiftscol(w);
    cval[idx++] = -1.0;
    error = GRBaddconstr(model, idx, cind, cval, GRB_EQUAL, 0.0, cname);
    if (error) goto QUIT;
}

/* Constraint: set minShift/maxShift variable to less <=/=> to the
* number of shifts among all workers */
for (w = 0; w < nWorkers; w++) {
    cind[w] = totShiftscol(w);
}
error = GRBaddgenconstrMin(model, NULL, minShiftcol, nWorkers, cind, GRB_INFINITY);
if (error) goto QUIT;
error = GRBaddgenconstrMax(model, NULL, maxShiftcol, nWorkers, cind, -GRB_INFINITY);
if (error) goto QUIT;

/* Set global sense for ALL objectives */
error = GRBsetintattr(model, GRB_INT_ATTR_MODELSENSE, GRB_MINIMIZE);
if (error) goto QUIT;

/* Set primary objective */
cind[0] = totSlackcol;
cval[0] = 1.0;
error = GRBsetobjectiven(model, 0, 2, 1.0, 2.0, 0.10, "TotalSlack", 0.0, 1, cind, cval);
if (error) goto QUIT;

/* Set secondary objective */
cind[0] = maxShiftcol;
cval[0] = 1.0;
cind[1] = minShiftcol;
cval[1] = -1.0;
error = GRBsetobjectiven(model, 1, 1, 1.0, 0, 0, "Fairness", 0.0, 2, cind, cval);
if (error) goto QUIT;

/* Save problem */
error = GRBwrite(model, "workforce5.lp");
if (error) goto QUIT;
error = GRBwrite(model, "workforce5.mps");
if (error) goto QUIT;

/* Optimize */
error = solveAndPrint(model, nShifts, nWorkers, Workers, & status);
if (error) goto QUIT;
if (status != GRB_OPTIMAL) goto QUIT;
QUIT:

/* Error reporting */

if (error)
{
    printf("ERROR: %s\n", GRBgeterrormsg(env));
    exit(1);
}

/* Free data */

free(cbeg);
free(cind);
free(cval);
free(sense);

/* Free model */

GRBfreemodel(model);

/* Free environment */

GRBfreeenv(env);

return 0;

int solveAndPrint(GRBmodel* model,
                int nShifts, int nWorkers, char** Workers,
                int* status)
{
    int error, w;
    double val;

    error = GRBoptimize(model);
    if (error) return error;

    error = GRBgetintattr(model, "Status", status);
    if (error) return error;

    if ((*status == GRB_INF_OR_UNBD) || (*status == GRB_INFEASIBLE) ||
        (*status == GRB_UNBOUNDED))
    {
        printf("The model cannot be solved "
               "because it is infeasible or unbounded\n");
        return 0;
    }  
    if (*status != GRB_OPTIMAL)
    {
        printf("Optimization was stopped with status %i\n", *status);
        return 0;
    }
/* Print total slack and the number of shifts worked for each worker */
error = GRBgetdblattrelement(model, "X", totSlackcol, &val);
if (error) return error;

printf("\nTotal slack required: %f\n", val);
for (w = 0; w < nWorkers; ++w)
{
  error = GRBgetdblattrelement(model, "X", totShiftscol(w), &val);
  if (error) return error;
  printf("%s worked %f shifts\n", Workers[w], val);
}
printf("\n");
return 0;

3.2 C++ Examples

This section includes source code for all of the Gurobi C++ examples. The same source code can be found in the examples/c++ directory of the Gurobi distribution.

callback_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/*
 This example reads a model from a file, sets up a callback that monitors optimization progress and implements a custom termination strategy, and outputs progress information to the screen and to a log file.

The termination strategy implemented in this callback stops the optimization of a MIP model once at least one of the following two conditions have been satisfied:
  1) The optimality gap is less than 10%
  2) At least 10000 nodes have been explored, and an integer feasible solution has been found.

Note that termination is normally handled through Gurobi parameters (MIPGap, Nodelimit, etc.). You should only use a callback for termination if the available parameters don't capture your desired termination criterion.
*/

#include "gurobi_c++.h"
#include <fstream>
#include <cmath>
using namespace std;

class mycallback: public GRBCallback
{
public:
  double lastiter;
  double lastnode;
  int numvars;
  GRBVar* vars;
  ofstream* logfile;

...


```c++
mycallback(int xnumvars, GRBVar* xvars, ofstream* xlogfile) {
  lastiter = lastnode = -GRB_INFINITY;
  numvars = xnumvars;
  vars = xvars;
  logfile = xlogfile;
}

protected:
void callback () {
  try {
    if (where == GRB_CB_POLLING) {
      // Ignore polling callback
    } else if (where == GRB_CB_PRESOLVE) {
      // Presolve callback
      int cdels = getIntInfo(GRB_CB_PRE_COLDEL);
      int rdels = getIntInfo(GRB_CB_PRE_ROWDEL);
      if (cdels || rdels) {
        cout << cdels << " columns and " << rdels
             << " rows are removed" << endl;
      }
    } else if (where == GRB_CB_SIMPLEX) {
      // Simplex callback
      double itcnt = getDoubleInfo(GRB_CB_SPX_ITRCNT);
      if (itcnt - lastiter >= 100) {
        lastiter = itcnt;
        double obj = getDoubleInfo(GRB_CB_SPX_OBJVAL);
        int ispert = getIntInfo(GRB_CB_SPX_ISPERT);
        double pinf = getDoubleInfo(GRB_CB_SPX_PRIMINF);
        double dinf = getDoubleInfo(GRB_CB_SPX_DUALINF);
        char ch;
        if (ispert == 0) ch = ' ';
        else if (ispert == 1) ch = 'S';
        else ch = 'P';
        cout << itcnt << " " << obj << ch << " 
             << pinf << " " << dinf << endl;
      }
    } else if (where == GRB_CB_MIP) {
      // General MIP callback
      double nodedcnt = getDoubleInfo(GRB_CB_MIP_NODCNT);
      double objbst = getDoubleInfo(GRB_CB_MIP_OBJBST);
      double objbnd = getDoubleInfo(GRB_CB_MIP_OBJBND);
      int solcnt = getIntInfo(GRB_CB_MIP_SOLCNT);
      if (nodedcnt - lastnode >= 100) {
        lastnode = nodedcnt;
        int actnodes = (int) getDoubleInfo(GRB_CB_MIP_NODLFT);
        int itcnt = (int) getDoubleInfo(GRB_CB_MIP_ITRCNT);
        int cutcnt = getIntInfo(GRB_CB_MIP_CUTCNT);
        cout << " nodedcnt " << " actnodes " << " itcnt " << " objbst " << " objbnd " << " solcnt " << " cutcnt " << endl;
      }
      if (fabs(objbst - objbnd) < 0.1 * (1.0 + fabs(objbst))) {
        cout << "Stop early - 10% gap achieved" << endl;
        abort();
      }
      if (nodedcnt >= 10000 && solcnt) {
        cout << "Stop early - 10000 nodes explored" << endl;
      }
  }
}
```
abort();

} else if (where == GRB_CB_MIPSOL) {
    // MIP solution callback
    int nodecnt = (int) getDoubleInfo(GRB_CB_MIPSOL_NODCNT);
    double obj = getDoubleInfo(GRB_CB_MIPSOL_OBJ);
    int solcnt = getIntInfo(GRB_CB_MIPSOL_SOLCNT);
    double* x = getSolution(vars, numvars);
    cout << "**** New solution at node " << nodecnt
        << ", obj " << obj << ", sol " << solcnt
        << ", x[0] = " << x[0] << " ****" << endl;
    delete[] x;
}
else if (where == GRB_CB_MIPNODE) {
    // MIP node callback
    cout << "**** New node ****" << endl;
    if (getIntInfo(GRB_CB_MIPNODE_STATUS) == GRB_OPTIMAL) {
        double* x = getNodeRel(vars, numvars);
        setSolution(vars, x, numvars);
        delete[] x;
    }
}
else if (where == GRB_CB_BARRIER) {
    // Barrier callback
    int itcnt = getIntInfo(GRB_CB_BARRIER_ITRCNT);
    double primobj = getDoubleInfo(GRB_CB_BARRIER_PRIMOBJ);
    double dualobj = getDoubleInfo(GRB_CB_BARRIER_DUALOBJ);
    double priminf = getDoubleInfo(GRB_CB_BARRIER_PRIMINF);
    double dualinf = getDoubleInfo(GRB_CB_BARRIER_DUALINF);
    double cmpl = getDoubleInfo(GRB_CB_BARRIER_COMPL);
    cout << itcnt << " " << primobj << " " << dualobj << " "
        << priminf << " " << dualinf << " " << cmpl << endl;
}
else if (where == GRB_CB_MESSAGE) {
    // Message callback
    string msg = getStringInfo(GRB_CB_MSG_STRING);
    *logfile << msg << endl;
    catch (GRBException e) {
        cout << "Error number: " << e.getErrorCode() << endl;
        cout << e.getMessage() << endl;
    }
    catch (...) {
        cout << "Error during callback" << endl;
    }
}

int main(int argc, char *argv[]) {
    if (argc < 2) {
        cout << "Usage: callback_c++ filename" << endl;
        return 1;
    }

    // Open log file
    ofstream logfile("cb.log");
    if (!logfile.is_open()) {

120
cout << "Cannot open cb.log for callback message" << endl;
    return 1;
}

GRBEnv *env = 0;
GRBVar *vars = 0;

try {
    // Create environment
    env = new GRBEnv();

    // Read model from file
    GRBModel model = GRBModel(*env, argv[1]);

    // Turn off display and heuristics
    model.set(GRB_IntParam_OutputFlag, 0);
    model.set(GRB_DoubleParam_Heuristics, 0.0);

    // Create a callback object and associate it with the model
    int numvars = model.get(GRB_IntAttr_NumVars);
    vars = model.getVars();
    mycallback cb = mycallback(numvars, vars, &logfile);
    model.setCallback(&cb);

    // Solve model and capture solution information
    model.optimize();

    cout << endl << "Optimization complete" << endl;
    if (model.get(GRB_IntAttr_SolCount) == 0) {
        cout << "No solution found, optimization status = 
             << model.get(GRB_IntAttr_Status) << endl;
    } else {
        cout << "Solution found, objective = 
             << model.get(GRB_DoubleAttr_ObjVal) << endl;
        for (int j = 0; j < numvars; j++) {
            GRBVar v = vars[j];
            double x = v.get(GRB_DoubleAttr_X);
            if (x != 0.0) {
                cout << v.get(GRB_StringAttr_VarName) << " " << x << endl;
            }
        }
    }
}

} catch (GRBException e) {
    cout << "Error number: " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
} catch (...) {
    cout << "Error during optimization" << endl;
}

// Close log file
logfile.close();

delete[] vars;
delete env;
dense_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */
/* This example formulates and solves the following simple QP model:

minimize x + y + x^2 + x*y + y^2 + y*z + z^2
subject to x + 2 y + 3 z >= 4
    x + y >= 1

The example illustrates the use of dense matrices to store A and Q
(and dense vectors for the other relevant data). We don’t recommend
that you use dense matrices, but this example may be helpful if you
already have your data in this format. */

#include "gurobi_c++.h"
using namespace std;

static bool
dense_optimize ( GRBEnv * env ,
    int rows ,
    int cols ,
    double * c, /* linear portion of objective function */
    double * Q, /* quadratic portion of objective function */
    double * A, /* constraint matrix */
    char * sense, /* constraint senses */
    double * rhs, /* RHS vector */
    double * lb, /* variable lower bounds */
    double * ub, /* variable upper bounds */
    char * vtype, /* variable types (continuous, binary, etc.) */
    double * solution ,
    double * objvalP )
{
    GRBModel model = GRBModel (* env );
    int i, j;
    bool success = false;

    /* Add variables to the model */

    GRBVar * vars = model.addVars (lb , ub , NULL , vtype , NULL , cols );

    /* Populate A matrix */

    for ( i = 0; i < rows ; i ++ ) {
        GRBLinExpr lhs = 0;
        for ( j = 0; j < cols ; j ++ )
            if ( A [ i* cols + j ] != 0 )
                lhs += A [ i* cols + j ] * vars [ j ];
        model.addConstr ( lhs , sense [ i ] , rhs [ i ]);
    }
    return 0;
}
GRBQuadExpr obj = 0;
for (j = 0; j < cols; j++)
    obj += c[j]*vars[j];
for (i = 0; i < cols; i++)
    for (j = 0; j < cols; j++)
        if (Q[i*cols+j] != 0)
            obj += Q[i*cols+j]*vars[i]*vars[j];

model.setObjective(obj);
model.optimize();
model.write("dense.lp");

if (model.get(GRB_IntAttr_Status) == GRB_OPTIMAL) {
    *objvalP = model.get(GRB_DoubleAttr_ObjVal);
    for (i = 0; i < cols; i++)
        solution[i] = vars[i].get(GRB_DoubleAttr_X);
    success = true;
}
delete[] vars;

return success;

int main(int argc, char * argv[])
{
    GRBEnv* env = 0;
    try {
        env = new GRBEnv();
        double c[] = {1, 1, 0};
        double Q[3][3] = {{1, 1, 0}, {0, 1, 1}, {0, 0, 1}};
        double A[2][3] = {{1, 2, 3}, {1, 1, 0}};
        char sense[] = {'>', '>'};
        double rhs[] = {4, 1};
        double lb[] = {0, 0, 0};
        bool success;
        double objval, sol[3];

        success = dense_optimize(env, 2, 3, c, &Q[0][0], &A[0][0], sense, rhs, lb, NULL, NULL, sol, &objval);
    }
    catch(GRBException e) {
        cout << "Error code = " << e.getErrorCode() << endl;
        cout << e.getMessage() << endl;
    }
    catch(...) {
        cout << "Exception during optimization" << endl;
    }

delete env;

}
return 0;
}

diet_c++.cpp

#include "gurobi_c++.h"
using namespace std;

void printSolution(GRBModel & model, int nCategories, int nFoods, GRBVar * buy, GRBVar * nutrition) throw(GRBException);

int main(int argc, char *argv[])
{
    GRBEnv* env = 0;
    GRBVar* nutrition = 0;
    GRBVar* buy = 0;
    try
    {
        // Nutrition guidelines, based on
        // USDA Dietary Guidelines for Americans, 2005
        const int nCategories = 4;
        string Categories[] = {
            "calories", "protein", "fat", "sodium"
        };
        double minNutrition[] = { 1800, 91, 0, 0 };
        double maxNutrition[] = { 2200, GRB_INFINITY, 65, 1779 };

        // Set of foods
        const int nFoods = 9;
        string Foods[] = {
            "hamburger", "chicken", "hot dog", "fries", "macaroni", "pizza", "salad", "milk", "ice cream"
        };
        double cost[] = {
            2.49, 2.89, 1.50, 1.89, 2.09, 1.99, 2.49, 0.89, 1.59
        };

        // Nutrition values for the foods
        double nutritionValues[][nCategories] = {
            { 410, 24, 26, 730 }, // hamburger
            { 420, 32, 10, 1190 }, // chicken
            { 560, 20, 32, 1800 }, // hot dog
            { 380, 4, 19, 270 }, // fries
            { 320, 12, 10, 930 }, // macaroni
            { 320, 15, 12, 820 }, // pizza
            { 320, 31, 12, 1230 }, // salad
            { 100, 8, 2.5, 125 }, // milk
            { 330, 8, 10, 180 } // ice cream
        };
    }
}

124
// Model
env = new GRBEnv();
GRBModel model = GRBModel(*env);
model.set(GRB_StringAttr_ModelName, "diet");

// Create decision variables for the nutrition information, 
// which we limit via bounds
nutrition = model.addVars(minNutrition, maxNutrition, 0, 0, 
Categories, nCategories);

// Create decision variables for the foods to buy
buy = model.addVars(0, 0, cost, 0, Foods, nFoods);

// The objective is to minimize the costs
model.set(GRB_IntAttr_ModelSense, GRB_MINIMIZE);

// Nutrition constraints
for (int i = 0; i < nCategories; ++i) {
    GRBLinExpr ntot = 0;
    for (int j = 0; j < nFoods; ++j) {
        ntot += nutritionValues[j][i] * buy[j];
    }
    model.addConstr(ntot == nutrition[i], Categories[i]);
}

// Solve
model.optimize();
printSolution(model, nCategories, nFoods, buy, nutrition);

  cout << "\nAdding constraint: at most 6 servings of dairy" << endl;

// Solve
model.optimize();
printSolution(model, nCategories, nFoods, buy, nutrition);
}

catch (GRBException e) {
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
} catch (...) {
    cout << "Exception during optimization" << endl;
}

delete[] nutrition;
delete[] buy;
delete env;
return 0;
}

void printSolution(GRBModel& model, int nCategories, int nFoods,
GRBVar * buy, GRBVar * nutrition) throw(GRBException)
{
    if (model.get(GRB_IntAttr_Status) == GRB_OPTIMAL)
    {
        cout << "\nCost: " << model.get(GRB_DoubleAttr_ObjVal) << endl;
        cout << "\nBuy: " << endl;
        for (int j = 0; j < nFoods; ++j)
        {
            if (buy[j].get(GRB_DoubleAttr_X) > 0.0001)
            {
                cout << buy[j].get(GRB_StringAttr_VarName) << " " <<
                     buy[j].get(GRB_DoubleAttr_X) << endl;
            }
        }
        cout << "\nNutrition: " << endl;
        for (int i = 0; i < nCategories; ++i)
        {
            cout << nutrition[i].get(GRB_StringAttr_VarName) << " " <<
                 nutrition[i].get(GRB_DoubleAttr_X) << endl;
        }
    }
    else
    {
        cout << "No solution" << endl;
    }
}

facility_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */
/*
Facility location: a company currently ships its product from 5 plants
to 4 warehouses. It is considering closing some plants to reduce
costs. What plant(s) should the company close, in order to minimize
transportation and fixed costs?

Based on an example from Frontline Systems:
http://www.solver.com/disfacility.htm
Used with permission.
*/
#include "gurobi_c++.h"
#include <sstream>
using namespace std;

int main(int argc,
         char *argv[])
{
    GRBEnv* env = 0;
    GRBVar* open = 0;
    GRBVar** transport = 0;
    int transportCt = 0;
    try
    {
const int nPlants = 5;
const int nWarehouses = 4;

double Demand[] = { 15, 18, 14, 20 };

double Capacity[] = { 20, 22, 17, 19, 18 };

double FixedCosts[] = { 12000, 15000, 17000, 13000, 16000 };

double TransCosts[][nPlants] = {
  { 4000, 2000, 3000, 2500, 4500 },
  { 2500, 2600, 3400, 3000, 4000 },
  { 1200, 1800, 2600, 4100, 3000 },
  { 2200, 2600, 3100, 3700, 3200 }
};

env = new GRBEnv();
GRBModel model = GRBModel(*env);
model.set(GRB_StringAttr_ModelName, "facility");

for (p = 0; p < nPlants; ++p)
{
  ostringstream vname;
  vname << "Open " << p;
  open[p].set(GRB_DoubleAttr_Obj, FixedCosts[p]);
  open[p].set(GRB_StringAttr_VarName, vname.str());
}

for (w = 0; w < nWarehouses; ++w)
{
  transport[w] = model.addVars(nPlants);
  transportCt++;

  for (p = 0; p < nPlants; ++p)
  {
    ostringstream vname;
    vname << "Trans " << p << "." << w;
    transport[w][p].set(GRB_DoubleAttr_Obj, TransCosts[w][p]);
    transport[w][p].set(GRB_StringAttr_VarName, vname.str());
  }
}
The objective is to minimize the total fixed and variable costs:

```c++
model.set(GRB_IntAttr_ModelSense, GRB_MINIMIZE);
```

Production constraints:
- Note that the right-hand limit sets the production to zero if the plant is closed.

```c++
for (p = 0; p < nPlants; ++p) {
    GRBLinExpr ptot = 0;
    for (w = 0; w < nWarehouses; ++w) {
        ptot += transport[w][p];
    }
    ostringstream cname;
    cname << "Capacity" << p;
    model.addConstr(ptot <= capacity[p] * open[p], cname.str());
}
```

Demand constraints:

```c++
for (w = 0; w < nWarehouses; ++w) {
    GRBLinExpr dtot = 0;
    for (p = 0; p < nPlants; ++p) {
        dtot += transport[w][p];
    }
    ostringstream cname;
    cname << "Demand" << w;
    model.addConstr(dtot == demand[w], cname.str());
}
```

Guess at the starting point: close the plant with the highest fixed costs; open all others:
- First, open all plants:

```c++
for (p = 0; p < nPlants; ++p) {
    open[p].set(GRB_DoubleAttr_Start, 1.0);
}
```

- Now close the plant with the highest fixed cost:

```c++
cout << "Initial guess:"

double maxFixed = -GRB_INFINITY;
for (p = 0; p < nPlants; ++p) {
    if (FixedCosts[p] > maxFixed) {
        maxFixed = FixedCosts[p];
    }
}
for (p = 0; p < nPlants; ++p) {
    if (FixedCosts[p] == maxFixed) {
        open[p].set(GRB_DoubleAttr_Start, 0.0);
    }
```
cout << " Closing plant " << p << endl << endl;
break;
}

// Use barrier to solve root relaxation
model.set(GRB_IntParam_Method, GRB_METHOD_BARRIER);

// Solve
model.optimize();

// Print solution
cout << "\nTOTAL COSTS: " << model.get(GRB_DoubleAttr_ObjVal) << endl;
cout << " SOLUTION:" << endl;
for (p = 0; p < nPlants; ++p)
{
    if (open[p].get(GRB_DoubleAttr_X) > 0.99)
    {
        cout << " Plant " << p << " open:" << endl;
        for (w = 0; w < nWarehouses; ++w)
        {
            if (transport[w][p].get(GRB_DoubleAttr_X) > 0.0001)
            {
                cout << " Transport " << transport[w][p].get(GRB_DoubleAttr_X) << " units to warehouse " << w << endl;
            }
        }
    }
    else
    {
        cout << " Plant " << p << " closed!" << endl;
    }
}

} catch (GRBException e)
{
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
} catch (...) {
    cout << "Exception during optimization" << endl;
}

delete[] open;
for (int i = 0; i < transportCt; ++i) {
    delete[] transport[i];
}
delete[] transport;
delete env;
return 0;
feasopt_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads a MIP model from a file, adds artificial
variables to each constraint, and then minimizes the sum of the
artificial variables. A solution with objective zero corresponds
to a feasible solution to the input model.
We can also use FeasRelax feature to do it. In this example, we
use minrelax=1, i.e. optimizing the returned model finds a solution
that minimizes the original objective, but only from among those
solutions that minimize the sum of the artificial variables. */

#include "gurobi_c++.h"
using namespace std;

int main(int argc, char *argv[])
{
  if (argc < 2)
  {
    cout << "Usage: feasopt_c++ filename" << endl;
    return 1;
  }

  GRBEnv* env = 0;
  GRBConstr* c = 0;
  try
  {
    env = new GRBEnv();
    GRBModel feasmodel = GRBModel(*env, argv[1]);

    // Create a copy to use FeasRelax feature later */
    GRBModel feasmodel1 = GRBModel(feasmodel);

    // clear objective
    feasmodel.setObjective(GRBLinExpr(0.0));

    // add slack variables
    c = feasmodel.getConstrs();
    for (int i = 0; i < feasmodel.get(GRB_IntAttr_NumConstrs); ++i)
    {
      char sense = c[i].get(GRB_CharAttr_Sense);
      if (sense != '>')
      {
        double coef = -1.0;
        feasmodel.addVar(0.0, GRB_INFINITY, 1.0, GRB_CONTINUOUS, 1,
                         &c[i], &coef, "ArtN_" + c[i].get(GRB_StringAttr_ConstrName));
      }
      if (sense != '<')
      {
        double coef = 1.0;
        feasmodel.addVar(0.0, GRB_INFINITY, 1.0, GRB_CONTINUOUS, 1,
                         &c[i], &coef, "ArtP_" + c[i].get(GRB_StringAttr_ConstrName));
      }
    }
  }
  return 0;
}
c[i].get(GRB_StringAttr_ConstrName));
}
}

// optimize modified model
feasmodel.optimize();
feasmodel.write("feasopt.lp");

// use FeasRelax feature */
feasmodel1.feasRelax(GRB_FEASRELAX_LINEAR, true, false, true);
feasmodel1.write("feasopt1.lp");
feasmodel1.optimize();
}

try
{
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
}

catch("");
{
    cout << "Error during optimization" << endl;
}

delete[] c;
delete env;
return 0;
}

fixanddive_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* Implement a simple MIP heuristic. Relax the model,
sort variables based on fractionality, and fix the 25% of
the fractional variables that are closest to integer variables.
Repeat until either the relaxation is integer feasible or
linearly infeasible. */

#include "gurobi_c++.h"
#include <algorithm>
#include <cmath>
#include <deque>
using namespace std;

bool vcomp(GRBVar*, GRBVar*) throw(GRBException);

int
main(int argc,
    char *argv[])
{
    if (argc < 2)
    {
        cout << "Usage: fixanddive_c++ filename" << endl;
        return 1;
    }
GRBEnv * env = 0;
GRBVar * x = 0;
try
{
    // Read model
    env = new GRBEnv();
    GRBModel model = GRBModel(*env, argv[1]);

    // Collect integer variables and relax them
    // Note that we use GRBVar* to copy variables
    deque<GRBVar*> intvars;
x = model.getVars();
    for (int j = 0; j < model.get(GRB_IntAttr_NumVars); ++j)
    {
        if (x[j].get(GRB_CharAttr_VType) != GRB_CONTINUOUS)
        {
            intvars.push_back(x[j]);
x[j].set(GRB_CharAttr_VType, GRB_CONTINUOUS);
        }
    }

    model.set(GRB_IntParam_OutputFlag, 0);
    model.optimize();

    // Perform multiple iterations. In each iteration, identify the first
    // quartile of integer variables that are closest to an integer value
    // in the relaxation, fix them to the nearest integer, and repeat.
    for (int iter = 0; iter < 1000; ++iter)
    {

        // create a list of fractional variables, sorted in order of
        // increasing distance from the relaxation solution to the nearest
        // integer value
        deque<GRBVar*> fractional;
        for (size_t j = 0; j < intvars.size(); ++j)
        {
            double sol = fabs(intvars[j]->get(GRB_DoubleAttr_X));
            if (fabs(sol - floor(sol + 0.5)) > 1e-5)
            {
                fractional.push_back(intvars[j]);
            }
        }

        cout << "Iteration " << iter << ", obj " <<
        model.get(GRB_DoubleAttr_ObjVal) << ", fractional " <<
        fractional.size() << endl;

        if (fractional.size() == 0)
        {
            cout << "Found feasible solution - objective " <<
            model.get(GRB_DoubleAttr_ObjVal) << endl;
            break;
        }
    }
}
// Fix the first quartile to the nearest integer value
sort(fractional.begin(), fractional.end(), vcomp);
int nfix = fractional.size() / 4;
nfix = (nfix > 1) ? nfix : 1;
for (int i = 0; i < nfix; ++i)
{
    GRBVar* v = fractional[i];
    double fixval = floor(v->get(GRB_DoubleAttr_X) + 0.5);
    v->set(GRB_DoubleAttr_LB, fixval);
    v->set(GRB_DoubleAttr_UB, fixval);
    cout << " Fix " << v->get(GRB_StringAttr_VarName) << " to " << fixval << " ( rel " << v->get(GRB_DoubleAttr_X) << " )" << endl;
}
model.optimize();

// Check optimization result
if (model.get(GRB_IntAttr_Status) != GRB_OPTIMAL)
{
    cout << "Relaxation is infeasible" << endl;
    break;
}

} catch (GRBException e)
{
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
} catch (...)
{
    cout << "Error during optimization" << endl;
}
delete[] x;
delete env;
return 0;

bool vcomp(GRBVar* v1, GRBVar* v2) throw(GRBException)
{
    double sol1 = fabs(v1->get(GRB_DoubleAttr_X));
    double sol2 = fabs(v2->get(GRB_DoubleAttr_X));
    double frac1 = fabs(sol1 - floor(sol1 + 0.5));
    double frac2 = fabs(sol2 - floor(sol2 + 0.5));
    return (frac1 < frac2);
}

genconstr_c++_.cpp

/* Copyright 2018, Gurobi Optimization, LLC */
/* In this example we show the use of general constraints for modeling
some common expressions. We use as an example a SAT-problem where we
want to see if it is possible to satisfy at least four (or all) clauses
of the logical for

\[ L = (x_0 \lor \neg x_1 \lor x_2) \land (x_1 \lor \neg x_2 \lor x_3) \land
(x_2 \lor \neg x_3 \lor x_0) \land (x_3 \lor \neg x_0 \lor x_1) \land
(\neg x_0 \lor \neg x_1 \lor x_2) \land (\neg x_1 \lor \neg x_2 \lor x_3) \land
(\neg x_2 \lor \neg x_3 \lor x_0) \land (\neg x_3 \lor \neg x_0 \lor x_1) \] 

We do this by introducing two variables for each literal (itself and its
negated value), a variable for each clause, and then two
variables for indicating if we can satisfy four, and another to identify
the minimum of the clauses (so if it one, we can satisfy all clauses)
and put these two variables in the objective.
i.e. the Objective function will be

* maximize Obj0 + Obj1
* Obj0 = MIN(Clause1, ..., Clause8)
* Obj1 = 1 -> Clause1 + ... + Clause8 >= 4
* thus, the objective value will be two if and only if we can satisfy all
* clauses; one if and only if at least four clauses can be satisfied, and
* zero otherwise. */

#include "gurobi_c++.h"
#include <sstream>
#include <iomanip>
using namespace std;

#define n 4
#define NLITERALS 4  // same as n
#define NCLAUSES 8
#define NOBJ 2

int main(void)
{
    GRBEnv *env = 0;

    try{
        // Example data
        // e.g. {0, n+1, 2} means clause (x0 or -x1 or x2)
        const int Clauses[][3] = {{ 0, n+1, 2}, { 1, n+2, 3},
                                  { 2, n+3, 0}, { 3, n+0, 1},
                                  {n+0, n+1, 2}, {n+1, n+2, 3},
                                  {n+2, n+3, 0}, {n+3, n+0, 1}};

        int i, status, nSolutions;

        // Create environment
        env = new GRBEnv("genconstr_c++.log");
// Create initial model
GRBModel model = GRBModel(*env);
model.set(GRB_StringAttr_ModelName, "genconstr_c++");

// Initialize decision variables and objective
GRBVar Lit[NLITERALS];
GRBVar NotLit[NLITERALS];
for (i = 0; i < NLITERALS; i++) {
    ostringstream vname;
    vname << "X" << i;
    Lit[i] = model.addVar(0.0, 1.0, 0.0, GRB_BINARY, vname.str());
    vname.str("");
    vname << "notX" << i;
    NotLit[i] = model.addVar(0.0, 1.0, 0.0, GRB_BINARY, vname.str());
}

GRBVar Cla[NCLAUSES];
for (i = 0; i < NCLAUSES; i++) {
    ostringstream vname;
    vname << "Clause" << i;
    Cla[i] = model.addVar(0.0, 1.0, 0.0, GRB_BINARY, vname.str());
}

GRBVar Obj[NOBJ];
for (i = 0; i < NOBJ; i++) {
    ostringstream vname;
    vname << "Obj" << i;
    Obj[i] = model.addVar(0.0, 1.0, 1.0, GRB_BINARY, vname.str());
}

// Link Xi and notXi
GRBLinExpr lhs;
for (i = 0; i < NLITERALS; i++) {
    ostringstream cname;
    cname << "CNSTR_X" << i;
    lhs = 0;
    lhs += Lit[i];
    lhs += NotLit[i];
    model.addConstr(lhs == 1.0, cname.str());
}

// Link clauses and literals
GRBVar clause[3];
for (i = 0; i < NCLAUSES; i++) {
    for (int j = 0; j < 3; j++) {
        if (Clauses[i][j] >= n) clause[j] = NotLit[Clausess[i][j]-n];
        else clause[j] = Lit[Clausess[i][j]];
    }
    ostringstream cname;
    cname << "CNSTR_Clause" << i;
    model.addGenConstrOr(Clause[i], clause, 3, cname.str());
}
// Link objs with clauses
model.addGenConstrMin(Obj[0], Cla, NCLAUSES,
GRB_INFINITY, "CNSTR_Obj0");

lhs = 0;
for (i = 0; i < NCLAUSES; i++) {
    lhs += Cla[i];
} model.addGenConstrIndicator(Obj[1], 1, lhs >= 4.0, "CNSTR_Obj1");

// Set global objective sense
model.set(GRB_IntAttr_ModelSense, GRB_MAXIMIZE);

// Save problem
model.write("genconstr_c++.mps");
model.write("genconstr_c++.lp");

// Optimize
model.optimize();

// Status checking
status = model.get(GRB_IntAttr_Status);

if (status == GRB_INF_OR_UNBD ||
status == GRB_INFEASIBLE ||
status == GRB_UNBOUNDED ) {
    cout << "The model cannot be solved " << "because it is infeasible or unbounded" << endl;
    return 1;
}
if (status != GRB_OPTIMAL) {
    cout << "Optimization was stopped with status " << status << endl;
    return 1;
}

// Print result
double objval = model.get(GRB_DoubleAttr_ObjVal);

if (objval > 1.9)
    cout << "Logical expression is satisfiable" << endl;
else if (objval > 0.9)
    cout << "At least four clauses can be satisfied" << endl;
else
    cout << "Not even three clauses can be satisfied" << endl;

} catch (GRBException e) {
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
}

} catch (...) {
    cout << "Exception during optimization" << endl;
}

// Free environment
delete env;

return 0;
/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads an LP model from a file and solves it. 
   If the model is infeasible or unbounded, the example turns off 
   presolve and solves the model again. If the model is infeasible, 
   the example computes an Irreducible Inconsistent Subsystem (IIS), 
   and writes it to a file */

#include "gurobi_c++.h"
using namespace std;

int main(int argc, char *argv[]) {
    if (argc < 2) {
        cout << "Usage: lp_c++ filename" << endl;
        return 1;
    }

    try {
        GRBEnv env = GRBEnv();
        GRBModel model = GRBModel(env, argv[1]);

        model.optimize();

        int optimstatus = model.get(GRB_IntAttr_Status);

        if (optimstatus == GRB_INF_OR_UNBD) {
            model.set(GRB_IntParam_Presolve, 0);
            model.optimize();
            optimstatus = model.get(GRB_IntAttr_Status);
        }

        if (optimstatus == GRB_OPTIMAL) {
            double objval = model.get(GRB_DoubleAttr_ObjVal);
            cout << "Optimal objective: " << objval << endl;
        } else if (optimstatus == GRB_INFEASIBLE) {
            cout << "Model is infeasible" << endl;

            // compute and write out IIS
            model.computeIIS();
            model.write("model.ilp");
        } else if (optimstatus == GRB_UNBOUNDED) {
            cout << "Model is unbounded" << endl;
        } else {
            cout << "Optimization was stopped with status = "
                 << optimstatus << endl;
        }
    }

    catch(GRBException e) {

    }
}
cout << "Error code = " << e.getErrorCode() << endl;
cout << e.getMessage() << endl;
} catch (...) {
cout << "Error during optimization" << endl;
}

return 0;

lpmethod_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* Solve a model with different values of the Method parameter; show which value gives the shortest solve time. */

#include "gurobi_c++.h"
using namespace std;

int main(int argc, char *argv[]) {

if (argc < 2) {
    cout << "Usage: lpmethod_c++ filename" << endl;
    return 1;
}

try {
    // Read model
    GRBEnv env = GRBEnv();
    GRBModel m = GRBModel(env, argv[1]);

    // Solve the model with different values of Method
    int bestMethod = -1;
    double bestTime = m.get(GRB_DoubleParam_TimeLimit);
    for (int i = 0; i <= 2; ++i) {
        m.reset();
        m.set(GRB_IntParam_Method, i);
        m.optimize();
        if (m.get(GRB_IntAttr_Status) == GRB_OPTIMAL) {
            bestTime = m.get(GRB_DoubleAttr_Runtime);
            bestMethod = i;
            // Reduce the TimeLimit parameter to save time
            // with other methods
            m.set(GRB_DoubleParam_TimeLimit, bestTime);
        }
    }

    // Report which method was fastest
    if (bestMethod == -1) {
        cout << "Unable to solve this model" << endl;
    } else {
        cout << "Solved in " << bestTime

138
```cpp

#include "gurobi_c++.h"
using namespace std;

int main(int argc,
         char *argv[])
{
    if (argc < 2)
    {
        cout << "Usage: lpmod_c++ filename" << endl;
        return 1;
    }

    GRBEnv* env = 0;
    GRBVar* v = 0;
    try
    {
        // Read model and determine whether it is an LP
        env = new GRBEnv();
        GRBModel model = GRBModel(*env, argv[1]);
        if (model.get(GRB_IntAttr_IsMIP) != 0)
        {
            cout << "The model is not a linear program" << endl;
            return 1;
        }

        model.optimize();

        int status = model.get(GRB_IntAttr_Status);

        if (((status == GRB_INF_OR_UNBD) || (status == GRB_INFEASIBLE)) ||
            (status == GRB_UNBOUNDED))
        {
            cout << "The model cannot be solved because it is "
```
if (status != GRB_OPTIMAL)
{
    cout << "Optimization was stopped with status " << status << endl;
    return 0;
}

// Find the smallest variable value
double minVal = GRB_INFINITY;
int minVar = 0;
v = model.getVars();
for (int j = 0; j < model.get(GRB_IntAttr_NumVars); ++j)
{
    double sol = v[j].get(GRB_DoubleAttr_X);
    if ((sol > 0.0001) && (sol < minVal) &&
        (v[j].get(GRB_DoubleAttr_LB) == 0.0))
    {
        minVal = sol;
        minVar = j;
    }
}

cout << "\n*** Setting " << v[minVar].get(GRB_StringAttr_VarName) << " from " << minVal << " to zero ***" << endl << endl;
v[minVar].set(GRB_DoubleAttr_UB, 0.0);

// Solve from this starting point
model.optimize();

// Save iteration & time info
double warmCount = model.get(GRB_DoubleAttr_IterCount);
double warmTime = model.get(GRB_DoubleAttr_Runtime);

// Reset the model and resolve
cout << "\n*** Resetting and solving "
<< "without an advanced start ***\n" << endl;
model.reset();
model.optimize();

// Save iteration & time info
double coldCount = model.get(GRB_DoubleAttr_IterCount);
double coldTime = model.get(GRB_DoubleAttr_Runtime);

cout << "\n*** Warm start: " << warmCount << " iterations, " <<
warmTime << " seconds" << endl;
cout << "*** Cold start: " << coldCount << " iterations, " <<
coldTime << " seconds" << endl;
}
catch (GRBException e)
{
    cout << "Error code = " << e.getErrorCode() << endl;
cout << e.getMessage() << endl;
mip1_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */
/* This example formulates and solves the following simple MIP model:
   maximize x + y + 2 z
   subject to x + 2 y + 3 z <= 4
       x + y >= 1
   x, y, z binary */
#include "gurobi_c++.h"
using namespace std;

int main(int argc, char *argv[]) {

  try {
    GRBEnv env = GRBEnv();
    GRBModel model = GRBModel(env);
    // Create variables
    GRBVar x = model.addVar(0.0, 1.0, 0.0, GRB_BINARY, "x");
    GRBVar y = model.addVar(0.0, 1.0, 0.0, GRB_BINARY, "y");
    GRBVar z = model.addVar(0.0, 1.0, 0.0, GRB_BINARY, "z");
    // Set objective: maximize x + y + 2 z
    model.setObjective(x + y + 2 * z, GRB_MAXIMIZE);
    // Add constraint: x + 2 y + 3 z <= 4
    model.addConstr(x + 2 * y + 3 * z <= 4, "c0");
    // Add constraint: x + y >= 1
    model.addConstr(x + y >= 1, "c1");
    // Optimize model
    model.optimize();
  } catch (...) {
    cout << "Error during optimization" << endl;
  }
  delete[] v;
  delete env;
  return 0;
}
cout << x.get(GRB_StringAttr_VarName) << " "
<< x.get(GRB_DoubleAttr_X) << endl;
cout << y.get(GRB_StringAttr_VarName) << " "
<< y.get(GRB_DoubleAttr_X) << endl;
cout << z.get(GRB_StringAttr_VarName) << " "
<< z.get(GRB_DoubleAttr_X) << endl;
cout << "Obj: " << model.get(GRB_DoubleAttr_ObjVal) << endl;
}
catch(GRBException e) {
  cout << "Error code = " << e.getErrorCode() << endl;
  cout << e.getMessage() << endl;
} catch(...) {
  cout << "Exception during optimization" << endl;
}

return 0;
}

mip2_c++-pp

/* Copyright 2018, Gurobi Optimization, LLC */
/* This example reads a MIP model from a file, solves it and 
prints the objective values from all feasible solutions 
generated while solving the MIP. Then it creates the fixed 
model and solves that model. */

#include "gurobi_c++.h"
#include <cmath>
using namespace std;

int main(int argc, char *argv[]) {
  if (argc < 2) {
    cout << "Usage: mip2_c++ filename" << endl;
    return 1;
  }

  GRBEnv *env = 0;
  GRBVar *vars = 0, *fvars = 0;
  try {
    env = new GRBEnv();
    GRBModel model = GRBModel(*env, argv[1]);
    if (model.get(GRB_IntAttr_IsMIP) == 0) {
      throw GRBException("Model is not a MIP");
    }
    model.optimize();
    int optimstatus = model.get(GRB_IntAttr_Status);
  } catch(GRBException e) {
cout << "Optimization complete" << endl;
double objval = 0;
if (optimstatus == GRB_OPTIMAL) {
    objval = model.get(GRB_DoubleAttr_ObjVal);
    cout << "Optimal objective: " << objval << endl;
} else if (optimstatus == GRB_INF_OR_UNBD) {
    cout << "Model is infeasible or unbounded" << endl;
    return 0;
} else if (optimstatus == GRB_INFEASIBLE) {
    cout << "Model is infeasible" << endl;
    return 0;
} else if (optimstatus == GRB_UNBOUNDED) {
    cout << "Model is unbounded" << endl;
    return 0;
} else {
    cout << "Optimization was stopped with status = "
        << optimstatus << endl;
    return 0;
}

/* Iterate over the solutions and compute the objectives */

int numvars = model.get(GRB_IntAttr_NumVars);
vars = model.getVars();
model.set(GRB_IntParam_OutputFlag, 0);

cout << endl;
for (int k = 0; k < model.get(GRB_IntAttr_SolCount); ++k) {
    model.set(GRB_IntParam_SolutionNumber, k);
    double objn = 0.0;
    for (int j = 0; j < numvars; j++) {
        GRBVar v = vars[j];
        objn += v.get(GRB_DoubleAttr_Obj) * v.get(GRB_DoubleAttr_Xn);
    }
    cout << "Solution " << k << " has objective: " << objn << endl;
}
cout << endl;
model.set(GRB_IntParam_OutputFlag, 1);

/* Create a fixed model, turn off presolve and solve */

GRBModel fixed = model.fixedModel();
fixed.set(GRB_IntParam_Presolve, 0);
fixed.optimize();

int foptimstatus = fixed.get(GRB_IntAttr_Status);

if (foptimstatus != GRB_OPTIMAL) {
    cerr << "Error: fixed model isn't optimal" << endl;
    return 0;
}
```cpp
double fobjval = fixed.get(GRB_DoubleAttr_ObjVal);

if (fabs(fobjval - objval) > 1.0e-6 * (1.0 + fabs(objval))) {
    cerr << "Error: objective values are different" << endl;
    return 0;
}

/* Print values of nonzero variables */
fvars = fixed.getVars();
for (int j = 0; j < numvars; j++) {
    GRBVar v = fvars[j];
    if (v.get(GRB_DoubleAttr_X) != 0.0) {
        cout << v.get(GRB_StringAttr_VarName) << " "
             << v.get(GRB_DoubleAttr_X) << endl;
    }
}

} catch (GRBException e) {
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
} catch (...) {
    cout << "Error during optimization" << endl;
}

delete[] fvars;
delete[] vars;
delete env;
return 0;
```

--

```cpp
multiobj_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* Want to cover three different sets but subject to a common budget of
   elements allowed to be used. However, the sets have different priorities to
   be covered; and we tackle this by using multi-objective optimization. */

#include "gurobi_c++.h"
#include <sstream>
#include <iomanip>
using namespace std;

int main(void)
{
    GRBEnv *env = 0;
    GRBVar *Elem = 0;
    int e, i, status, nSolutions;

    try{
        // Sample data
        const int groundSetSize = 20;
        const int nSubsets = 4;
        const int Budget = 12;
        double Set[][20] =
```
int SetObjPriority[] = {3, 2, 2, 1};
double SetObjWeight[] = {1.0, 0.25, 1.25, 1.0};

// Create environment
env = new GRBEnv("multiobj_c++.log");

// Create initial model
GRBModel model = GRBModel(*env);
model.set(GRB_StringAttr_ModelName, "multiobj_c++");

// Initialize decision variables for ground set:
// x[e] == 1 if element e is chosen for the covering.
Elem = model.addVars(groundSetSize, GRB_BINARY);
for (e = 0; e < groundSetSize; e++) {
    ostringstream vname;
    vname << "El" << e;
    Elem[e].set(GRB_StringAttr_VarName, vname.str());
}

// Constraint: limit total number of elements to be picked to be at most
// Budget
GRBLinExpr lhs;
lhs = 0;
for (e = 0; e < groundSetSize; e++) {
    lhs += Elem[e];
}
model.addConstr(lhs <= Budget, "Budget");

// Set global sense for ALL objectives
model.set(GRB_IntAttr_ModelSense, GRB_MAXIMIZE);

// Limit how many solutions to collect
model.set(GRB_IntParam_PoolSolutions, 100);

// Set and configure i-th objective
for (i = 0; i < nSubsets; i++) {
    GRBLinExpr objn = 0;
    for (e = 0; e < groundSetSize; e++)
        objn += Set[i][e]*Elem[e];
    ostringstream vname;
    vname << "Set" << i;
    model.setObjectiveN(objn, i, SetObjPriority[i], SetObjWeight[i],
                        1.0 + i, 0.01, vname.str());
}

// Save problem
model.write("multiobj_c++.lp");

// Optimize
model.optimize();
// Status checking
status = model.get(GRB_IntAttr_Status);
if (status == GRB_INF_OR_UNBD ||
    status == GRB_INFEASIBLE ||
    status == GRB_UNBOUNDED)
{
    cout << "The model cannot be solved " << "because it is infeasible or unbounded" << endl;
    return 1;
}
if (status != GRB_OPTIMAL)
{
    cout << "Optimization was stopped with status " << status << endl;
    return 1;
}

// Print best selected set
cout << "Selected elements in best solution:" << endl << "\t";
for (e = 0; e < groundSetSize; e++)
{
    if (Elem[e].get(GRB_DoubleAttr_X) < .9) continue;
    cout << "El" << e;
}
cout << endl;

// Print number of solutions stored
nSolutions = model.get(GRB_IntAttr_SolCount);
cout << "Number of solutions found: " << nSolutions << endl;

// Print objective values of solutions
if (nSolutions > 10) nSolutions = 10;
cout << "Objective values for first " << nSolutions << " solutions:" << endl;
for (i = 0; i < nSubsets; i++)
{
    model.set(GRB_IntParam_ObjNumber, i);
    cout << "\tSet " << i;
    for (e = 0; e < nSolutions; e++)
    {
        cout << " ";
        model.set(GRB_IntParam_SolutionNumber, e);
        double val = model.get(GRB_DoubleAttr_ObjNVal);
        cout << std::setw(6) << val;
    }
    cout << endl;
}
catch (GRBException e)
{
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
}
catch (...)
{
    cout << "Exception during optimization" << endl;
}

// Free environment/vars
delete[] Elem;
delete env;
/* Copyright 2018, Gurobi Optimization, LLC */

/* Use parameters that are associated with a model. 

A MIP is solved for a few seconds with different sets of parameters. 
The one with the smallest MIP gap is selected, and the optimization 
is resumed until the optimal solution is found. */

#include "gurobi_c++.h"
using namespace std;

int main(int argc,
         char *argv[])
{
    if (argc < 2)
    {
        cout << "Usage: params_c++ filename" << endl;
        return 1;
    }

    GRBEnv* env = 0;
    GRBModel *bestModel = 0, *m = 0;
    try
    {
        // Read model and verify that it is a MIP
        env = new GRBEnv();
        m = new GRBModel(*env, argv[1]);
        if (m->get(GRB_IntAttr_IsMIP) == 0)
        {
            cout << "The model is not an integer program" << endl;
            return 1;
        }

        // Set a 2 second time limit
        m->set(GRB_DoubleParam_TimeLimit, 2);

        // Now solve the model with different values of MIPFocus
        bestModel = new GRBModel(*m);
        bestModel->optimize();
        for (int i = 1; i <= 3; ++i)
        {
            m->reset();
            m->set(GRB_IntParam_MIPFocus, i);
            m->optimize();
            if (bestModel->get(GRB_DoubleAttr_MIPGap) >
                m->get(GRB_DoubleAttr_MIPGap))
            {
                swap(bestModel, m);
            }
    }

    return 0;
}
// Finally, delete the extra model, reset the time limit and
// continue to solve the best model to optimality
delete m;
m = 0;
bestModel->set(GRB_DoubleParam_TimeLimit, GRB_INFINITY);
bestModel->optimize();
cout << "Solved with MIPFocus: " <<
bestModel->get(GRB_IntParam_MIPFocus) << endl;

} catch (GRBException e)
{
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
} catch (...)
{
    cout << "Error during optimization" << endl;
}

delete bestModel;
delete m;
delete env;
return 0;

.piecewise_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */
/* This example considers the following separable, convex problem:
minimize f(x) - y + g(z)
subject to x + 2 y + 3 z <= 4
       x + y  >= 1
       x, y, z <= 1

where f(u) = exp(-u) and g(u) = 2 u^2 - 4 u, for all real u. It
formulates and solves a simpler LP model by approximating f and
g with piecewise-linear functions. Then it transforms the model
into a MIP by negating the approximation for f, which corresponds
to a non-convex piecewise-linear function, and solves it again. */

#include "gurobi_c++.h"
#include <cmath>
using namespace std;

double f(double u) { return exp(-u); }
double g(double u) { return 2 * u * u - 4 * u; }

int main(int argc,
         char *argv[])
{
    double *ptu = NULL;
    double *ptf = NULL;
    double *ptg = NULL;

    try {

        // Create environment
        GRBEnv env = GRBEnv();

        // Create a new model
        GRBModel model = GRBModel(env);

        // Create variables
        double lb = 0.0, ub = 1.0;

        GRBVar x = model.addVar(lb, ub, 0.0, GRB_CONTINUOUS, "x");
        GRBVar y = model.addVar(lb, ub, 0.0, GRB_CONTINUOUS, "y");
        GRBVar z = model.addVar(lb, ub, 0.0, GRB_CONTINUOUS, "z");

        // Set objective for y
        model.setObjective(-y);

        // Add piecewise-linear objective functions for x and z
        int npts = 101;
        ptf = new double[npts];
        ptg = new double[npts];

        for (int i = 0; i < npts; i++) {
            ptu[i] = lb + (ub - lb) * i / (npts - 1);
            ptf[i] = f(ptu[i]);
            ptg[i] = g(ptu[i]);
        }

        model.setPWLObj(x, npts, ptu, ptf);
        model.setPWLObj(z, npts, ptu, ptg);

        // Add constraint: x + 2 y + 3 z <= 4
        model.addConstr(x + 2 * y + 3 * z <= 4, "c0");

        // Add constraint: x + y >= 1
        model.addConstr(x + y >= 1, "c1");

        // Optimize model as an LP
        model.optimize();

        cout << "IsMIP: " << model.get(GRB_IntAttr_IsMIP) << endl;
    }
}
cout << x.get(GRB_StringAttr_VarName) << " " << x.get(GRB_DoubleAttr_X) << endl;
cout << y.get(GRB_StringAttr_VarName) << " " << y.get(GRB_DoubleAttr_X) << endl;
cout << z.get(GRB_StringAttr_VarName) << " " << z.get(GRB_DoubleAttr_X) << endl;

for (int i = 0; i < npts; i++) {
    ptf[i] = -ptf[i];
}
model.setPWLObj(x, npts, ptu, ptf);

model.optimize();

try {
cout << "Obj: " << model.get(GRB_DoubleAttr_ObjVal) << endl;

cout << endl;

} catch(GRBException e) {
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
} catch(...) {
    cout << "Exception during optimization" << endl;
}

delete[] ptu;
delete[] ptf;
delete[] ptg;

return 0;

poolsearch_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* We find alternative epsilon-optimal solutions to a given knapsack problem by using PoolSearchMode */
```cpp
#include "gurobi_c++.h"
#include <sstream>
#include <iomanip>

using namespace std;

int main(void)
{
    GRBEnv *env = 0;
    GRBVar *Elem = 0;
    int e, status, nSolutions;

    try {
        // Sample data
        const int groundSetSize = 10;
        double objCoef[10] =
            {32, 32, 15, 15, 6, 6, 1, 1, 1, 1};
        double knapsackCoef[10] =
            {16, 16, 8, 8, 4, 4, 2, 2, 1, 1};
        double Budget = 33;

        // Create environment
        env = new GRBEnv("poolsearch_c++.log");

        // Create initial model
        GRBModel model = GRBModel(*env);
        model.set(GRB_StringAttr_ModelName, "poolsearch_c++");

        // Initialize decision variables for ground set:
        // x[e] == 1 if element e is chosen
        Elem = model.addVars(groundSetSize, GRB_BINARY);
        model.set(GRB_DoubleAttr_Obj, Elem, objCoef, groundSetSize);

        for (e = 0; e < groundSetSize; e++) {
            ostringstream vname;
            vname << "El" << e;
            Elem[e].set(GRB_StringAttr_VarName, vname.str());
        }

        // Constraint: limit total number of elements to be picked to be at most Budget
        GRBLinExpr lhs;
        lhs = 0;
        for (e = 0; e < groundSetSize; e++) {
            lhs += Elem[e] * knapsackCoef[e];
        }
        model.addConstr(lhs <= Budget, "Budget");

        // set global sense for ALL objectives
        model.set(GRB_IntAttr_ModelSense, GRB_MAXIMIZE);

        // Limit how many solutions to collect
        model.set(GRB_IntParam_PoolSolutions, 1024);

        // Limit the search space by setting a gap for the worst possible solution that will be accepted
        model.set(GRB_DoubleParam_PoolGap, 0.10);
    }
}
```

// do a systematic search for the k-best solutions
model.set(GRB_IntParam.PoolSearchMode, 2);

// save problem
model.write("poolsearch_c++.lp");

// Optimize
model.optimize();

// Status checking
status = model.get(GRB_IntAttr_Status);
if (status == GRB_INF_OR_UNBD ||
    status == GRB_INFEASIBLE ||
    status == GRB_UNBOUNDED) {
    cout << "The model cannot be solved " <<
         "because it is infeasible or unbounded" << endl;
    return 1;
}
if (status != GRB_OPTIMAL) {
    cout << "Optimization was stopped with status " << status << endl;
    return 1;
}

// Print best selected set
for (e = 0; e < groundSetSize; e++) {
    if (Elem[e].get(GRB_DoubleAttr_X) < .9)
        continue;
    cout << "El" << e;
}
cout << endl;

// Print number of solutions stored
nSolutions = model.get(GRB_IntAttr_SolCount);
cout << "Number of solutions found: " << nSolutions << endl;

// Print objective values of solutions
for (e = 0; e < nSolutions; e++) {
    model.set(GRB_IntParam_SolutionNumber, e);
    cout << model.get(GRB_DoubleAttr_PoolObjVal) << " ";
    if (e%15 == 14) cout << endl;
}
cout << endl;

// print fourth best set if available
if (nSolutions >= 4) {
    model.set(GRB_IntParam_SolutionNumber, 3);
    for (e = 0; e < groundSetSize; e++) {
        if (Elem[e].get(GRB_DoubleAttr_Xn) < .9) continue;
        cout << " El" << e;
    }
cout << endl;
}
catch (GRBException e) {
  cout << "Error code = " << e.getErrorCode() << endl;
  cout << e.getMessage() << endl;
}
catch (...) {
  cout << "Exception during optimization" << endl;
}

// Free environment/vars
delete[] Elem;
delete env;
return 0;

sensitivity_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */
/* A simple sensitivity analysis example which reads a MIP model from a file and solves it. Then each binary variable is set to 1-X, where X is its value in the optimal solution, and the impact on the objective function value is reported. */

#include "gurobi_c++.h"
using namespace std;

int main(int argc, char * argv[]) {
  if (argc < 2) {
    cout << "Usage: sensitivity_c++ filename" << endl;
    return 1;
  }

  GRBVar * vars = NULL;
  double* origX = NULL;

  try {
    // Create environment
    GRBEnv env = GRBEnv();

    // Read and solve model
    GRBModel model = GRBModel(env, argv[1]);

    if (model.get(GRB_IntAttr_IsMIP) == 0) {
      cout << "Model is not a MIP" << endl;
      return 1;
    }

    model.optimize();
  } catch (GRBException e) {
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
  }
  catch (...) {
    cout << "Exception during optimization" << endl;
  }

  // Free environment/vars
  delete[] Elem;
  delete env;
  return 0;
}
if (model.get(GRB_IntAttr_Status) != GRB_OPTIMAL) {
    cout << "Optimization ended with status "
    << model.get(GRB_IntAttr_Status) << endl;
    return 1;
}

// Store the optimal solution

double origObjVal = model.get(GRB_DoubleAttr_ObjVal);
vars = model.getVars();
int numVars = model.get(GRB_IntAttr_NumVars);
origX = model.get(GRB_DoubleAttr_X, vars, numVars);

// Disable solver output for subsequent solves
model.set(GRB_IntParam_OutputFlag, 0);

// Iterate through unfixed, binary variables in model

for (int i = 0; i < numVars; i++) {
    GRBVar v = vars[i];
    char vType = v.get(GRB_CharAttr_VType);

    if (v.get(GRB_DoubleAttr_LB) == 0 && v.get(GRB_DoubleAttr_UB) == 1
        && (vType == GRB_BINARY || vType == GRB_INTEGER)) {
        // Set variable to 1-X, where X is its value in optimal solution
        if (origX[i] < 0.5) {
            v.set(GRB_DoubleAttr_LB, 1.0);
            v.set(GRB_DoubleAttr_Start, 1.0);
        } else {
            v.set(GRB_DoubleAttr_UB, 0.0);
            v.set(GRB_DoubleAttr_Start, 0.0);
        }

        // Update MIP start for the other variables
        for (int j = 0; j < numVars; j++) {
            if (j != i) {
                vars[j].set(GRB_DoubleAttr_Start, origX[j]);
            }
        }

        // Solve for new value and capture sensitivity information
        model.optimize();

        if (model.get(GRB_IntAttr_Status) == GRB_OPTIMAL) {
            cout << "Objective sensitivity for variable "
                 << v.get(GRB_StringAttr_VarName) << " is 
                 << (model.get(GRB_DoubleAttr_ObjVal) - origObjVal) << endl;
        } else {
            cout << "Objective sensitivity for variable "
                 << v.get(GRB_StringAttr_VarName) << " is infinite" << endl;
        }
    }
}
/* This example formulates and solves the following simple QCP model: 
   maximize x 
   subject to x + y + z = 1 
          x^2 + y^2 <= z^2 (second-order cone) 
          x^2 <= yz (rotated second-order cone) 
*/
#include "gurobi_c++.h"
using namespace std;

int main(int argc, char *argv[])
{
    try {
        GRBEnv env = GRBEnv();
        GRBModel model = GRBModel(env);

        // Create variables
        GRBVar x = model.addVar(0.0, GRB_INFINITY, 0.0, GRB_CONTINUOUS, "x");
        GRBVar y = model.addVar(0.0, GRB_INFINITY, 0.0, GRB_CONTINUOUS, "y");
        GRBVar z = model.addVar(0.0, GRB_INFINITY, 0.0, GRB_CONTINUOUS, "z");

        // Set objective
        GRBLinExpr obj = x;
        model.setObjective(obj, GRB_MAXIMIZE);

        // Restore the original variable bounds
        x.set(GRB_DoubleAttr_LB, 0.0);
        x.set(GRB_DoubleAttr_UB, 1.0);
    }
}

qcp_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */
// Add linear constraint: x + y + z = 1
model.addConstr(x + y + z == 1, "c0");

// Add second-order cone: x^2 + y^2 <= z^2
model.addQConstr(x*x + y*y <= z*z, "qc0");

// Add rotated cone: x^2 <= yz
model.addQConstr(x*x <= y*z, "qc1");

// Optimize model
model.optimize();

cout << x.get(GRB_StringAttr_VarName) << " "
    << x.get(GRB_DoubleAttr_X) << endl;
cout << y.get(GRB_StringAttr_VarName) << " "
    << y.get(GRB_DoubleAttr_X) << endl;
cout << z.get(GRB_StringAttr_VarName) << " "
    << z.get(GRB_DoubleAttr_X) << endl;

cout << "Obj: " << model.get(GRB_DoubleAttr_ObjVal) << endl;

} catch(GRBException e) {
    cout << "Error code = " << e.getErrorCode() << endl;
cout << e.getMessage() << endl;
} catch(...) { 
    cout << "Exception during optimization" << endl;
}

return 0;

qp_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example formulates and solves the following simple QP model:
   minimize     x^2 + x*y + y^2 + y*z + z^2 + 2 x
   subject to   x + 2 y + 3 z >= 4
                 x + y >= 1

   It solves it once as a continuous model, and once as an integer model. */

#include "gurobi_c++.h"
using namespace std;

int main(int argc, char *argv[]) {


try {
    GRBEnv env = GRBEnv();
    GRBModel model = GRBModel(env);

    // Create variables
    GRBVar x = model.addVar(0.0, 1.0, 0.0, GRB_CONTINUOUS, "x");
    GRBVar y = model.addVar(0.0, 1.0, 0.0, GRB_CONTINUOUS, "y");
    GRBVar z = model.addVar(0.0, 1.0, 0.0, GRB_CONTINUOUS, "z");

    // Set objective
    GRBQuadExpr obj = x*x + x*y + y*y + y*z + z*z + 2*x;
    model.setObjective(obj);

    // Add constraint: x + 2 y + 3 z >= 4
    model.addConstr(x + 2 * y + 3 * z >= 4, "c0");

    // Add constraint: x + y >= 1
    model.addConstr(x + y >= 1, "c1");

    // Optimize model
    model.optimize();

    cout << x.get(GRB_StringAttr_VarName) << " "
         << x.get(GRB_DoubleAttr_X) << endl;
    cout << y.get(GRB_StringAttr_VarName) << " "
         << y.get(GRB_DoubleAttr_X) << endl;
    cout << z.get(GRB_StringAttr_VarName) << " "
         << z.get(GRB_DoubleAttr_X) << endl;

    cout << "Obj: " << model.get(GRB_DoubleAttr_ObjVal) << endl;

    // Change variable types to integer
    x.set(GRB_CharAttr_VType, GRB_INTEGER);
    y.set(GRB_CharAttr_VType, GRB_INTEGER);
    z.set(GRB_CharAttr_VType, GRB_INTEGER);

    // Optimize model
    model.optimize();

    cout << x.get(GRB_StringAttr_VarName) << " "
         << x.get(GRB_DoubleAttr_X) << endl;
    cout << y.get(GRB_StringAttr_VarName) << " "
         << y.get(GRB_DoubleAttr_X) << endl;
    cout << z.get(GRB_StringAttr_VarName) << " "
         << z.get(GRB_DoubleAttr_X) << endl;

    cout << "Obj: " << model.get(GRB_DoubleAttr_ObjVal) << endl;
}
```cpp
} catch (GRBException e) {
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
} catch (...) {
    cout << "Exception during optimization" << endl;
}

return 0;
}

sos_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example creates a very simple Special Ordered Set (SOS) model.
The model consists of 3 continuous variables, no linear constraints,
and a pair of SOS constraints of type 1. */

#include "gurobi_c++.h"
using namespace std;

int main(int argc, char *argv[]) {
    GRBEnv *env = 0;
    GRBVar *x = 0;
    try {
        env = new GRBEnv();

        GRBModel model = GRBModel(*env);

        // Create variables
        double ub[] = {1, 1, 2};
        double obj[] = {-2, -1, -1};
        string names[] = {"x0", "x1", "x2"};

        x = model.addVars(NULL, ub, obj, NULL, names, 3);

        // Add first SOS1: x0=0 or x1=0
        GRBVar sosv1[] = {x[0], x[1]};
        double soswt1[] = {1, 2};
        model.addSOS(sosv1, soswt1, 2, GRB_SOS_TYPE1);

        // Add second SOS1: x0=0 or x2=0 */
        GRBVar sosv2[] = {x[0], x[2]};
        double soswt2[] = {1, 2};
        model.addSOS(sosv2, soswt2, 2, GRB_SOS_TYPE1);

        // Optimize model
```
model.optimize();

for (int i = 0; i < 3; i++)
    cout << x[i].get(GRB_StringAttr_VarName) << " " << x[i].get(GRB_DoubleAttr_X) << endl;
    cout << "Obj: " << model.get(GRB_DoubleAttr_ObjVal) << endl;
}

} catch (GRBException e) {
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
} catch (...) {
    cout << "Exception during optimization" << endl;
}

delete[] x;
delete env;
return 0;

*/

#include "gurobi_c++.h"
#include <sstream>
using namespace std;

#define sd 3
#define n (sd*sd)

string itos(int i) {stringstream s; s << i; return s.str(); }

int main(int argc, char *argv[])
{
    try {
        GRBEnv env = GRBEnv();

        Sudoku example.

        The Sudoku board is a 9x9 grid, which is further divided into a 3x3 grid of 3x3 grids. Each cell in the grid must take a value from 0 to 9. No two grid cells in the same row, column, or 3x3 subgrid may take the same value.

        In the MIP formulation, binary variables x[i,j,v] indicate whether cell <i,j> takes value 'v'. The constraints are as follows:
        1. Each cell must take exactly one value (sum_v x[i,j,v] = 1)
        2. Each value is used exactly once per row (sum_i x[i,j,v] = 1)
        3. Each value is used exactly once per column (sum_j x[i,j,v] = 1)
        4. Each value is used exactly once per 3x3 subgrid (sum_grid x[i,j,v] = 1)

        Input datasets for this example can be found in examples/data/sudoku*.
```java
GRBModel model = GRBModel(env);

GRBVar vars[n][n][n];
int i, j, v;

// Create 3-D array of model variables
for (i = 0; i < n; i++) {
    for (j = 0; j < n; j++) {
        for (v = 0; v < n; v++) {
            string s = "G_" + itos(i) + "_" + itos(j) + "_" + itos(v);
            vars[i][j][v] = model.addVar(0.0, 1.0, 0.0, GRB_BINARY, s);
        }
    }
}

// Add constraints
// Each cell must take one value
for (i = 0; i < n; i++) {
    for (j = 0; j < n; j++) {
        GRBLinExpr expr = 0;
        for (v = 0; v < n; v++)
            expr += vars[i][j][v];
        string s = "V_" + itos(i) + "_" + itos(j);
        model.addConstr(expr, GRB_EQUAL, 1.0, s);
    }
}

// Each value appears once per row
for (i = 0; i < n; i++) {
    for (v = 0; v < n; v++) {
        GRBLinExpr expr = 0;
        for (j = 0; j < n; j++)
            expr += vars[i][j][v];
        string s = "R_" + itos(i) + "_" + itos(v);
        model.addConstr(expr == 1.0, s);
    }
}

// Each value appears once per column
for (j = 0; j < n; j++) {
    for (v = 0; v < n; v++) {
        GRBLinExpr expr = 0;
        for (i = 0; i < n; i++)
            expr += vars[i][j][v];
        string s = "C_" + itos(j) + "_" + itos(v);
        model.addConstr(expr == 1.0, s);
    }
}

// Each value appears once per sub-grid
```
for (v = 0; v < n; v++) {
    for (int i0 = 0; i0 < sd; i0++) {
        for (int j0 = 0; j0 < sd; j0++) {
            GRBLinExpr expr = 0;
            for (int i1 = 0; i1 < sd; i1++) {
                for (int j1 = 0; j1 < sd; j1++) {
                    expr += vars[i0*sd+i1][j0*sd+j1][v];
                }
            }
            string s = "Sub_" + itos(v) + "_" + itos(i0) + "_" + itos(j0);
            model.addConstr(expr == 1.0, s);
        }
    }
}

// Fix variables associated with pre-specified cells

char input[10];
for (i = 0; i < n; i++) {
    cin >> input;
    for (j = 0; j < n; j++) {
        int val = (int) input[j] - 48 - 1; // 0-based
        if (val >= 0)
            vars[i][j][val].set(GRB_DoubleAttr_LB, 1.0);
    }
}

// Optimize model

model.optimize();

// Write model to file

model.write("sudoku.lp");

cout << endl;
for (i = 0; i < n; i++) {
    for (j = 0; j < n; j++) {
        for (v = 0; v < n; v++) {
            if (vars[i][j][v].get(GRB_DoubleAttr_X) > 0.5)
                cout << v+1;
        }
    }
    cout << endl;
}

cout << endl;
}
catch(GRBException e) {
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
}
catch (...) {
    cout << "Error during optimization" << endl;
}

return 0;
/* Copyright 2018, Gurobi Optimization, LLC */

/* Solve a traveling salesman problem on a randomly generated set of points using lazy constraints. The base MIP model only includes 'degree-2' constraints, requiring each node to have exactly two incident edges. Solutions to this model may contain subtours - tours that don't visit every node. The lazy constraint callback adds new constraints to cut them off. */

#include "gurobi_c++.h"
#include <cassert>
#include <cstdlib>
#include <cmath>
#include <sstream>
using namespace std;

string itos(int i) { stringstream s; s << i; return s.str(); }

double distance(double* x, double* y, int i, int j);

void findsubtour(int n, double** sol, int* tourlenP, int* tour);

// Subtour elimination callback. Whenever a feasible solution is found, find the smallest subtour, and add a subtour elimination constraint if the tour doesn't visit every node.

class subtourelim: public GRBCallback {

public:
    GRBVar** vars;
    int n;

    subtourelim(GRBVar** xvars, int xn) {
        vars = xvars;
        n = xn;
    }

    protected:
    void callback() {
    
    try {
        if (where == GRB_CB_MIPSOL) {
            // Found an integer feasible solution - does it visit every node?
            double **x = new double*[n];
            int *tour = new int[n];
            int i, j, len;
            for (i = 0; i < n; i++)
                x[i] = getSolution(vars[i], n);

            findsubtour(n, x, &len, tour);

            if (len < n) {
                // Add subtour elimination constraint
                GRBLinExpr expr = 0;
                for (i = 0; i < len; i++)
                    for (j = i+1; j < len; j++)
                        expr += vars[tour[i]][tour[j]];
        }
    }
    }

    private:
    ~subtourelim();
};

tsp_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* Solve a traveling salesman problem on a randomly generated set of points using lazy constraints. The base MIP model only includes 'degree-2' constraints, requiring each node to have exactly two incident edges. Solutions to this model may contain subtours - tours that don't visit every node. The lazy constraint callback adds new constraints to cut them off. */

#include "gurobi_c++.h"
#include <cassert>
#include <cstdlib>
#include <cmath>
#include <sstream>
using namespace std;

string itos(int i) { stringstream s; s << i; return s.str(); }

double distance(double* x, double* y, int i, int j);

void findsubtour(int n, double** sol, int* tourlenP, int* tour);

// Subtour elimination callback. Whenever a feasible solution is found, find the smallest subtour, and add a subtour elimination constraint if the tour doesn't visit every node.

class subtourelim: public GRBCallback {

public:
    GRBVar** vars;
    int n;

    subtourelim(GRBVar** xvars, int xn) {
        vars = xvars;
        n = xn;
    }

    protected:
    void callback() {
    
    try {
        if (where == GRB_CB_MIPSOL) {
            // Found an integer feasible solution - does it visit every node?
            double **x = new double*[n];
            int *tour = new int[n];
            int i, j, len;
            for (i = 0; i < n; i++)
                x[i] = getSolution(vars[i], n);

            findsubtour(n, x, &len, tour);

            if (len < n) {
                // Add subtour elimination constraint
                GRBLinExpr expr = 0;
                for (i = 0; i < len; i++)
                    for (j = i+1; j < len; j++)
                        expr += vars[tour[i]][tour[j]];
        }
    }
    }

    private:
    ~subtourelim();
};

#include <iostream>

int main() {
    // Create a new model
    GRBModel model = new GRBModel();

    int n = 10;
    double** x = new double*[n];
    double** y = new double*[n];

    // Populate the model
    for (int i = 0; i < n; i++)
        for (int j = 0; j < n; j++)
            distance(x, y, i, j);

    // Add degree-2 constraints
    for (int i = 0; i < n; i++)
        for (int j = 0; j < n; j++)
            expr += vars[tour[i]][tour[j]];

    // Solve the model
    model.Optimize();

    return 0;
}

addLazy(expr <= len-1);
}
for (i = 0; i < n; i++)
    delete[] x[i];
delete[] x;
delete[] tour;
} catch (GRBException e) {
    cout << "Error number: " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
} catch (...) {
    cout << "Error during callback" << endl;
}
};

// Given an integer-feasible solution 'sol', find the smallest
// sub-tour. Result is returned in 'tour', and length is
// returned in 'tourlenP'.

void findsubtour(int n,
    double** sol,
    int* tourlenP,
    int* tour)
{
    bool* seen = new bool[n];
    int bestind, bestlen;
    int i, node, len, start;
    for (i = 0; i < n; i++)
        seen[i] = false;
    start = 0;
    bestlen = n+1;
    bestind = -1;
    node = 0;
    while (start < n) {
        for (node = 0; node < n; node++)
            if (!seen[node])
                break;
        if (node == n)
            break;
        for (len = 0; len < n; len++) {
            tour[start+len] = node;
            seen[node] = true;
            for (i = 0; i < n; i++) {
                if (sol[node][i] > 0.5 && !seen[i]) {
                    node = i;
                    break;
                }
            }
            if (i == n) {
                len++;
                if (len < bestlen) {
                    bestlen = len;
                    bestind = node;
                }
            }
        }
    }
}
bestlen = len;
bestind = start;
}
start += len;
break;
}
}

for (i = 0; i < bestlen; i++)
tour[i] = tour[bestind+i];
*tourlenP = bestlen;

delete[] seen;
}

// Euclidean distance between points 'i' and 'j'.
double distance(double* x, double* y, int i, int j)
{
    double dx = x[i]-x[j];
    double dy = y[i]-y[j];
    return sqrt(dx*dx+dy*dy);
}

int main(int argc, char *argv[])
{
    if (argc < 2) {
        cout << "Usage: tsp_c++ size" << endl;
        return 1;
    }

    int n = atoi(argv[1]);
double* x = new double[n];
double* y = new double[n];

    int i;
    for (i = 0; i < n; i++) {
        x[i] = ((double) rand())/RAND_MAX;
        y[i] = ((double) rand())/RAND_MAX;
    }

    GRBEnv *env = NULL;
    GRBVar **vars = NULL;

    vars = new GRBVar*[n];
    for (i = 0; i < n; i++)
        vars[i] = new GRBVar[n];
try {
    int j;

    env = new GRBEnv();
    GRBModel model = GRBModel(*env);

    // Must set LazyConstraints parameter when using lazy constraints
    model.set(GRB_IntParam_LazyConstraints, 1);

    // Create binary decision variables
    for (i = 0; i < n; i++) {
        for (j = 0; j <= i; j++) {
            vars[i][j] = model.addVar(0.0, 1.0, distance(x, y, i, j),
                                       GRB_BINARY, "x_"+itos(i)="_"+itos(j));
            vars[j][i] = vars[i][j];
        }
    }

    // Degree-2 constraints
    for (i = 0; i < n; i++) {
        GRBLinExpr expr = 0;
        for (j = 0; j < n; j++)
            expr += vars[i][j];
        model.addConstr(expr == 2, "deg2_"+itos(i));
    }

    // Forbid edge from node back to itself
    for (i = 0; i < n; i++)
        vars[i][i].set(GRB_DoubleAttr_UB, 0);

    // Set callback function
    subtourelim cb = subtourelim(vars, n);
    model.setCallback(&cb);

    // Optimize model
    model.optimize();

    // Extract solution
    if (model.get(GRB_IntAttr_SolCount) > 0) {
        double **sol = new double*[n];
        for (i = 0; i < n; i++)
            sol[i] = model.get(GRB_DoubleAttr_X, vars[i], n);

        int* tour = new int[n];
        int len;

        findsubtour(n, sol, &len, tour);
        assert(len == n);
cout << "Tour: ";
for (i = 0; i < len; i++)
    cout << tour[i] << " ";
cout << endl;

for (i = 0; i < n; i++)
    delete[] sol[i];
delete[] sol;
delete[] tour;
}

} catch (GRBException e) {
    cout << "Error number: " << e.getErrorCode() << endl;
cout << e.getMessage() << endl;
} catch (...) {
    cout << "Error during optimization" << endl;
}

for (i = 0; i < n; i++)
    delete[] vars[i];
delete[] vars;
delete[] x;
delete[] y;
delete env;
return 0;
}

tune_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads a model from a file and tunes it.
 It then writes the best parameter settings to a file
 and solves the model using these parameters. */

#include "gurobi_c++.h"
#include <cmath>
using namespace std;

int main(int argc, char *argv[])
{
    if (argc < 2) {
        cout << "Usage: tune_c++ filename" << endl;
        return 1;
    }

    GRBEnv *env = 0;
    try {
        env = new GRBEnv();

        // Read model from file
        GRBModel model = GRBModel(*env, argv[1]);
// Set the TuneResults parameter to 1
model.set(GRB_IntParam_TuneResults, 1);

// Tune the model
model.tune();

// Get the number of tuning results
int resultcount = model.get(GRB_IntAttr_TuneResultCount);
if (resultcount > 0) {
    // Load the tuned parameters into the model's environment
    model.getTuneResult(0);
    // Write tuned parameters to a file
    model.write("tune.prm");
    // Solve the model using the tuned parameters
    model.optimize();
}
}

// Catch GRBException or other exceptions
catch(GRBException e) {
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
} catch (...) {
    cout << "Error during tuning" << endl;
}

delete env;
return 0;

workforce1_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a
particular day. If the problem cannot be solved, use IIS to find a set of
conflicting constraints. Note that there may be additional conflicts
besides what is reported via IIS. */

#include "gurobi_c++.h"
#include <sstream>
using namespace std;

int main(int argc,
    char *argv[])
{
    GRBEnv* env = 0;
    GRBConstr* c = 0;
GRBVar** x = 0;
int xCt = 0;
try
{

    // Sample data
    const int nShifts = 14;
    const int nWorkers = 7;

    // Sets of days and workers
    string Shifts[] =
    string Workers[] =

    // Number of workers required for each shift
    double shiftRequirements[] =
    { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

    // Amount each worker is paid to work one shift
    double pay[] = { 10, 12, 10, 8, 8, 9, 11 };

    // Worker availability: 0 if the worker is unavailable for a shift
    double availability[][nShifts] =
    { { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1 },
      { 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 1 },
      { 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1 },
      { 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1 },
      { 1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 1 },
      { 1, 1, 1, 0, 0, 1, 1, 1, 0, 1, 1, 1 },
      { 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1 } };

    // Model
    env = new GRBEnv();
    GRBModel model = GRBModel(*env);
    model.set(GRB_StringAttr_ModelName, "assignment");

    // Assignment variables: x[w][s] == 1 if worker w is assigned
    // to shift s. Since an assignment model always produces integer
    // solutions, we use continuous variables and solve as an LP.
    x = new GRBVar*[nWorkers];
    for (int w = 0; w < nWorkers; ++w)
    {
        x[w] = model.addVars(nShifts);
        xCt++;
        for (int s = 0; s < nShifts; ++s)
        {
            ostringstream vname;
            vname << Workers[w] << "." << Shifts[s];
            x[w][s].set(GRB_DoubleAttr_UB, availability[w][s]);
            x[w][s].set(GRB_DoubleAttr_Obj, pay[w]);
            x[w][s].set(GRB_StringAttr_VarName, vname.str());
        }
    }
}
// The objective is to minimize the total pay costs
model.set(GRB_IntAttr_ModelSense, GRB_MINIMIZE);

// Constraint: assign exactly shiftRequirements[s] workers
// to each shift s
for (int s = 0; s < nShifts; ++s)
{
    GRBLinExpr lhs = 0;
    for (int w = 0; w < nWorkers; ++w)
    {
        lhs += x[w][s];
    }
    model.addConstr(lhs == shiftRequirements[s], Shifts[s]);
}

// Optimize
model.optimize();
int status = model.get(GRB_IntAttr_Status);
if (status == GRB_UNBOUNDED)
{
    cout << "The model cannot be solved "
         << "because it is unbounded" << endl;
    return 1;
}
if (status == GRB_OPTIMAL)
{
    cout << "The optimal objective is " <<
         model.get(GRB_DoubleAttr_ObjVal) << endl;
    return 0;
}
if ((status != GRB_INF_OR_UNBD) && (status != GRB_INFEASIBLE))
{
    cout << "Optimization was stopped with status " << status << endl;
    return 1;
}

// do IIS
cout << "The model is infeasible; computing IIS" << endl;
model.computeIIS();
cout << "\nThe following constraint(s) "
    << "cannot be satisfied:" << endl;
c = model.getConstrs();
for (int i = 0; i < model.get(GRB_IntAttr_NumConstrs); ++i)
{
    if (c[i].get(GRB_IntAttr_IISConstr) == 1)
    {
        cout << c[i].get(GRB_StringAttr_ConstrName) << endl;
    }
}
catch (GRBException e)
{
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
}
catch (...) {
    cout << "Exception during optimization" << endl;
}

delete[] c;
for (int i = 0; i < xCt; ++i) {
    delete[] x[i];
}
delete[] x;
delete env;
return 0;

workforce2_c+++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a
   particular day. If the problem cannot be solved, use IIS iteratively to
   find all conflicting constraints. */

#include "gurobi_c++.h"
#include <sstream>
#include <deque>
using namespace std;

int main(int argc, char *argv[]) {
    GRBEnv * env = 0;
    GRBConstr * c = 0;
    GRBVar ** x = 0;
    int xCt = 0;
    try {

        // Sample data
        const int nShifts = 14;
        const int nWorkers = 7;

        // Sets of days and workers
        string Shifts[] = {
            "Mon", "Tue", "Wed", "Thu", "Fri", "Sat",
            "SunS"};
        string Workers[] = {

        // Number of workers required for each shift
        double shiftRequirements[] = {
            3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5
        };

        // Amount each worker is paid to work one shift
double pay[] = { 10, 12, 10, 8, 8, 9, 11 }

// Worker availability: 0 if the worker is unavailable for a shift
double availability[][nShifts] =
{ { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1 },
 { 1, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1 },
 { 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 },
 { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1 },
 { 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1 },
 { 1, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 1 },
 { 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 } };
<< "because it is unbounded" << endl;
return 1;
}
if (status == GRB_OPTIMAL)
{
  cout << "The optimal objective is " <<
model.get(GRB_DoubleAttr_ObjVal) << endl;
return 0;
}
if ((status != GRB_INF_OR_UNBD) && (status != GRB_INFEASIBLE))
{
  cout << "Optimization was stopped with status " << status << endl;
  return 1;
}

// do IIS
cout << "The model is infeasible; computing IIS" << endl;
deque<string> removed;

// Loop until we reduce to a model that can be solved
while (1)
{
  model.computeIIS();
  cout << "\nThe following constraint cannot be satisfied:" << endl;
  c = model.getConstrs();
  for (int i = 0; i < model.get(GRB_IntAttr_NumConstrs); ++i)
  {
    if (c[i].get(GRB_IntAttr_IISConstr) == 1)
    {
      cout << c[i].get(GRB_StringAttr_ConstrName) << endl;
      // Remove a single constraint from the model
      removed.push_back(c[i].get(GRB_StringAttr_ConstrName));
      model.remove(c[i]);
      break;
    }
  }
delete[] c;
c = 0;

cout << endl;
model.optimize();
status = model.get(GRB_IntAttr_Status);

if (status == GRB_UNBOUNDED)
{
  cout << "The model cannot be solved because it is unbounded" << endl;
  return 0;
}
if (status == GRB_OPTIMAL)
{
  break;
}
if ((status != GRB_INF_OR_UNBD) && (status != GRB_INFEASIBLE))
{
  cout << "Optimization was stopped with status " << status << endl;
  return 1;
}
cout << "The following constraints were removed "
<< "to get a feasible LP:" << endl;

for (deque<string>::iterator r = removed.begin();
   r != removed.end();
   ++r)
{
   cout << *r << " ";
}
cout << endl;

} catch (GRBException e)
{
   cout << "Error code = " << e.getErrorCode() << endl;
   cout << e.getMessage() << endl;
} catch (...)
{
   cout << "Exception during optimization" << endl;
}

delete[] c;
for (int i = 0; i < xCt; ++i) {
   delete[] x[i];
}
delete[] x;
delete env;
return 0;
}

workforce3_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a
   particular day. If the problem cannot be solved, relax the model
to determine which constraints cannot be satisfied, and how much
they need to be relaxed. */

#include "gurobi_c++.h"
#include <sstream>
using namespace std;

int main(int argc,
         char *argv[])
{
   GRBEnv* env = 0;
   GRBConstr* c = 0;
   GRBVar** x = 0;
   GRBVar* vars = 0;
   int xCt = 0;
   try
// Sample data
const int nShifts = 14;
const int nWorkers = 7;

// Sets of days and workers
string Shifts[] =
{ "Mon1", "Tue2", "Wed3", "Thu4", "Fri5", "Sat6", 
  "Sun7", "Mon8", "Tue9", "Wed10", "Thu11", "Fri12", "Sat13",  
  "Sun14" }; 
string Workers[] =

// Number of workers required for each shift
double shiftRequirements[] =
{ 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 }; 

// Amount each worker is paid to work one shift
double pay[] = { 10, 12, 10, 8, 8, 9, 11 }; 

// Worker availability: 0 if the worker is unavailable for a shift
double availability[][nShifts] = 
{ { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1 },  
  { 1, 1, 0, 0, 1, 0, 1, 1, 0, 1, 0, 1 },  
  { 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },  
  { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1 },  
  { 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 0, 1 }, 
  { 1, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 1 },  
  { 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 } }; 

// Model
env = new GRBEnv();
GRBModel model = GRBModel(*env);
model.set(GRB_StringAttr_ModelName, "assignment"); 

// Assignment variables: x[w][s] == 1 if worker w is assigned 
// to shift s. Since an assignment model always produces integer 
// solutions, we use continuous variables and solve as an LP.
x = new GRBVar*[nWorkers];
for (int w = 0; w < nWorkers; ++w)
{
x[w] = model.addVars(nShifts);
xCt++;
for (int s = 0; s < nShifts; ++s)
{
    stringstream vname;
    vname << Workers[w] << "." << Shifts[s];
    x[w][s].set(GRB_DoubleAttr_UB, availability[w][s]);
    x[w][s].set(GRB_DoubleAttr_Obj, pay[w]);
    x[w][s].set(GRB_StringAttr_VarName, vname.str());
}
}

// The objective is to minimize the total pay costs
model.set(GRB_IntAttr_ModelSense, GRB_MINIMIZE);
// Constraint: assign exactly \texttt{shiftRequirements}[s] workers
// to each shift \texttt{s}
for (int s = 0; s < nShifts; ++s)
{
    GRBLinExpr lhs = 0;
    for (int w = 0; w < nWorkers; ++w)
    {
        lhs += x[w][s];
    }
    model.addConstr(lhs == shiftRequirements[s], Shifts[s]);
}

// Optimize
model.optimize();
int status = model.get(GRB_IntAttr_Status);
if (status == GRB_UNBOUNDED)
{
    cout << "The model cannot be solved " <<
         "because it is unbounded" << endl;
    return 1;
}
if (status == GRB_OPTIMAL)
{
    cout << "The optimal objective is " <<
         model.get(GRB_DoubleAttr_ObjVal) << endl;
    return 0;
}
if ((status != GRB_INF_OR_UNBD) && (status != GRB_INFEASIBLE))
{
    cout << "Optimization was stopped with status " << status << endl;
    return 1;
}

// Relax the constraints to make the model feasible
cout << "The model is infeasible; relaxing the constraints" << endl;
int orignumvars = model.get(GRB_IntAttr_NumVars);
model.feasRelax(0, false, false, true);
model.optimize();
status = model.get(GRB_IntAttr_Status);
if ((status == GRB_INF_OR_UNBD) || (status == GRB_INFEASIBLE) ||
    (status == GRB_UNBOUNDED))
{
    cout << "The relaxed model cannot be solved " <<
         "because it is infeasible or unbounded" << endl;
    return 1;
}
if (status != GRB_OPTIMAL)
{
    cout << "Optimization was stopped with status " << status << endl;
    return 1;
}

cout << "\nSlack values:" << endl;
vars = model.getVars();
for (int i = orignumvars; i < model.get(GRB_IntAttr_NumVars); ++i)
{  
    GRBVar sv = vars[i];  
    if (sv.get(GRB_DoubleAttr_X) > 1e-6)  
    {  
        cout << sv.get(GRB_StringAttr_VarName) << " = " <<  
            sv.get(GRB_DoubleAttr_X) << endl;  
    }  
}

catch (GRBException e)  
{  
    cout << "Error code = " << e.getErrorCode() << endl;  
    cout << e.getMessage() << endl;  
}  

try  
{  
    delete[] c;  
    for (int i = 0; i < xCt; ++i) {  
        delete[] x[i];  
    }  
    delete[] x;  
    delete[] vars;  
    delete env;  
    return 0;  
}

workforce4_c++.cpp

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a  
* particular day. We use Pareto optimization to solve the model:  
* first, we minimize the linear sum of the slacks. Then, we constrain  
* the sum of the slacks, and we minimize a quadratic objective that  
* tries to balance the workload among the workers. */

#include "gurobi_c++.h"
#include <sstream>
using namespace std;

int solveAndPrint(GRBModel& model, GRBVar& totSlack,  
    int nWorkers, string* Workers,  
    GRBVar* totShifts) throw(GRBException);

int main(int argc,  
    char *argv[])  
{
    GRBEnv* env = 0;
    GRBVar** x = 0;
    GRBVar* slacks = 0;
    GRBVar* totShifts = 0;
    ...
GRBVar * diffShifts = 0;
int xCt = 0;

try
{
// Sample data
const int nShifts = 14;
const int nWorkers = 7;

// Sets of days and workers
string Shifts[] =
string Workers[] =

// Number of workers required for each shift
double shiftRequirements[] =
{ 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

// Worker availability: 0 if the worker is unavailable for a shift
double availability[][nShifts] =
{ { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
  { 1, 1, 1, 0, 1, 0, 1, 1, 0, 0, 1, 0, 1, 0 },
  { 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
  { 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
  { 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 1, 1 },
  { 1, 1, 1, 0, 0, 1, 0, 1, 1, 1, 1, 0, 1, 1 },
  { 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 } };

// Model
env = new GRBEnv();
GRBModel model = GRBModel(*env);
model.set(GRB_StringAttr_ModelName, "assignment");

// Assignment variables: x[w][s] == 1 if worker w is assigned
// to shift s. This is no longer a pure assignment model, so we must
// use binary variables.
x = new GRBVar*[nWorkers];
int s, w;

for (w = 0; w < nWorkers; ++w) {
  x[w] = model.addVars(nShifts);
  xCt++;

  for (s = 0; s < nShifts; ++s) {
    ostringstream vname;
    vname << Workers[w] << "." << Shifts[s];
    x[w][s].set(GRB_DoubleAttr_UB, availability[w][s]);
    x[w][s].set(GRB_CharAttr_VType, GRB_BINARY);
    x[w][s].set(GRB_StringAttr_VarName, vname.str());
  }
}
// Slack variables for each shift constraint so that the shifts can
// be satisfied
slacks = model.addVars(nShifts);
for (s = 0; s < nShifts; ++s) {
    ostringstream vname;
    vname << Shifts[s] << " Slack";
    slacks[s].set(GRB_StringAttr_VarName, vname.str());
}

// Variable to represent the total slack
GRBVar totSlack = model.addVar(0, GRB_INFINITY, 0, GRB_CONTINUOUS, "totSlack");

// Variables to count the total shifts worked by each worker
totShifts = model.addVars(nWorkers);
for (w = 0; w < nWorkers; ++w) {
    ostringstream vname;
    vname << Workers[w] << " TotShifts";
    totShifts[w].set(GRB_StringAttr_VarName, vname.str());
}

GRBLinExpr lhs;

// Constraint: assign exactly shiftRequirements[s] workers
// to each shift s
for (s = 0; s < nShifts; ++s) {
    lhs = 0;
    lhs += slacks[s];
    for (w = 0; w < nWorkers; ++w) {
        lhs += x[w][s];
    }
    model.addConstr(lhs == shiftRequirements[s], Shifts[s]);
}

// Constraint: set totSlack equal to the total slack
lhs = 0;
for (s = 0; s < nShifts; ++s) {
    lhs += slacks[s];
} model.addConstr(lhs == totSlack, "totSlack");

// Constraint: compute the total number of shifts for each worker
for (w = 0; w < nWorkers; ++w) {
    lhs = 0;
    for (s = 0; s < nShifts; ++s) {
        lhs += x[w][s];
    }
    ostringstream vname;
    vname << "totShifts" << Workers[w];
    model.addConstr(lhs == totShifts[w], vname.str());
}
// Objective: minimize the total slack
GRBLinExpr obj = 0;
obj += totSlack;
model.setObjective(obj);

// Optimize
int status = solveAndPrint(model, totSlack, nWorkers, Workers, totShifts);
if (status != GRB_OPTIMAL)
    return 1;

// Constrain the slack by setting its upper and lower bounds
totSlack.set(GRB_DoubleAttr_UB, totSlack.get(GRB_DoubleAttr_X));
totSlack.set(GRB_DoubleAttr_LB, totSlack.get(GRB_DoubleAttr_X));

// Variable to count the average number of shifts worked
GRBVar avgShifts =
    model.addVar(0, GRB_INFINITY, 0, GRB_CONTINUOUS, "avgShifts");

// Variables to count the difference from average for each worker;
// note that these variables can take negative values.
diffShifts = model.addVars(nWorkers);
for (w = 0; w < nWorkers; ++w) {
    ostringstream vname;
    vname << Workers[w] << " Diff";
    diffShifts[w].set(GRB_StringAttr_VarName, vname.str());
    diffShifts[w].set(GRB_DoubleAttr_LB, -GRB_INFINITY);
}

// Constraint: compute the average number of shifts worked
lhs = 0;
for (w = 0; w < nWorkers; ++w) {
    lhs += totShifts[w];
}
model.addConstr(lhs == nWorkers * avgShifts, "avgShifts");

// Constraint: compute the difference from the average number of shifts
for (w = 0; w < nWorkers; ++w) {
    lhs = 0;
    lhs += totShifts[w];
    lhs -= avgShifts;
    ostringstream vname;
    vname << Workers[w] << " Diff";
    model.addConstr(lhs == diffShifts[w], vname.str());
}

// Objective: minimize the sum of the square of the difference from the
// average number of shifts worked
GRBQuadExpr qobj;
for (w = 0; w < nWorkers; ++w) {
    qobj += diffShifts[w] * diffShifts[w];
}
model.setObjective(qobj);

// Optimize
status = solveAndPrint(model, totSlack, nWorkers, Workers, totShifts);
if (status != GRB_OPTIMAL)
    return 1;
}
catch (GRBException e) {
    cout << "Error code = " << e.getErrorCode() << endl;
    cout << e.getMessage() << endl;
}
catch (...) {
    cout << "Exception during optimization" << endl;
}

for (int i = 0; i < xCt; ++i) {
    delete[] x[i];
}
delete[] x;
delete[] slacks;
delete[] totShifts;
delete[] diffShifts;
delete env;

return 0;

int solveAndPrint(GRBModel& model,
        GRBVar& totSlack,
        int    nWorkers,
        string* Workers,
        GRBVar* totShifts) throw(GRBException)
{
    model.optimize();
    int status = model.get(GRB_IntAttr_Status);

    if ((status == GRB_INF_OR_UNBD) || (status == GRB_INFEASIBLE) || (status == GRB_UNBOUNDED) ) {
        cout << "The model cannot be solved " << "because it is infeasible or unbounded" << endl;
        return status;
    }
    if (status != GRB_OPTIMAL) {
        cout << "Optimization was stopped with status " << status << endl;
        return status;
    }

    // Print total slack and the number of shifts worked for each worker
    cout << "Total slack required: " << totSlack.get(GRB_DoubleAttr_X) << endl;
    for (int w = 0; w < nWorkers; ++w) {
        cout << Workers[w] << " worked " << totShifts[w].get(GRB_DoubleAttr_X) << " shifts" << endl;
    }
    cout << endl;
    return status;
}
/* Assign workers to shifts; each worker may or may not be available on a
particular day. We use multi-objective optimization to solve the model.
The highest-priority objective minimizes the sum of the slacks
(i.e., the total number of uncovered shifts). The secondary objective
minimizes the difference between the maximum and minimum number of
shifts worked among all workers. The second optimization is allowed
to degrade the first objective by up to the smaller value of 10% and 2 */

#include "gurobi_c++.h"
#include <sstream>
using namespace std;

int solveAndPrint(GRBModel& model, GRBVar& totSlack,
                   int nWorkers, string* Workers,
                   GRBVar* totShifts) throw(GRBException);

int main(int argc,
         char *argv[])
{
  GRBEnv *env = 0;
  GRBVar **x = 0;
  GRBVar *slacks = 0;
  GRBVar *totShifts = 0;
  int xCt = 0;
  int s, w;

  try {
    // Sample data
    const int nShifts = 14;
    const int nWorkers = 8;

    // Sets of days and workers
    string Shifts[] =
    { "Mon1", "Tue2", "Wed3", "Thu4", "Fri5", "Sat6",
      "Sun7", "Mon8", "Tue9", "Wed10", "Thu11", "Fri12", "Sat13",
      "Sun14" };
    string Workers[] =

    // Number of workers required for each shift
    double shiftRequirements[] =
    { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

    // Worker availability: 0 if the worker is unavailable for a shift
    double availability[][14] =
    { { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
      { 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 1, 0, 0 },
      { 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1 },
      { 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
      { 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1, 1 },
      { 1, 1, 1, 0, 0, 1, 0, 1, 1, 0, 0, 1, 1, 1 },
      { 1, 1, 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
// Create environment
even = new GRBEnv("workforce5_c++.log");

// Create initial model
GRBModel model = GRBModel(*env);
model.set(GRB_StringAttr_ModelName, "workforce5_c++");

// Initialize assignment decision variables:
// x[w][s] == 1 if worker w is assigned to shift s.
// This is no longer a pure assignment model, so we must
// use binary variables.
x = new GRBVar*[nWorkers];
for (w = 0; w < nWorkers; w++) {
x[w] = model.addVars(nShifts, GRB_BINARY);
xCt++;
for (s = 0; s < nShifts; s++) {
    ostringstream vname;
    vname << Workers[w] << "." << Shifts[s];
x[w][s].set(GRB_DoubleAttr_UB, availability[w][s]);
x[w][s].set(GRB_StringAttr_VarName, vname.str());
}
}

// Initialize slack decision variables
slacks = model.addVars(nShifts);
for (s = 0; s < nShifts; s++) {
    ostringstream vname;
    vname << Shifts[s] << "Slack";
    slacks[s].set(GRB_StringAttr_VarName, vname.str());
}

// Variable to represent the total slack
GRBVar totSlack = model.addVar(0, GRB_INFINITY, 0, GRB_CONTINUOUS, "totSlack");

// Initialize variables to count the total shifts worked by each worker
totShifts = model.addVars(nWorkers);
for (w = 0; w < nWorkers; w++) {
    ostringstream vname;
    vname << Workers[w] << "TotShifts";
    totShifts[w].set(GRB_StringAttr_VarName, vname.str());
}

GRBLinExpr lhs;

// Constraint: assign exactly shiftRequirements[s] workers
// to each shift s, plus the slack
for (s = 0; s < nShifts; s++) {
lhs = 0;
lhs += slacks[s];
for (w = 0; w < nWorkers; w++) {
    lhs += x[w][s];
}
model.addConstr(lhs == shiftRequirements[s], Shifts[s]);

// Constraint: set totSlack column equal to the total slack
lhs = 0;
for (s = 0; s < nShifts; s++) {
    lhs += slacks[s];
}
model.addConstr(lhs == totSlack, "totSlack");

// Constraint: compute the total number of shifts for each worker
for (w = 0; w < nWorkers; w++) {
    lhs = 0;
    for (s = 0; s < nShifts; s++) {
        lhs += x[w][s];
    }
    ostringstream vname;
    vname << "totShifts" << Workers[w];
    model.addConstr(lhs == totShifts[w], vname.str());
}

// Constraint: set minShift/maxShift variable to less <=/>= to the
// number of shifts among all workers
GRBVar minShift = model.addVar(0, GRB_INFINITY, 0, GRB_CONTINUOUS, "minShift");
GRBVar maxShift = model.addVar(0, GRB_INFINITY, 0, GRB_CONTINUOUS, "maxShift");
model.addGenConstrMin(minShift, totShifts, nWorkers, GRB_INFINITY, "minShift");
model.addGenConstrMax(maxShift, totShifts, nWorkers, -GRB_INFINITY, "maxShift");

// Set global sense for ALL objectives
model.set(GRB_IntAttr_ModelSense, GRB_MINIMIZE);

// Set primary objective
model.setObjectiveN(totSlack, 0, 2, 1.0, 2.0, 0.1, "TotalSlack");

// Set secondary objective
model.setObjectiveN(maxShift - minShift, 1, 1, 1.0, 0, 0, "Fairness");

// Save problem
model.write("workforce5_c++.lp");

// Optimize
int status = solveAndPrint(model, totSlack, nWorkers, Workers, totShifts);

// Delete local variables
if (status != GRB_OPTIMAL)
    return 1;
}
catch (GRBException e){
    cout << "Error code = " << e.getErrorCode() << endl;
cout << e.getMessage() << endl;
}
catch (...) {
    cout << "Exception during optimization" << endl;
}
for (s = 0; s < xCt; s++)
    delete[] x[s];
delete[] x;
delete[] slacks;
delete[] totShifts;
delete env;
return 0;
}

int solveAndPrint(GRBModel & model,
                  GRBVar & totSlack,
                  int nWorkers,
                  string* Workers,
                  GRBVar* totShifts) throw (GRBException)
{
    model.optimize();
    int status = model.get (GRB_IntAttr_Status);
    if ((status == GRB_INF_OR_UNBD) ||
        (status == GRB_INFEASIBLE) ||
        (status == GRB_UNBOUNDED)) {
        cout << "The model cannot be solved " <<
              "because it is infeasible or unbounded" << endl;
        return status;
    }
    if (status != GRB_OPTIMAL) {
        cout << "Optimization was stopped with status " << status << endl;
        return status;
    }
    // Print total slack and the number of shifts worked for each worker
    cout << endl << "Total slack required: " <<
         totSlack.get (GRB_DoubleAttr_X) << endl;
    for (int w = 0; w < nWorkers; ++w) {
        cout << Workers[w] << " worked " <<
             totShifts[w].get (GRB_DoubleAttr_X) << " shifts" << endl;
    }
    cout << endl;
    return status;
}

3.3 Java Examples

This section includes source code for all of the Gurobi Java examples. The same source code can be found in the examples/java directory of the Gurobi distribution.

Callback.java
import gurobi.*;
import java.io.FileWriter;
import java.io.IOException;

public class Callback extends GRBCallback {
    private double lastiter;
    private double lastnode;
    private GRBVar[] vars;
    private FileWriter logfile;

    public Callback(GRBVar[] xvars, FileWriter xlogfile) {
        lastiter = lastnode = GRB.INFINITY;
        vars = xvars;
        logfile = xlogfile;
    }

    protected void callback() {
        try {
            if (where == GRB.CB_POLLING) {
                // Ignore polling callback
            } else if (where == GRB.CB_PRESOLVE) {
                // Presolve callback
                int cdels = getIntInfo(GRB.CB_PRE_COLDEL);
                int rdels = getIntInfo(GRB.CB_PRE_ROWDEL);
                if (cdels != 0 || rdels != 0) {
                    System.out.println(cdels + " columns and " + rdels
                                       + " rows are removed");
                }
            } else if (where == GRB.CB_SIMPLEX) {
                // Simplex callback
                double itcnt = getDoubleInfo(GRB.CB_SPX_ITRCNT);
                if (itcnt - lastiter >= 100) {
                    lastiter = itcnt;
                    double obj = getDoubleInfo(GRB.CB_SPX_OBJVAL);
                    int ispert = getIntInfo(GRB.CB_SPX_ISPERT);
                    double pinf = getDoubleInfo(GRB.CB_SPX_PRIMINF);
                }
            }
        } catch (RuntimeException e) {
            System.err.println(e.getMessage());
        }
    }
}
double dinf = getDoubleInfo(GRB.CB_SPX_DUALINF);
char ch;
if (ispert == 0) ch = ' ';
else if (ispert == 1) ch = 'S';
else ch = 'P';
System.out.println(itcnt + " " + obj + ch + " "
    + pinf + " " + dinf);
}
else if (where == GRB.CB_MIP) {
    // General MIP callback
    double nodecnt = getDoubleInfo(GRB.CB_MIP_NODCNT);
    double objbst = getDoubleInfo(GRB.CB_MIP_OBJBST);
    double objbnd = getDoubleInfo(GRB.CB_MIP_OBJBND);
    int solcnt = getIntInfo(GRB.CB_MIP_SOLCNT);
    if (nodecnt - lastnode >= 100) {
        lastnode = nodecnt;
        int actnodes = (int) getDoubleInfo(GRB.CB_MIP_NODLFT);
        int itcnt = (int) getDoubleInfo(GRB.CB_MIP_ITRCNT);
        int cutcnt = getIntInfo(GRB.CB_MIP_CUTCNT);
        System.out.println(nodecnt + " " + actnodes + " "
            + itcnt + " " + objbst + " " + objbnd + " "
            + solcnt + " " + cutcnt);
    }
    if (Math.abs(objbst - objbnd) < 0.1 * (1.0 + Math.abs(objbst))) {
        System.out.println("Stop early - 10% gap achieved");
      abort();
    }
    if (nodecnt >= 10000 && solcnt > 0) {
        System.out.println("Stop early - 10000 nodes explored");
        abort();
    }
}
else if (where == GRB.CB_MIPSOL) {
    // MIP solution callback
    int nodecnt = (int) getDoubleInfo(GRB.CB_MIPSOL_NODCNT);
    double obj = getDoubleInfo(GRB.CB_MIPSOL_OBJ);
    int solcnt = getIntInfo(GRB.CB_MIPSOL_SOLCNT);
    double[] x = getSolution(vars);
    System.out.println("**** New solution at node " + nodecnt
        + ", obj " + obj + ", sol " + solcnt
        + ", x[0] = " + x[0] + " ****");
}
else if (where == GRB.CB_MIPNODE) {
    // MIP node callback
    System.out.println("**** New node ****");
    if (getIntInfo(GRB.CB_MIPNODE_STATUS) == GRB.OPTIMAL) {
        double[] x = getNodeRel(vars);
      setSolution(vars, x);
    }
}
else if (where == GRB.CB_BARRIER) {
    // Barrier callback
    int itcnt = getIntInfo(GRB.CB_BARRIER_ITRCNT);
    double primobj = getDoubleInfo(GRB.CB_BARRIER_PRIMOBJ);
    double dualobj = getDoubleInfo(GRB.CB_BARRIER_DUALOBJ);
    double priminf = getDoubleInfo(GRB.CB_BARRIER_PRIMINF);
    double dualinf = getDoubleInfo(GRB.CB_BARRIER_DUALINF);
    double cmpl = getDoubleInfo(GRB.CB_BARRIER_COMPL);
    System.out.println(itcnt + " " + primobj + " " + dualobj + " "
    + priminf + " " + dualinf + " ");
}
public static void main(String[] args) {

    if (args.length < 1) {
        System.out.println("Usage: java Callback filename");
        System.exit(1);
    }

    FileWriter logfile = null;

    try {
        // Create environment
        GRBEnv env = new GRBEnv();

        // Read model from file
        GRBModel model = new GRBModel(env, args[0]);

        // Turn off display and heuristics
        model.set(GRB.IntParam.OutputFlag, 0);
        model.set(GRB.DoubleParam.Heuristics, 0.0);

        // Open log file
        logfile = new FileWriter("cb.log");

        // Create a callback object and associate it with the model
        GRBVar[] vars = model.getVars();
        Callback cb = new Callback(vars, logfile);
        model.setCallback(cb);

        // Solve model and capture solution information
        model.optimize();

        System.out.println("\n");
        System.out.println("Optimization complete");
        if (model.get(GRB.IntAttr.SolCount) == 0) {
            System.out.println("No solution found, optimization status = " + model.get(GRB.IntAttr.Status));
        } else {
            System.out.println("Solution found, objective = " + model.get(GRB.DoubleAttr.ObjVal));
        }
    }

    catch (GRBException e) {
        System.out.println("Error code: " + e.getErrorCode());
        System.out.println(e.getMessage());
        e.printStackTrace();
    } catch (Exception e) {
        System.out.println("Error during callback");
        e.printStackTrace();
    }
}

String[] vnames = model.get(GRB.StringAttr.VarName, vars);
double[] x = model.get(GRB.DoubleAttr.X, vars);

for (int j = 0; j < vars.length; j++) {
    if (x[j] != 0.0) System.out.println(vnames[j] + " " + x[j]);
}

// Dispose of model and environment
model.dispose();
environ.dispose();

} catch (GRBException e) {
    System.out.println("Error code: " + e.getErrorCode());
    System.out.println(e.getMessage());
    e.printStackTrace();
} catch (Exception e) {
    System.out.println("Error during optimization");
    e.printStackTrace();
} finally {
    // Close log file
    if (logfile != null) {
        try { logfile.close(); } catch (IOException e) {}  
    }
}

Dense.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example formulates and solves the following simple QP model:

minimize x + y + x^2 + x*y + y^2 + y*z + z^2
subject to x + 2 y + 3 z >= 4
          x + y >= 1

The example illustrates the use of dense matrices to store A and Q
(and dense vectors for the other relevant data). We don't recommend
that you use dense matrices, but this example may be helpful if you
already have your data in this format. */

import gurobi.*;

public class Dense {

    protected static boolean dense_optimize(GRBEnv env,
        int rows,
        int cols,
        double[] c, // linear portion of objective function
        double[][] Q, // quadratic portion of objective function
        double[][] A, // constraint matrix

    }
boolean success = false;

try {
    GRBModel model = new GRBModel(env);

    // Add variables to the model
    GRBVar[] vars = model.addVars(lb, ub, null, vtype, null);

    // Populate A matrix
    for (int i = 0; i < rows; i++) {
        GRBLinExpr expr = new GRBLinExpr();
        for (int j = 0; j < cols; j++)
            if (A[i][j] != 0)
                expr.addTerm(A[i][j], vars[j]);
        model.addConstr(expr, sense[i], rhs[i], "");
    }

    // Populate objective
    GRBQuadExpr obj = new GRBQuadExpr();
    if (Q != null) {
        for (int i = 0; i < cols; i++)
            for (int j = 0; j < cols; j++)
                if (Q[i][j] != 0)
                    obj.addTerm(Q[i][j], vars[i], vars[j]);
        for (int j = 0; j < cols; j++)
            if (c[j] != 0)
                obj.addTerm(c[j], vars[j]);
        model.setObjective(obj);
    }

    // Solve model
    model.optimize();

    // Extract solution
    if (model.get(GRB.IntAttr.Status) == GRB.Status.OPTIMAL) {
        success = true;
        for (int j = 0; j < cols; j++)
            solution[j] = vars[j].get(GRB.DoubleAttr.X);
    }
    model.dispose();
} catch (GRBException e) {
System.out.println("Error code: " + e.getErrorCode() + ". " +
    e.getMessage());
e.printStackTrace();
}
return success;
}

public static void main(String[] args) {
    try {
        GRBEnv env = new GRBEnv();
        double c[] = new double[] {1, 1, 0};
        double Q[][] = new double[][3] {{1, 1, 0}, {0, 1, 1}, {0, 0, 1}};
        double A[][] = new double[][3] {{1, 2, 3}, {1, 1, 0}};
        char sense[] = new char[] {'>', '>', '>'};
        double rhs[] = new double[] {4, 1};
        double lb[] = new double[] {0, 0, 0};
        boolean success;
        double sol[] = new double[3];

        success = dense_optimize(env, 2, 3, c, Q, A, sense, rhs,
                                   lb, null, null, sol);

        if (success) {
        }

        // Dispose of environment
        env.dispose();
    } catch (GRBException e) {
        System.out.println("Error code: " + e.getErrorCode() + ". " +
                            e.getMessage());
e.printStackTrace();
    }
}

Diet.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* Solve the classic diet model, showing how to add constraints
   to an existing model. */

import gurobi.*;

public class Diet {

    public static void main(String[] args) {
        try {

            // Nutrition guidelines, based on
            // USDA Dietary Guidelines for Americans, 2005
String Categories[] =
    new String[] { "calories", "protein", "fat", "sodium" };
int nCategories = Categories.length;
double minNutrition[] = new double[] { 1800, 91, 0, 0 };
double maxNutrition[] = new double[] { 2200, GRB.INFINITY, 65, 1779 };

// Set of foods
String Foods[] =
    new String[] { "hamburger", "chicken", "hot dog", "fries",  
                   "macaroni", "pizza", "salad", "milk", "ice cream" };
int nFoods = Foods.length;
double cost[] =
    new double[] { 2.49, 2.89, 1.50, 1.89, 2.09, 1.99, 2.49, 0.89, 
                   1.59 };

// Nutrition values for the foods
double nutritionValues[][] =
    new double[][] {  
        { 410, 24, 26, 730 }, // hamburger 
        { 420, 32, 10, 1190 }, // chicken  
        { 560, 20, 32, 1800 }, // hot dog 
        { 380, 4, 19, 270 }, // fries 
        { 320, 12, 10, 930 }, // macaroni  
        { 320, 15, 12, 820 }, // pizza 
        { 320, 31, 12, 1230 }, // salad 
        { 100, 8, 2.5, 125 }, // milk  
        { 330, 8, 10, 180 } // ice cream 
    };

// Model
GRBEnv env = new GRBEnv();
GRBModel model = new GRBModel(env);
model.set(GRB.StringAttr.ModelName, "diet");

// Create decision variables for the nutrition information,
// which we limit via bounds
GRBVar[] nutrition = new GRBVar[nCategories];
for (int i = 0; i < nCategories; ++i) {
    nutrition[i] =
        model.addVar(minNutrition[i], maxNutrition[i], 0, GRB.CONTINUOUS,  
                      Categories[i]);
}

// Create decision variables for the foods to buy
GRBVar[] buy = new GRBVar[nFoods];
for (int j = 0; j < nFoods; ++j) {
    buy[j] =
        model.addVar(0, GRB.INFINITY, cost[j], GRB.CONTINUOUS, Foods[j]);
}

// The objective is to minimize the costs
model.set(GRB.IntAttr.ModelSense, GRB.MINIMIZE);

// Nutrition constraints
for (int i = 0; i < nCategories; ++i) {
    GRBLinExpr ntot = new GRBLinExpr();
for (int j = 0; j < nFoods; ++j) {
    ntot.addTerm(nutritionValues[j][i], buy[j]);
}
model.addConstr(ntot, GRB.EQUAL, nutrition[i], Categories[i]);

// Solve
model.optimize();
printSolution(model, buy, nutrition);

System.out.println("\nAdding constraint: at most 6 servings of dairy");
GRBLinExpr lhs = new GRBLinExpr();
lhs.addTerm(1.0, buy[7]);
lhs.addTerm(1.0, buy[8]);
model.addConstr(lhs, GRB.LESS_EQUAL, 6.0, "limit_dairy");

// Solve
model.optimize();
printSolution(model, buy, nutrition);

// Dispose of model and environment
model.dispose();
env.dispose();

} catch (GRBException e) {
    System.out.println("Error code: " + e.getErrorCode() + ". " + e.getMessage());
}

private static void printSolution(GRBModel model, GRBVar[] buy, GRBVar[] nutrition) throws GRBException {
    if (model.get(GRB.IntAttr.Status) == GRB.Status.OPTIMAL) {
        System.out.println("\nCost: " + model.get(GRB.DoubleAttr.ObjVal));
        System.out.println("\nBuy:");
        for (int j = 0; j < buy.length; ++j) {
            if (buy[j].get(GRB.DoubleAttr.X) > 0.0001) {
                System.out.println(buy[j].get(GRB.StringAttr.VarName) + " " + buy[j].get(GRB.DoubleAttr.X));
            }
        }
        System.out.println("\nNutrition:");
        for (int i = 0; i < nutrition.length; ++i) {
            System.out.println(nutrition[i].get(GRB.StringAttr.VarName) + " " + nutrition[i].get(GRB.DoubleAttr.X));
        }
    } else {
        System.out.println("No solution");
    }
}

Facility.java

/* Copyright 2018, Gurobi Optimization, LLC */
/* Facility location: a company currently ships its product from 5 plants to 4 warehouses. It is considering closing some plants to reduce costs. What plant(s) should the company close, in order to minimize transportation and fixed costs?

Based on an example from Frontline Systems:
http://www.solver.com/disfacility.htm
Used with permission.
*/

import gurobi.*;

public class Facility {

    public static void main(String[] args) {
        try {

            // Warehouse demand in thousands of units
double Demand[] = new double[] { 15, 18, 14, 20 };

            // Plant capacity in thousands of units
double Capacity[] = new double[] { 20, 22, 17, 19, 18 };

            // Fixed costs for each plant
double FixedCosts[] =
                new double[] { 12000, 15000, 17000, 13000, 16000 };

            // Transportation costs per thousand units
double TransCosts[][] =
                new double[][] { { 4000, 2000, 3000, 2500, 4500 },
                                 { 2500, 2600, 3400, 3000, 4000 },
                                 { 1200, 1800, 2600, 4100, 3000 },
                                 { 2200, 2600, 3100, 3700, 3200 } };

            // Number of plants and warehouses
            int nPlants = Capacity.length;
            int nWarehouses = Demand.length;

            // Model
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env);
            model.set(GRB.StringAttr.ModelName, "facility");

            // Plant open decision variables: open[p] == 1 if plant p is open.
            GRBVar[] open = new GRBVar[nPlants];
            for (int p = 0; p < nPlants; ++p) {
                open[p] = model.addVar(0, GRB.INFINITY, FixedCosts[p], GRB.BINARY, "Open" + p);
            }

            // Transportation decision variables: how much to transport from
            // a plant p to a warehouse w
            GRBVar[][] transport = new GRBVar[nWarehouses][nPlants];
            for (int w = 0; w < nWarehouses; ++w) {
                for (int p = 0; p < nPlants; ++p) {
                    transport[w][p] =
                        model.addVar(0, GRB.INFINITY, TransCosts[w][p], GRB.CONTINUOUS,
                        [193]
The objective is to minimize the total fixed and variable costs:

```java
model.set(GRB.IntAttr.ModelSense, GRB.MINIMIZE);
```

Production constraints:

```java
// Note that the right-hand limit sets the production to zero if the plant is closed
for (int p = 0; p < nPlants; ++p) {
    GRBLinExpr ptot = new GRBLinExpr();
    for (int w = 0; w < nWarehouses; ++w) {
        ptot.addTerm(1.0, transport[w][p]);
    }
    GRBLinExpr limit = new GRBLinExpr();
    limit.addTerm(Capacity[p], open[p]);
    model.addConstr(ptot, GRB.LESS_EQUAL, limit, "Capacity" + p);
}
```

Demand constraints:

```java
for (int w = 0; w < nWarehouses; ++w) {
    GRBLinExpr dtot = new GRBLinExpr();
    for (int p = 0; p < nPlants; ++p) {
        dtot.addTerm(1.0, transport[w][p]);
    }
    model.addConstr(dtot, GRB.EQUAL, Demand[w], "Demand" + w);
}
```

Guess at the starting point: close the plant with the highest fixed costs; open all others:

```java
// First, open all plants
for (int p = 0; p < nPlants; ++p) {
    open[p].set(GRB.DoubleAttr.Start, 1.0);
}
```

Now close the plant with the highest fixed cost:

```java
System.out.println("Initial guess: ");
double maxFixed = -GRB.INFINITY;
for (int p = 0; p < nPlants; ++p) {
    if (FixedCosts[p] > maxFixed) {
        maxFixed = FixedCosts[p];
    }
}
for (int p = 0; p < nPlants; ++p) {
    if (FixedCosts[p] == maxFixed) {
        open[p].set(GRB.DoubleAttr.Start, 0.0);
        System.out.println("Closing plant 
" + p + "\n");
        break;
    }
}
```

Use barrier to solve root relaxation:

```java
model.set(GRB.IntParam.Method, GRB.METHOD_BARRIER);
```
// Solve
model.optimize();

// Print solution
System.out.println("\nTOTAL COSTS: " + model.get(GRB.DoubleAttr.ObjVal));
System.out.println("SOLUTION: ");
for (int p = 0; p < nPlants; ++p) {
    if (open[p].get(GRB.DoubleAttr.X) > 0.99) {
        System.out.println(" Plant " + p + " open:");
        for (int w = 0; w < nWarehouses; ++w) {
            if (transport[w][p].get(GRB.DoubleAttr.X) > 0.0001) {
                System.out.println(" Transport " +
                transport[w][p].get(GRB.DoubleAttr.X) +
                " units to warehouse " + w);
            }
        }
    } else {
        System.out.println(" Plant " + p + " closed!");
    }
}

// Dispose of model and environment
model.dispose();
env.dispose();
}
}

Feasopt.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads a MIP model from a file, adds artificial
variables to each constraint, and then minimizes the sum of the
artificial variables. A solution with objective zero corresponds
to a feasible solution to the input model.
We can also use FeasRelax feature to do it. In this example, we
use minrelax=1, i.e. optimizing the returned model finds a solution
that minimizes the original objective, but only from among those
solutions that minimize the sum of the artificial variables. */

import gurobi.*;

public class Feasopt {
    public static void main(String[] args) {
        if (args.length < 1) {
            System.out.println("Usage: java Feasopt filename");
            System.exit(1);
        }
        try {

GRBEnv env = new GRBEnv();
GRBModel feasmodel = new GRBModel(env, args[0]);

// Create a copy to use FeasRelax feature later */
GRBModel feasmodel1 = new GRBModel(feasmodel);

// Clear objective
feasmodel.setObjective(new GRBLinExpr());

// Add slack variables
GRBConstr[] c = feasmodel.getConstrs();
for (int i = 0; i < c.length; ++i) {
    char sense = c[i].get(GRB.CharAttr.Sense);
    if (sense != '>') {
        GRBConstr[] constrs = new GRBConstr[] { c[i] };
        double[] coeffs = new double[] { -1 };
        feasmodel.addVar(0.0, GRB.INFINITY, 1.0, GRB.CONTINUOUS, constrs,
                       coeffs, "ArtN_" + i.get(GRB.StringAttr.ConstrName));
    }
    if (sense != '<') {
        GRBConstr[] constrs = new GRBConstr[] { c[i] };
        double[] coeffs = new double[] { 1 };
        feasmodel.addVar(0.0, GRB.INFINITY, 1.0, GRB.CONTINUOUS, constrs,
                       coeffs, "ArtP_" + c[i].get(GRB.StringAttr.ConstrName));
    }
}

// Optimize modified model
feasmodel.optimize();
feasmodel.write("feasopt.lp");

// use FeasRelax feature */
feasmodel1.feasRelax(GRB.FEASRELAX_LINEAR, true, false, true);
feasmodel1.write("feasopt1.lp");
feasmodel1.optimize();

// Dispose of model and environment
feasmodel1.dispose();
feasmodel.dispose();
env.dispose();
}

} catch (GRBException e) {
    System.out.println("Error code: " + e.getErrorCode() + ". " + e.getMessage());
}

}

Fixanddive.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* Implement a simple MIP heuristic. Relax the model, sort variables based on fractionality, and fix the 25% of
the fractional variables that are closest to integer variables. Repeat until either the relaxation is integer feasible or linearly infeasible. */

import gurobi.*;
import java.util.*;

public class Fixanddive {
    public static void main(String[] args) {

        // Comparison class used to sort variable list based on relaxation
        // fractionality

        class FractionalCompare implements Comparator<GRBVar> {
            public int compare(GRBVar v1, GRBVar v2) {
                try {
                    double sol1 = Math.abs(v1.get(GRB.DoubleAttr.X));
                    double sol2 = Math.abs(v2.get(GRB.DoubleAttr.X));
                    double frac1 = Math.abs(sol1 - Math.floor(sol1 + 0.5));
                    double frac2 = Math.abs(sol2 - Math.floor(sol2 + 0.5));
                    if (frac1 < frac2) {
                        return -1;
                    } else if (frac1 == frac2) {
                        return 0;
                    } else {
                        return 1;
                    }
                }

                catch (GRBException e) {
                    System.out.println("Error code: "+e.getErrorCode()+". "+e.getMessage());
                }

                return 0;
            }
        }

        if (args.length < 1) {
            System.out.println("Usage: java Fixanddive filename");
            System.exit(1);
        }

        try {
            // Read model
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env, args[0]);

            // Collect integer variables and relax them
            ArrayList<GRBVar> intvars = new ArrayList<GRBVar>();
            for (GRBVar v : model.getVars()) {
                if (v.get(GRB.CharAttr.VType) != GRB.CONTINUOUS) {
                    intvars.add(v);
                    v.set(GRB.CharAttr.VType, GRB.CONTINUOUS);
                }
            }

            model.set(GRB.IntParam.OutputFlag, 0);
            model.optimize();
        }
    }
}
// Perform multiple iterations. In each iteration, identify the first quartile of integer variables that are closest to an integer value in the relaxation, fix them to the nearest integer, and repeat.

for (int iter = 0; iter < 1000; ++iter) {

    // create a list of fractional variables, sorted in order of increasing distance from the relaxation solution to the nearest integer value
    ArrayList<GRBVar> fractional = new ArrayList<GRBVar>();
    for (GRBVar v : intvars) {
        double sol = Math.abs(v.get(GRB.DoubleAttr.X));
        if (Math.abs(sol - Math.floor(sol + 0.5)) > 1e-5) {
            fractional.add(v);
        }
    }

    System.out.println("Iteration " + iter + ", obj " + model.get(GRB.DoubleAttr.ObjVal) + ", fractional " + fractional.size());

    if (fractional.size() == 0) {
        System.out.println("Found feasible solution - objective " + model.get(GRB.DoubleAttr.ObjVal));
        break;
    }

    // Fix the first quartile to the nearest integer value
    Collections.sort(fractional, new FractionalCompare());
    int nfix = Math.max(fractional.size() / 4, 1);
    for (int i = 0; i < nfix; ++i) {
        GRBVar v = fractional.get(i);
        double fixval = Math.floor(v.get(GRB.DoubleAttr.X) + 0.5);
        v.set(GRB.DoubleAttr.LB, fixval);
        v.set(GRB.DoubleAttr.UB, fixval);
        System.out.println(" Fix " + v.get(GRB.StringAttr.VarName) + " to " + fixval + " ( rel " + v.get(GRB.DoubleAttr.X) + ")");
    }

    model.optimize();

    // Check optimization result
    if (model.get(GRB.IntAttr.Status) != GRB.Status.OPTIMAL) {
        System.out.println("Relaxation is infeasible");
        break;
    }

    // Dispose of model and environment
    model.dispose();
    env.dispose();
catch (GRBException e) {
    System.out.println("Error code: " + e.getErrorCode() + ". " + e.getMessage());
}

Genconstr.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* In this example we show the use of general constraints for modeling some common expressions. We use as an example a SAT-problem where we want to see if it is possible to satisfy at least four (or all) clauses of the logical for

L = (x0 or ~x1 or x2) and (x1 or ~x2 or x3) and
(x2 or ~x3 or x0) and (x3 or ~x0 or x1)
(-x0 or ~x1 or x2) and (-x1 or ~x2 or x3) and
(-x2 or ~x3 or x0) and (-x3 or ~x0 or x1)

We do this by introducing two variables for each literal (itself and its negated value), a variable for each clause, and then two variables for indicating if we can satisfy four, and another to identify the minimum of the clauses (so if it one, we can satisfy all clauses) and put these two variables in the objective. i.e. the Objective function will be

maximize Obj0 + Obj1

Obj0 = MIN(Clause1, ..., Clause8)
Obj1 = 1 -> Clause1 + ... + Clause8 >= 4

thus, the objective value will be two if and only if we can satisfy all clauses; one if and only if at least four clauses can be satisfied, and zero otherwise. */

import gurobi.*;

public class Genconstr {

    public static final int n = 4;
    public static final int NLITERALS = 4; // same as n
    public static final int NCLAUSES = 8;
    public static final int NOBJ = 2;

    public static void main(String[] args) {
        try {
            // Example data:
            // e.g. {0, n+1, 2} means clause (x0 or ~x1 or x2)
            int Clauses[][] = new int[][] {
                { 0, n+1, 2}, { 1, n+2, 3},
            }
int i, status, nSolutions;

// Create environment
GRBEnv env = new GRBEnv("Genconstr.log");

// Create initial model
GRBModel model = new GRBModel(env);
model.set(GRB.StringAttr.ModelName, "Genconstr");

// Initialize decision variables and objective
GRBVar[] Lit = new GRBVar[NLITERALS];
GRBVar[] NotLit = new GRBVar[NLITERALS];
for (i = 0; i < NLITERALS; i++) {
    Lit[i] = model.addVar(0.0, 1.0, 0.0, GRB.BINARY, "X" + String.valueOf(i));
    NotLit[i] = model.addVar(0.0, 1.0, 0.0, GRB.BINARY, "notX" + String.valueOf(i));
}

GRBVar[] Cla = new GRBVar[NCLAUSES];
for (i = 0; i < NCLAUSES; i++) {
    Cla[i] = model.addVar(0.0, 1.0, 0.0, GRB.BINARY, "Clause" + String.valueOf(i));
}

GRBVar[] Obj = new GRBVar[NOBJ];
for (i = 0; i < NOBJ; i++) {
    Obj[i] = model.addVar(0.0, 1.0, 1.0, GRB.BINARY, "Obj" + String.valueOf(i));
}

// Link Xi and notXi
GRBLinExpr lhs;
for (i = 0; i < NLITERALS; i++) {
    lhs = new GRBLinExpr();
    lhs.addTerm(1.0, Lit[i]);
    lhs.addTerm(1.0, NotLit[i]);
    model.addConstr(lhs, GRB.EQUAL, 1.0, "CNSTR_X" + String.valueOf(i));
}

// Link clauses and literals
for (i = 0; i < NCLAUSES; i++) {
    GRBVar[] clause = new GRBVar[3];
    for (int j = 0; j < 3; j++) {
        if (Clauses[i][j] >= n) clause[j] = NotLit[Clauses[i][j]-n];
        else clause[j] = Lit[Clauses[i][j]];
    }
    model.addGenConstrOr(Cla[i], clause, "CNSTR_Clause" + String.valueOf(i));
}

// Link objs with clauses
model.addGenConstrMin(Obj[0], Cla, GRB.INFINITY, "CNSTR_Obj0");
lhs = new GRBLinExpr();
for (i = 0; i < NCLAUSES; i++) {
    lhs.addTerm(1.0, Cla[i]);
}
model.addGenConstrIndicator(Obj[1], 1, lhs, GRB.GREATER_EQUAL, 4.0, "CNSTR_Obj1");

// Set global objective sense
model.set(GRB.IntAttr.ModelSense, GRB.MAXIMIZE);

// Save problem
model.write("Genconstr.mps");
model.write("Genconstr.lp");

// Optimize
model.optimize();

// Status checking
status = model.get(GRB.IntAttr.Status);

if (status == GRB.INF_OR_UNBD ||
    status == GRB.INFEASIBLE ||
    status == GRB.UNBOUNDED)
    { System.out.println("The model cannot be solved " + 
                        "because it is infeasible or unbounded");
        System.exit(1);
    }
if (status != GRB.OPTIMAL)
    { System.out.println("Optimization was stopped with status " + status);
        System.exit(1);
    }

// Print result
double objval = model.get(GRB.DoubleAttr.ObjVal);

if (objval > 1.9)
    System.out.println("Logical expression is satisfiable");
else if (objval > 0.9)
    System.out.println("At least four clauses can be satisfied");
else
    System.out.println("Not even three clauses can be satisfied");

// Dispose of model and environment
model.dispose();
env.dispose();

} catch (GRBException e) {
    System.out.println("Error code: " + e.getErrorCode() + ". " +
                       e.getMessage());
}
}

Lp.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads an LP model from a file and solves it.
 If the model is infeasible or unbounded, the example turns off
 presolve and solves the model again. If the model is infeasible,
the example computes an Irreducible Inconsistent Subsystem (IIS),
and writes it to a file */

import gurobı.*;

class Lp {
  public static void main(String[] args) {
    if (args.length < 1) {
      System.out.println("Usage: java Lp filename");
      System.exit(1);
    }
    try {
      GRBEnv env = new GRBEnv();
      GRBModel model = new GRBModel(env, args[0]);
      model.optimize();
      int optimstatus = model.get(GRB.IntAttr.Status);
      if (optimstatus == GRB.Status.INF_OR_UNBD) {
        model.set(GRB.IntParam.Presolve, 0);
        model.optimize();
        optimstatus = model.get(GRB.IntAttr.Status);
      }
      if (optimstatus == GRB.Status.OPTIMAL) {
        double objval = model.get(GRB.DoubleAttr_ObjVal);
        System.out.println("Optimal objective: " + objval);
      } else if (optimstatus == GRB.Status.INFEASIBLE) {
        System.out.println("Model is infeasible");
      } else if (optimstatus == GRB.Status.UNBOUNDED) {
        System.out.println("Model is unbounded");
      } else {
        System.out.println("Optimization was stopped with status = "
          + optimstatus);
      }
      // Dispose of model and environment
      model.dispose();
      env.dispose();
    } catch (GRBException e) {
      System.out.println("Error code: " + e.getErrorCode() + ". " +
        e.getMessage());
    }
  }
}

Lpmethod.java

 202
/* Copyright 2018, Gurobi Optimization, LLC */

/* Solve a model with different values of the Method parameter; show which value gives the shortest solve time. */

import gurobi.*;

public class Lpmethod {

    public static void main(String[] args) {

        if (args.length < 1) {
            System.out.println("Usage: java Lpmethod filename");
            System.exit(1);
        }

        try {
            // Read model
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env, args[0]);

            // Solve the model with different values of Method
            int bestMethod = -1;
            double bestTime = model.get(GRB.DoubleParam.TimeLimit);
            for (int i = 0; i <= 2; ++i) {
                model.reset();
                model.set(GRB.IntParam.Method, i);
                model.optimize();
                if (model.get(GRB.IntAttr.Status) == GRB.Status.OPTIMAL) {
                    bestTime = model.get(GRB.DoubleAttr.Runtime);
                    bestMethod = i;
                    // Reduce the TimeLimit parameter to save time
                    // with other methods
                    model.set(GRB.DoubleParam.TimeLimit, bestTime);
                }
            }

            // Report which method was fastest
            if (bestMethod == -1) {
                System.out.println("Unable to solve this model");
            } else {
                System.out.println("Solved in " + bestTime
                    + " seconds with Method: " + bestMethod);
            }

            // Dispose of model and environment
            model.dispose();
            env.dispose();

        } catch (GRBException e) {
            System.out.println("Error code: " + e.getErrorCode() + ". "
                + e.getMessage());
        }
    }
}
import gurobi.*;

public class Lpmod {
    public static void main(String[] args) {
        if (args.length < 1) {
            System.out.println("Usage: java Lpmod filename");
            System.exit(1);
        }

        try {
            // Read model and determine whether it is an LP
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env, args[0]);
            if (model.get(GRB.IntAttr.IsMIP) != 0) {
                System.out.println("The model is not a linear program");
                System.exit(1);
            }

            model.optimize();

            int status = model.get(GRB.IntAttr.Status);

            if (status == GRB.Status.INF_OR_UNBD ||
                status == GRB.Status.INFEASIBLE ||
                status == GRB.Status.UNBOUNDED ) {
                System.out.println("The model cannot be solved because it is " + "infeasible or unbounded");
                System.exit(1);
            }

            if (status != GRB.Status.OPTIMAL) {
                System.out.println("Optimization was stopped with status " + status);
                System.exit(0);
            }

            // Find the smallest variable value
            double minVal = GRB.INFINITY;
            GRBVar minVar = null;
            for (GRBVar v : model.getVars()) {
                double sol = v.get(GRB.DoubleAttr.X);
                if ((sol > 0.0001) && (sol < minVal) &&
                    (v.get(GRB.DoubleAttr.LB) == 0.0)) {
                    minVal = sol;
                    minVar = v;
                }
            }
        }
    }
}
System.out.println("\n*** Setting " +
    minVar.get(GRB.StringAttr.VarName) + " from " + minVal +
    " to zero ***\n");
minVar.set(GRB.DoubleAttr.UB, 0.0);

// Solve from this starting point
model.optimize();

// Save iteration & time info
double warmCount = model.get(GRB.DoubleAttr.IterCount);
double warmTime = model.get(GRB.DoubleAttr.Runtime);

// Reset the model and resolve
System.out.println("\n*** Resetting and solving "
    + "without an advanced start ***\n");
model.reset();
model.optimize();

double coldCount = model.get(GRB.DoubleAttr.IterCount);
double coldTime = model.get(GRB.DoubleAttr.Runtime);

System.out.println("\n*** Warm start: " + warmCount + " iterations, " +
    warmTime + " seconds\n");
System.out.println("*** Cold start: " + coldCount + " iterations, " +
    coldTime + " seconds\n");

// Dispose of model and environment
model.dispose();
env.dispose();
}

try {
    System.out.println("Error code: " + e.getErrorCode() + ". " +
    e.getMessage());
}

}

Mip1.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example formulates and solves the following simple MIP model:

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

*/

import gurobi.*;

public class Mip1 {
    public static void main(String[] args) {
        try {
            System.out.println("
*** Setting " +
    minVar.get(GRB.StringAttr.VarName) + " from " + minVal +
    " to zero ***\n");
minVar.set(GRB.DoubleAttr.UB, 0.0);

// Solve from this starting point
model.optimize();

// Save iteration & time info
double warmCount = model.get(GRB.DoubleAttr.IterCount);
double warmTime = model.get(GRB.DoubleAttr.Runtime);

// Reset the model and resolve
System.out.println("\n*** Resetting and solving "
    + "without an advanced start ***\n");
model.reset();
model.optimize();

double coldCount = model.get(GRB.DoubleAttr.IterCount);
double coldTime = model.get(GRB.DoubleAttr.Runtime);

System.out.println("\n*** Warm start: " + warmCount + " iterations, " +
    warmTime + " seconds\n");
System.out.println("*** Cold start: " + coldCount + " iterations, " +
    coldTime + " seconds\n");

// Dispose of model and environment
model.dispose();
env.dispose();
}

try {
    System.out.println("Error code: " + e.getErrorCode() + ". " +
    e.getMessage());
}

}
GRBEnv env = new GRBEnv("mip1.log");
GRBModel model = new GRBModel(env);

// Create variables
GRBVar x = model.addVar(0.0, 1.0, 0.0, GRB.BINARY, "x");
GRBVar y = model.addVar(0.0, 1.0, 0.0, GRB.BINARY, "y");
GRBVar z = model.addVar(0.0, 1.0, 0.0, GRB.BINARY, "z");

// Set objective: maximize x + y + 2 z
GRBLinExpr expr = new GRBLinExpr();
expr.addTerm(1.0, x); expr.addTerm(1.0, y); expr.addTerm(2.0, z);
model.setObjective(expr, GRB.MAXIMIZE);

// Add constraint: x + 2 y + 3 z <= 4
expr = new GRBLinExpr();
expr.addTerm(1.0, x); expr.addTerm(2.0, y); expr.addTerm(3.0, z);
model.addConstr(expr, GRB.LESS_EQUAL, 4.0, "c0");

// Add constraint: x + y >= 1
expr = new GRBLinExpr();
expr.addTerm(1.0, x); expr.addTerm(1.0, y);
model.addConstr(expr, GRB.GREATER_EQUAL, 1.0, "c1");

// Optimize model
model.optimize();

System.out.println(x.get(GRB.StringAttr.VarName) + " " + x.get(GRB.DoubleAttr.X));
System.out.println(y.get(GRB.StringAttr.VarName) + " " + y.get(GRB.DoubleAttr.X));
System.out.println(z.get(GRB.StringAttr.VarName) + " " + z.get(GRB.DoubleAttr.X));

System.out.println("Obj: " + model.get(GRB.DoubleAttr.ObjVal));

// Dispose of model and environment
model.dispose();
env.dispose();
}
}

Mip2.java

/* Copyright 2018, Gurobi Optimization, LLC */
/* This example reads a MIP model from a file, solves it and
prints the objective values from all feasible solutions
generated while solving the MIP. Then it creates the fixed
model and solves that model. */

import gurobi.*;

public class Mip2 {
    public static void main(String[] args) {
        if (args.length < 1) {
            System.out.println("Usage: java Mip2 filename");
            System.exit(1);
        }

        try {
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env, args[0]);
            if (model.get(GRB.IntAttr.IsMIP) == 0) {
                System.out.println("Model is not a MIP");
                System.exit(1);
            }
            model.optimize();
            int optimstatus = model.get(GRB.IntAttr.Status);
            double objval = 0;
            if (optimstatus == GRB.Status.OPTIMAL) {
                objval = model.get(GRB.DoubleAttr.ObjVal);
                System.out.println("Optimal objective: " + objval);
            } else if (optimstatus == GRB.Status.INF_OR_UNBD) {
                System.out.println("Model is infeasible or unbounded");
                return;
            } else if (optimstatus == GRB.Status.INFEASIBLE) {
                System.out.println("Model is infeasible");
                return;
            } else if (optimstatus == GRB.Status.UNBOUNDED) {
                System.out.println("Model is unbounded");
                return;
            } else {
                System.out.println("Optimization was stopped with status = "
                        + optimstatus);
                return;
            }

            /* Iterate over the solutions and compute the objectives */
            GRBVar[] vars = model.getVars();
            model.set(GRB.IntParam.OutputFlag, 0);

            System.out.println();
            for (int k = 0; k < model.get(GRB.IntAttr.SolCount); ++k) {
                model.set(GRB.IntParam.SolutionNumber, k);
                double objn = 0.0;
                for (int j = 0; j < vars.length; j++) {
                    objn += vars[j].get(GRB.DoubleAttr.Obj)
                }
            }
        }
    }
}
* vars[j].get(GRB.DoubleAttr.Xn);
}
System.out.println("Solution " + k + " has objective: " + objn);
}
System.out.println();
model.set(GRB.IntParam.OutputFlag, 1);
/* Create a fixed model, turn off presolve and solve */
GRBModel fixed = model.fixedModel();
fixed.set(GRB.IntParam.Presolve, 0);
fixed.optimize();
int foptimstatus = fixed.get(GRB.IntAttr.Status);
if (foptimstatus != GRB.Status.OPTIMAL) {
  System.err.println("Error: fixed model isn’t optimal");
  return;
}
double fobjval = fixed.get(GRB.DoubleAttr.ObjVal);
if (Math.abs(fobjval - objval) > 1.0e-6 * (1.0 + Math.abs(objval))) {
  System.err.println("Error: objective values are different");
  return;
}
GRBVar[] fvars = fixed.getVars();
double[] x = fixed.get(GRB.DoubleAttr.X, fvars);
String[] vnames = fixed.get(GRB.StringAttr.VarName, fvars);
for (int j = 0; j < fvars.length; j++) {
  if (x[j] != 0.0) {
    System.out.println(vnames[j] + " " + x[j]);
  }
}
// Dispose of models and environment
fixed.dispose();
model.dispose();
env.dispose();
}
catch (GRBException e) {
  System.out.println("Error code: " + e.getErrorCode() + ". " + e.getMessage());
}
}

Multiobj.java

/* Copyright 2018, Gurobi Optimization, LLC */
/* Want to cover three different sets but subject to a common budget of
elements allowed to be used. However, the sets have different priorities to
be covered; and we tackle this by using multi-objective optimization. */

import gurobi.*;

public class Multiobj {
    public static void main(String[] args) {
        try {
            // Sample data
            int groundSetSize = 20;
            int nSubsets = 4;
            int Budget = 12;
            double[][] Set = {
                { 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 },
                { 0, 0, 0, 0, 0, 1, 1, 1, 1, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1 },
                { 0, 0, 0, 1, 1, 0, 1, 1, 0, 0, 0, 0, 0, 1, 1, 0, 1, 1, 0, 0 },
                { 0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0 } }
            ;
            int SetObjPriority[] = {3, 2, 2, 1};
            double SetObjWeight[] = {1.0, 0.25, 1.25, 1.0};
            int e, i, status, nSolutions;

            // Create environment
            GRBEnv env = new GRBEnv("Multiobj.log");

            // Create initial model
            GRBModel model = new GRBModel(env);
            model.set(GRB.StringAttr.ModelName, "Multiobj");

            // Initialize decision variables for ground set:
            // x[e] == 1 if element e is chosen for the covering.
            GRBVar[] Elem = model.addVars(groundSetSize, GRB.BINARY);
            for (e = 0; e < groundSetSize; e++) {
                String vname = "El" + String.valueOf(e);
                Elem[e].set(GRB.StringAttr.VarName, vname);
            }

            // Constraint: limit total number of elements to be picked to be at most
            // Budget
            GRBLinExpr lhs = new GRBLinExpr();
            for (e = 0; e < groundSetSize; e++) {
                lhs.addTerm(1.0, Elem[e]);
            }
            model.addConstr(lhs, GRB.LESS_EQUAL, Budget, "Budget");

            // Set global sense for ALL objectives
            model.set(GRB.IntAttr.ModelSense, GRB.MAXIMIZE);

            // Limit how many solutions to collect
            model.set(GRB.IntParam.PoolSolutions, 100);

            // Set and configure i-th objective
            for (i = 0; i < nSubsets; i++) {
                GRBLinExpr objn = new GRBLinExpr();
                String vname = "Set" + String.valueOf(i);
            }
        } catch (OracleException e) { System.out.println("Error: " + e.getMessage()); }
    }
}
for (e = 0; e < groundSetSize; e++)
    objn.addTerm(Set[i][e], Elem[e]);

model.setObjectiveN(objn, i, SetObjPriority[i], SetObjWeight[i],
          1.0 + i, 0.01, vname);
}

// Save problem
model.write("Multiobj.lp");

// Optimize
model.optimize();

// Status checking
status = model.get(GRB.IntAttr.Status);
if (status == GRB.INF_OR_UNBD ||
    status == GRB.INFEASIBLE ||
    status == GRB.UNBOUNDED ) {
    System.out.println("The model cannot be solved " +
                        "because it is infeasible or unbounded");
    System.exit(1);
}
if (status != GRB.OPTIMAL) {
    System.out.println("Optimization was stopped with status " + status);
    System.exit(1);
}

// Print best selected set
System.out.println("Selected elements in best solution:");
System.out.println("\t");
for (e = 0; e < groundSetSize; e++) {
    if (Elem[e].get(GRB.DoubleAttr.X) < .9) continue;
    System.out.print("El" + e);
}
System.out.println();

// Print number of solutions stored
nSolutions = model.get(GRB.IntAttr.SolCount);
System.out.println("Number of solutions found: " + nSolutions);

// Print objective values of solutions
if (nSolutions > 10) nSolutions = 10;
System.out.println("Objective values for first " + nSolutions);
System.out.println(" solutions:");
for (i = 0; i < nSubsets; i++) {
    model.set(GRB.IntParam.ObjNumber, i);
    System.out.print("\tSet" + i);
    for (e = 0; e < nSolutions; e++) {
        System.out.print(" ");
        model.set(GRB.IntParam.SolutionNumber, e);
        double val = model.get(GRB.DoubleAttr.ObjNVal);
        System.out.print(" " + val);
    }
}
import gurobi.*;

public class Params {

    public static void main(String[] args) {

        if (args.length < 1) {
            System.out.println("Usage: java Params filename");
            System.exit(1);
        }

        try {
            // Read model and verify that it is a MIP
            GRBEnv env = new GRBEnv();
            GRBModel m = new GRBModel(env, args[0]);
            if (m.get(GRB.IntAttr.IsMIP) == 0) {
                System.out.println("The model is not an integer program");
                System.exit(1);
            }

            // Set a 2 second time limit
            m.set(GRB.DoubleParam.TimeLimit, 2);

            // Now solve the model with different values of MIPFocus
            GRBModel bestModel = new GRBModel(m);
            bestModel.optimize();
            for (int i = 1; i <= 3; ++i) {
                m.reset();
                m.set(GRB.IntParam.MIPFocus, i);
                m.optimize();
                if (bestModel.get(GRB.DoubleAttr.MIPGap) >
                    m.get(GRB.DoubleAttr.MIPGap)) {
                    GRBModel swap = bestModel;
                    bestModel = m;
                }

            }

        } catch (GRBException e) {
            System.out.println("Error code = " + e.getErrorCode());
            System.out.println(e.getMessage());
        }
    }
}

/* Copyright 2018, Gurobi Optimization, LLC */

/* Use parameters that are associated with a model.

A MIP is solved for a few seconds with different sets of parameters. The one with the smallest MIP gap is selected, and the optimization is resumed until the optimal solution is found. */
m = swap;
}
}

// Finally, delete the extra model, reset the time limit and
// continue to solve the best model to optimality
m.dispose();
bestModel.set(GRB.DoubleParam.TimeLimit, GRB.INFINITY);
bestModel.optimize();
System.out.println("Solved with MIPFocus: " +
    bestModel.get(GRB.IntParam.MIPFocus));

} catch (GRBException e) {
    System.out.println("Error code: "+ e.getErrorCode() + ". " +
        e.getMessage());
}
}

Piecewise.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example considers the following separable, convex problem:

minimize f(x) - y + g(z)
subject to x + 2 y + 3 z <= 4
     x + y >= 1
     x, y, z <= 1

where f(u) = \exp(-u) and g(u) = 2 u^2 - 4 u, for all real u. It
formulates and solves a simpler LP model by approximating f and
g with piecewise-linear functions. Then it transforms the model
into a MIP by negating the approximation for f, which corresponds
to a non-convex piecewise-linear function, and solves it again.
*/

import gurobi.*;

public class Piecewise {
    private static double f(double u) { return Math.exp(-u); }
    private static double g(double u) { return 2 * u * u - 4 * u; }

    public static void main(String[] args) {
        try {
            // Create environment
            GRBEnv env = new GRBEnv();
            // Create a new model
            GRBModel model = new GRBModel(env);
            // Create variables

            // Define variables
            GRBVar x = model.addVar(0, 1, 0, GRB.BINARY, "x");
            GRBVar y = model.addVar(0, 1, 0, GRB.BINARY, "y");
            GRBVar z = model.addVar(0, 1, 0, GRB.BINARY, "z");

            // Add constraints
            model.addConstr(x + 2*y + 3*z <= 4, "c0");
            model.addConstr(x + y >= 1, "c1");
            model.addConstr(x <= 1, "c2");
            model.addConstr(y <= 1, "c3");
            model.addConstr(z <= 1, "c4");

            // Add objective
            model.setObjective(f(x) - y + g(z), GRB.MINIMIZE);

            // Optimize
            model.optimize();

            // Print solution
            System.out.println("Solution:");
            System.out.println("x = "+ x.getGlobObjVal());
            System.out.println("y = "+ y.getGlobObjVal());
            System.out.println("z = "+ z.getGlobObjVal());

            //model.dispose();
        } catch (GRBException e) {
            System.out.println("Error code: "+ e.getErrorCode() + ". " +
                e.getMessage());
        }
    }
}

212
double lb = 0.0, ub = 1.0;

GRBVar x = model.addVar(lb, ub, 0.0, GRB.CONTINUOUS, "x");
GRBVar y = model.addVar(lb, ub, 0.0, GRB.CONTINUOUS, "y");
GRBVar z = model.addVar(lb, ub, 0.0, GRB.CONTINUOUS, "z");

// Set objective for y
GRBLinExpr obj = new GRBLinExpr();
obj.addTerm(-1.0, y);
model.setObjective(obj);

// Add piecewise-linear objective functions for x and z
int npts = 101;
double[] ptu = new double[npts];
double[] ptf = new double[npts];
double[] ptg = new double[npts];
for (int i = 0; i < npts; i++) {
    ptu[i] = lb + (ub - lb) * i / (npts - 1);
    ptf[i] = f(ptu[i]);
    ptg[i] = g(ptu[i]);
}
model.setPWLObj(x, ptu, ptf);
model.setPWLObj(z, ptu, ptg);

// Add constraint: x + 2 y + 3 z <= 4
GRBLinExpr expr = new GRBLinExpr();
expr.addTerm(1.0, x); expr.addTerm(2.0, y); expr.addTerm(3.0, z);
model.addConstr(expr, GRB.LESS_EQUAL, 4.0, "c0");

// Add constraint: x + y >= 1
expr = new GRBLinExpr();
expr.addTerm(1.0, x); expr.addTerm(1.0, y);
model.addConstr(expr, GRB.GREATER_EQUAL, 1.0, "c1");

// Optimize model as an LP
model.optimize();
System.out.println("IsMIP: " + model.get(GRB.IntAttr.IsMIP));
System.out.println("Obj: " + model.get(GRB.DoubleAttr.ObjVal));
System.out.println();

// Negate piecewise-linear objective function for x
for (int i = 0; i < npts; i++) {
    ptf[i] = -ptf[i];
}
model.setPWLObj(x, ptu, ptf);

// Optimize model as a MIP
model.optimize();

System.out.println("IsMIP: "+ model.get(GRB.IntAttr.IsMIP));
System.out.println(x.get(GRB.StringAttr.VarName)
    + " " +x.get(GRB.DoubleAttr.X));
System.out.println(y.get(GRB.StringAttr.VarName)
    + " " +y.get(GRB.DoubleAttr.X));
System.out.println(z.get(GRB.StringAttr.VarName)
    + " " +z.get(GRB.DoubleAttr.X));
System.out.println("Obj: "+ model.get(GRB.DoubleAttr.ObjVal));

// Dispose of model and environment
model.dispose();
env.dispose();

} catch (GRBException e) {
    System.out.println("Error code: "+ e.getErrorCode() + ". " +
        e.getMessage());
}

Poolsearch.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* We find alternative epsilon-optimal solutions to a given knapsack
   problem by using PoolSearchMode */

import gurobi.*;

public class Poolsearch {

    public static void main(String[] args) {

        try{
            // Sample data
            int groundSetSize = 10;
            double objCoef[] = new double[] {32, 32, 15, 15, 6, 6, 1, 1, 1, 1};
            double knapsackCoef[] = new double[] {16, 16, 8, 8, 4, 4, 2, 2, 1, 1};
            double Budget = 33;
int e, status, nSolutions;

// Create environment
GRBEnv env = new GRBEnv("Poolsearch.log");

// Create initial model
GRBModel model = new GRBModel(env);
model.set(GRB.StringAttr.ModelName, "Poolsearch");

// Initialize decision variables for ground set:
// x[e] == 1 if element e is chosen
GRBVar[] Elem = model.addVars(groundSetSize, GRB.BINARY);
model.set(GRB.DoubleAttr.Obj, Elem, objCoef, 0, groundSetSize);
for (e = 0; e < groundSetSize; e++) {
    Elem[e].set(GRB.StringAttr.VarName, "El" + String.valueOf(e));
}

// Constraint: limit total number of elements to be picked to be at most Budget
GRBLinExpr lhs = new GRBLinExpr();
for (e = 0; e < groundSetSize; e++) {
    lhs.addTerm(knapsackCoef[e], Elem[e]);
}
model.addConstr(lhs, GRB.LESS_EQUAL, Budget, "Budget");

// set global sense for ALL objectives
model.set(GRB.IntAttr.ModelSense, GRB.MAXIMIZE);

// Limit how many solutions to collect
model.set(GRB.IntParam.PoolSolutions, 1024);

// Limit the search space by setting a gap for the worst possible solution that will be accepted
model.set(GRB.DoubleParam.PoolGap, 0.10);

// do a systematic search for the k-best solutions
model.set(GRB.IntParam.PoolSearchMode, 2);

// save problem
model.write("Poolsearch.lp");

// Optimize
model.optimize();

// Status checking
status = model.get(GRB.IntAttr.Status);
if (status == GRB.INF_OR_UNBD) {
    status = GRB.INFEASIBLE;
}
if (status == GRB.UNBOUNDED) {
    System.out.println("The model cannot be solved " +
                        "because it is infeasible or unbounded");
    System.exit(1);
}
if (status != GRB.OPTIMAL) {
    System.out.println("Optimization was stopped with status " + status);
}
Qcp.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example formulates and solves the following simple QCP model:

maximize \( x \)
subject to
\( x + y + z = 1 \)
\( x^2 + y^2 \leq z^2 \) (second-order cone)

QCP.java
x^2 <= yz  (rotated second-order cone)

import gurobi.*;

public class Qcp {
    public static void main(String[] args) {
        try {
            GRBEnv env = new GRBEnv("qcp.log");
            GRBModel model = new GRBModel(env);

            // Create variables
            GRBVar x = model.addVar(0.0, GRB.INFINITY, 0.0, GRB.CONTINUOUS, "x");
            GRBVar y = model.addVar(0.0, GRB.INFINITY, 0.0, GRB.CONTINUOUS, "y");
            GRBVar z = model.addVar(0.0, GRB.INFINITY, 0.0, GRB.CONTINUOUS, "z");

            // Set objective
            GRBLinExpr obj = new GRBLinExpr();
            obj.addTerm(1.0, x);
            model.setObjective(obj, GRB.MAXIMIZE);

            // Add linear constraint: x + y + z = 1
            GRBLinExpr expr = new GRBLinExpr();
            expr.addTerm(1.0, x); expr.addTerm(1.0, y); expr.addTerm(1.0, z);
            model.addConstr(expr, GRB.EQUAL, 1.0, "c0");

            // Add second-order cone: x^2 + y^2 <= z^2
            GRBQuadExpr qexpr = new GRBQuadExpr();
            qexpr.addTerm(1.0, x, x);
            qexpr.addTerm(1.0, y, y);
            qexpr.addTerm(-1.0, z, z);
            model.addQConstr(qexpr, GRB.LESS_EQUAL, 0.0, "qc0");

            // Add rotated cone: x^2 <= yz
            qexpr = new GRBQuadExpr();
            qexpr.addTerm(1.0, x, x);
            qexpr.addTerm(-1.0, y, z);
            model.addQConstr(qexpr, GRB.LESS_EQUAL, 0.0, "qc1");

            // Optimize model
            model.optimize();

            System.out.println(x.get(GRB.StringAttr.VarName) + " " + x.get(GRB.DoubleAttr.X));
            System.out.println(y.get(GRB.StringAttr.VarName) + " " + y.get(GRB.DoubleAttr.X));
            System.out.println(z.get(GRB.StringAttr.VarName) + " " + z.get(GRB.DoubleAttr.X));

            System.out.println("Obj: " + model.get(GRB.DoubleAttr.ObjVal) + " ");
        }
    }
}

217
obj.getValue();
System.out.println();

// Dispose of model and environment
model.dispose();
env.dispose();

} catch (GRBException e) {
    System.out.println("Error code: "+e.getErrorCode()+". "+
        e.getMessage());
}
}

Qp.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example formulates and solves the following simple QP model:

minimize x^2 + x*y + y^2 + y*z + z^2 + 2 x
subject to x + 2 y + 3 z >= 4
        x + y >= 1

It solves it once as a continuous model, and once as an integer model. */

import gurobi.*;

public class Qp {
    public static void main(String[] args) {
        try {
            GRBEnv env = new GRBEnv("qp.log");
            GRBModel model = new GRBModel(env);

            // Create variables
            GRBVar x = model.addVar(0.0, 1.0, 0.0, GRB.CONTINUOUS, "x");
            GRBVar y = model.addVar(0.0, 1.0, 0.0, GRB.CONTINUOUS, "y");
            GRBVar z = model.addVar(0.0, 1.0, 0.0, GRB.CONTINUOUS, "z");

            // Set objective
            GRBQuadExpr obj = new GRBQuadExpr();
            obj.addTerm(1.0, x, x);
            obj.addTerm(1.0, x, y);
            obj.addTerm(1.0, y, y);
            obj.addTerm(1.0, y, z);
            obj.addTerm(1.0, z, z);
            obj.addTerm(2.0, x);
            model.setObjective(obj);

            // Add constraint: x + 2 y + 3 z >= 4
            GRBLinExpr expr = new GRBLinExpr();
            expr.addTerm(1.0, x);
            expr.addTerm(2.0, y);
            expr.addTerm(3.0, z);
            model.addConstr(expr, GRB.GE, 4.0);

            model.optimize();

            // Print result
            System.out.println("Status : " + model.Status);
            System.out.println("Obj Val : " + model.getObjVal());
            System.out.println("Solution: x = " + x.get(GRB.DoubleAttr.X) +
                " y = " + y.get(GRB.DoubleAttr.X) + " z = " + z.get(GRB.DoubleAttr.X));

        } catch (GRBException e) {
            System.out.println("Error code: " + e.getErrorCode() + ". " +
                e.getMessage());
        }
    }
}
expr.addTerm(1.0, x); expr.addTerm(2.0, y); expr.addTerm(3.0, z);
model.addConstr(expr, GRB.GREATER_EQUAL, 4.0, "c0");

// Add constraint: x + y >= 1

expr = new GRBLinExpr();
expr.addTerm(1.0, x); expr.addTerm(1.0, y);
model.addConstr(expr, GRB.GREATER_EQUAL, 1.0, "c1");

// Optimize model

model.optimize();

System.out.println(x.get(GRB.StringAttr.VarName) + " " + x.get(GRB.DoubleAttr.X));
System.out.println(y.get(GRB.StringAttr.VarName) + " " + y.get(GRB.DoubleAttr.X));
System.out.println(z.get(GRB.StringAttr.VarName) + " " + z.get(GRB.DoubleAttr.X));

System.out.println("Obj: " + model.get(GRB.DoubleAttr.ObjVal) + " " + obj.getValue());
System.out.println();

// Change variable types to integer

x.set(GRB.CharAttr.VType, GRB.INTEGER);
y.set(GRB.CharAttr.VType, GRB.INTEGER);
z.set(GRB.CharAttr.VType, GRB.INTEGER);

// Optimize again

model.optimize();

System.out.println(x.get(GRB.StringAttr.VarName) + " " + x.get(GRB.DoubleAttr.X));
System.out.println(y.get(GRB.StringAttr.VarName) + " " + y.get(GRB.DoubleAttr.X));
System.out.println(z.get(GRB.StringAttr.VarName) + " " + z.get(GRB.DoubleAttr.X));

System.out.println("Obj: " + model.get(GRB.DoubleAttr.ObjVal) + " " + obj.getValue());

// Dispose of model and environment

model.dispose();
env.dispose();

} catch (GRBException e) {
System.out.println("Error code: " + e.getErrorCode() + ". " + e.getMessage());
}
}
Sensitivity.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* A simple sensitivity analysis example which reads a MIP model from a file and solves it. Then each binary variable is set to 1-X, where X is its value in the optimal solution, and the impact on the objective function value is reported. */

import gurobi.*;

public class Sensitivity {

    public static void main(String[] args) {

        if (args.length < 1) {
            System.out.println("Usage: java Sensitivity filename");
            System.exit(1);
        }

        try {

            // Create environment
            GRBEnv env = new GRBEnv();

            // Read and solve model
            GRBModel model = new GRBModel(env, args[0]);

            if (model.get(GRB.IntAttr.IsMIP) == 0) {
                System.out.println("Model is not a MIP");
                System.exit(1);
            }

            model.optimize();

            if (model.get(GRB.IntAttr.Status) != GRB.OPTIMAL) {
                System.out.println("Optimization ended with status " + model.get(GRB.IntAttr.Status));
                System.exit(1);
            }

            // Store the optimal solution
            double origObjVal = model.get(GRB.DoubleAttr.ObjVal);
            GRBVar[] vars = model.getVars();
            double[] origX = model.get(GRB.DoubleAttr.X, vars);

            // Disable solver output for subsequent solves
            model.set(GRB.IntParam.OutputFlag, 0);

            // Iterate through unfixed, binary variables in model

        } finally {
            env.dispose();
        }
    }
}

220
for (int i = 0; i < vars.length; i++) {
  GRBVar v = vars[i];
  char vType = v.get(GRB.CharAttr.VType);

  if (v.get(GRB.DoubleAttr.LB) == 0 && v.get(GRB.DoubleAttr.UB) == 1 && (vType == GRB.BINARY || vType == GRB.INTEGER)) {
    // Set variable to 1-X, where X is its value in optimal solution
    if (origX[i] < 0.5) {
      v.set(GRB.DoubleAttr.LB, 1.0);
      v.set(GRB.DoubleAttr.Start, 1.0);
    } else {
      v.set(GRB.DoubleAttr.UB, 0.0);
      v.set(GRB.DoubleAttr.Start, 0.0);
    }

    // Update MIP start for the other variables
    for (int j = 0; j < vars.length; j++) {
      if (j != i) {
        vars[j].set(GRB.DoubleAttr.Start, origX[j]);
      }
    }

    // Solve for new value and capture sensitivity information
    model.optimize();

    if (model.get(GRB.IntAttr.Status) == GRB.OPTIMAL) {
      System.out.println("Objective sensitivity for variable " + v.get(GRB.StringAttr.VarName) + " is " + (model.get(GRB.DoubleAttr.ObjVal) - origObjVal));
    } else {
      System.out.println("Objective sensitivity for variable " + v.get(GRB.StringAttr.VarName) + " is infinite");
    }

    // Restore the original variable bounds
    v.set(GRB.DoubleAttr.LB, 0.0);
    v.set(GRB.DoubleAttr.UB, 1.0);
  }
}

// Dispose of model and environment
model.dispose();
env.dispose();

} catch (GRBException e) {
  System.out.println("Error code: " + e.getErrorCode());
  System.out.println(e.getMessage());
  e.printStackTrace();
}
Sos.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example creates a very simple Special Ordered Set (SOS) model. The model consists of 3 continuous variables, no linear constraints, and a pair of SOS constraints of type 1. */

import gurobi.*;

public class Sos {
    public static void main(String[] args) {
        try {
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env);

            // Create variables
            double ub[] = {1, 1, 2};
            double obj[] = {-2, -1, -1};
            String names[] = {"x0", "x1", "x2"};

            GRBVar[] x = model.addVars(null, ub, obj, null, names);

            // Add first SOS1: x0=0 or x1=0
            GRBVar sosv1[] = {x[0], x[1]};
            double soswt1[] = {1, 2};
            model.addSOS(sosv1, soswt1, GRB.SOS_TYPE1);

            // Add second SOS1: x0=0 or x2=0
            GRBVar sosv2[] = {x[0], x[2]};
            double soswt2[] = {1, 2};
            model.addSOS(sosv2, soswt2, GRB.SOS_TYPE1);

            // Optimize model
            model.optimize();

            for (int i = 0; i < 3; i++)
                System.out.println(x[i].get(GRB.StringAttr.VarName) + " = " + x[i].get(GRB.DoubleAttr.X));

            // Dispose of model and environment
            model.dispose();
            env.dispose();
        }
        catch (GRBException e) {
            System.out.println("Error code: " + e.getErrorCode() + ". " + e.getMessage());
        }
    }
}

222
Sudoku.java

/* Copyright 2018, Gurobi Optimization, LLC */
/*
Sudoku example.

The Sudoku board is a 9x9 grid, which is further divided into a 3x3 grid of 3x3 grids. Each cell in the grid must take a value from 0 to 9. No two grid cells in the same row, column, or 3x3 subgrid may take the same value.

In the MIP formulation, binary variables x[i,j,v] indicate whether cell <i,j> takes value 'v'. The constraints are as follows:
1. Each cell must take exactly one value (sum_v x[i,j,v] = 1)
2. Each value is used exactly once per row (sum_i x[i,j,v] = 1)
3. Each value is used exactly once per column (sum_j x[i,j,v] = 1)
4. Each value is used exactly once per 3x3 subgrid (sum_grid x[i,j,v] = 1)

Input datasets for this example can be found in examples/data/sudoku*.
*/

import gurobi.*;
import java.io.*;

public class Sudoku {
  public static void main(String[] args) {
    int n = 9;
    int s = 3;

    if (args.length < 1) {
      System.out.println("Usage: java Sudoku filename");
      System.exit(1);
    }

    try {
      GRBEnv env = new GRBEnv();
      GRBModel model = new GRBModel(env);

      // Create 3-D array of model variables
      GRBVar[][][] vars = new GRBVar[n][n][n];

      for (int i = 0; i < n; i++) {
        for (int j = 0; j < n; j++) {
          for (int v = 0; v < n; v++) {
            String st = "G_" + String.valueOf(i) + "_" + String.valueOf(j) + "_" + String.valueOf(v);
            vars[i][j][v] = model.addVar(0.0, 1.0, 0.0, GRB.BINARY, st);
          }
        }
      }
    }
  }
}
// Add constraints

GRBLinExpr expr;

// Each cell must take one value
for (int i = 0; i < n; i++) {
    for (int j = 0; j < n; j++) {
        expr = new GRBLinExpr();
        expr.addTerms(null, vars[i][j]);
        String st = "V_" + String.valueOf(i) + "_" + String.valueOf(j);
        model.addConstr(expr, GRB.EQUAL, 1.0, st);
    }
}

// Each value appears once per row
for (int i = 0; i < n; i++) {
    for (int v = 0; v < n; v++) {
        expr = new GRBLinExpr();
        for (int j = 0; j < n; j++)
            expr.addTerm(1.0, vars[i][j][v]);
        String st = "R_" + String.valueOf(i) + "_" + String.valueOf(v);
        model.addConstr(expr, GRB.EQUAL, 1.0, st);
    }
}

// Each value appears once per column
for (int j = 0; j < n; j++) {
    for (int v = 0; v < n; v++) {
        expr = new GRBLinExpr();
        for (int i = 0; i < n; i++)
            expr.addTerm(1.0, vars[i][j][v]);
        String st = "C_" + String.valueOf(j) + "_" + String.valueOf(v);
        model.addConstr(expr, GRB.EQUAL, 1.0, st);
    }
}

// Each value appears once per sub-grid
for (int v = 0; v < n; v++) {
    for (int i0 = 0; i0 < s; i0++) {
        for (int j0 = 0; j0 < s; j0++) {
            expr = new GRBLinExpr();
            for (int i1 = 0; i1 < s; i1++)
                expr.addTerm(1.0, vars[i0*s+i1][j0*s+j1][v]);
        }
        String st = "Sub_" + String.valueOf(v) + "_" + String.valueOf(i0)
                    + "_" + String.valueOf(j0);
        model.addConstr(expr, GRB.EQUAL, 1.0, st);
    }
}
// Fix variables associated with pre-specified cells

File file = new File(args[0]);
FileInputStream fis = new FileInputStream(file);
byte[] input = new byte[n];

for (int i = 0; i < n; i++) {
    fis.read(input);
    for (int j = 0; j < n; j++) {
        int val = (int) input[j] - 48 - 1; // 0-based
        if (val >= 0)
            vars[i][j][val].set(GRB.DoubleAttr.LB, 1.0);
    }
}

// read the endline byte
fis.read();

// Optimize model
model.optimize();

// Write model to file
model.write("sudoku.lp");

double[][][] x = model.get(GRB.DoubleAttr.X, vars);

System.out.println();
for (int i = 0; i < n; i++) {
    for (int j = 0; j < n; j++) {
        for (int v = 0; v < n; v++) {
            if (x[i][j][v] > 0.5) {
                System.out.print(v+1);
            }
        }
    }
    System.out.println();
}

// Dispose of model and environment
model.dispose();
env.dispose();

} catch (GRBException e) {
    System.out.println("Error code: " + e.getErrorCode() + ". " + e.getMessage());
}
} catch (IOException e) {
    System.out.println("IO Error");
}
}

Tsp.java

/* Copyright 2018, Gurobi Optimization, LLC */
// Solve a traveling salesman problem on a randomly generated set of
// points using lazy constraints. The base MIP model only includes
// 'degree-2' constraints, requiring each node to have exactly
// two incident edges. Solutions to this model may contain subtours —
// tours that don’t visit every node. The lazy constraint callback
// adds new constraints to cut them off.

import gurobi.*;

public class Tsp extends GRBCallback {
    private GRBVar[][] vars;

    public Tsp(GRBVar[][] xvars) {
        vars = xvars;
    }

    // Subtour elimination callback. Whenever a feasible solution is found,
    // find the subtour that contains node 0, and add a subtour elimination
    // constraint if the tour doesn’t visit every node.
    protected void callback() {
        try {
            if (where == GRB.CB_MIPSOL) {
                // Found an integer feasible solution - does it visit every node?
                int n = vars.length;
                int[] tour = findsubtour(getSolution(vars));

                if (tour.length < n) {
                    // Add subtour elimination constraint
                    GRBLinExpr expr = new GRBLinExpr();
                    for (int i = 0; i < tour.length; i++)
                        for (int j = i + 1; j < tour.length; j++)
                            expr.addTerm(1.0, vars[tour[i]][tour[j]]);
                    addLazy(expr, GRB.LESS_EQUAL, tour.length - 1);
                }
            }
        } catch (GRBException e) {
            System.out.println("Error code: " + e.getErrorCode() + ". " +
                                e.getMessage());
            e.printStackTrace();
        }
    }

    // Given an integer-feasible solution 'sol', return the smallest
    // sub-tour (as a list of node indices).
    protected static int[] findsubtour(double[][] sol) {
        int n = sol.length;
        boolean[] seen = new boolean[n];
        int[] tour = new int[n];
        int bestind, bestlen;
        int i, node, len, start;

        for (i = 0; i < n; i++)
            if (seen[i]) { bestind = i; bestlen = 1; }
```
seen[i] = false;

start = 0;
bestlen = n+1;
bestind = -1;
node = 0;
while (start < n) {
    for (node = 0; node < n; node++)
        if (!seen[node])
            break;
    if (node == n)
        break;
    for (len = 0; len < n; len++) {
        tour[start+len] = node;
        seen[node] = true;
        for (i = 0; i < n; i++) {
            if (sol[node][i] > 0.5 && !seen[i]) {
                node = i;
                break;
            }
        }
        if (i == n) {
            len ++;
            if (len < bestlen) {
                bestlen = len;
                bestind = start;
            }
            start += len;
            break;
        }
    }
}

int result[] = new int[bestlen];
for (i = 0; i < bestlen; i++)
    result[i] = tour[bestind+i];
return result;

// Euclidean distance between points 'i' and 'j'
protected static double distance(double[] x,
                                   double[] y,
                                   int i,
                                   int j) {
    double dx = x[i]-x[j];
    double dy = y[i]-y[j];
    return Math.sqrt(dx*dx+dy*dy);
}

public static void main(String[] args) {
    if (args.length < 1) {
        System.out.println("Usage: java Tsp ncities");
        System.exit(1);
    }
```
int n = Integer.parseInt(args[0]);

try {
    GRBEnv env = new GRBEnv();
    GRBModel model = new GRBModel(env);
    // Must set LazyConstraints parameter when using lazy constraints
    model.set(GRB.IntParam.LazyConstraints, 1);
    double[] x = new double[n];
    double[] y = new double[n];
    for (int i = 0; i < n; i++) {
        x[i] = Math.random();
        y[i] = Math.random();
    }
    // Create variables
    GRBVar[][] vars = new GRBVar[n][n];
    for (int i = 0; i < n; i++) {
        for (int j = 0; j <= i; j++) {
            vars[i][j] = model.addVar(0.0, 1.0, distance(x, y, i, j),
                                        GRB.BINARY,
                                        "x"+String.valueOf(i)+"."+String.valueOf(j));
            vars[j][i] = vars[i][j];
        }
    }
    // Degree-2 constraints
    for (int i = 0; i < n; i++) {
        GRBLinExpr expr = new GRBLinExpr();
        for (int j = 0; j < n; j++)
            expr.addTerm(1.0, vars[i][j]);
        model.addConstr(expr, GRB.EQUAL, 2.0, "deg2_"+String.valueOf(i));
    }
    // Forbid edge from node back to itself
    for (int i = 0; i < n; i++)
        vars[i][i].set(GRB.DoubleAttr.UB, 0.0);
    model.setCallback(new Tsp(vars));
    model.optimize();
    if (model.get(GRB.IntAttr.SolCount) > 0) {
        int[] tour = findsubtour(model.get(GRB.DoubleAttr.X, vars));
        assert tour.length == n;
        System.out.print("Tour: ");
        for (int i = 0; i < tour.length; i++)
            System.out.print(String.valueOf(tour[i]) + " ");
        System.out.println();
    }
}
Tune.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads a model from a file and tunes it. It then writes the best parameter settings to a file and solves the model using these parameters. */

import gurobi.*;

public class Tune {
    public static void main(String[] args) {
        if (args.length < 1) {
            System.out.println("Usage: java Tune filename");
            System.exit(1);
        }

        try {
            GRBEnv env = new GRBEnv();

            // Read model from file
            GRBModel model = new GRBModel(env, args[0]);

            // Set the TuneResults parameter to 1
            model.set(GRB.IntParam.TuneResults, 1);

            // Tune the model
            model.tune();

            // Get the number of tuning results
            int resultcount = model.get(GRB.IntAttr.TuneResultCount);

            if (resultcount > 0) {
                // Load the tuned parameters into the model's environment
                model.getTuneResult(0);

                // Write the tuned parameters to a file
                model.write("tuneprm");

                // Solve the model using the tuned parameters
            }
        }
    }
}

// Dispose of model and environment
model.dispose();
env.dispose();

} catch (GRBException e) {
    System.out.println("Error code: "+e.getErrorCode()+". "+
e.getMessage());
e.printStackTrace();
}

Tune.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads a model from a file and tunes it. It then writes the best parameter settings to a file and solves the model using these parameters. */

import gurobi.*;

public class Tune {
    public static void main(String[] args) {
        if (args.length < 1) {
            System.out.println("Usage: java Tune filename");
            System.exit(1);
        }

        try {
            GRBEnv env = new GRBEnv();

            // Read model from file
            GRBModel model = new GRBModel(env, args[0]);

            // Set the TuneResults parameter to 1
            model.set(GRB.IntParam.TuneResults, 1);

            // Tune the model
            model.tune();

            // Get the number of tuning results
            int resultcount = model.get(GRB.IntAttr.TuneResultCount);

            if (resultcount > 0) {
                // Load the tuned parameters into the model's environment
                model.getTuneResult(0);

                // Write the tuned parameters to a file
                model.write("tuneprm");

                // Solve the model using the tuned parameters
            }
        }
    }
}

// Dispose of model and environment
model.dispose();
env.dispose();

} catch (GRBException e) {
    System.out.println("Error code: "+e.getErrorCode()+". "+
e.getMessage());
e.printStackTrace();
}
model.optimize();
}

// Dispose of model and environment
model.dispose();
env.dispose();
}
catch (GRBException e) {
    System.out.println("Error code: " + e.getErrorCode() + ". " + e.getMessage());
}

Workforce1.java
/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a particular day. If the problem cannot be solved, use IIS to find a set of conflicting constraints. Note that there may be additional conflicts besides what is reported via IIS. */

import gurobi.*;

public class Workforce1 {

    public static void main(String[] args) {
        try {
            // Sample data
            // Sets of days and workers
            String Shifts[] =
            String Workers[] =

            int nShifts = Shifts.length;
            int nWorkers = Workers.length;

            // Number of workers required for each shift
            double shiftRequirements[] =
                new double[] { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

            // Amount each worker is paid to work one shift
            double pay[] = new double[] { 10, 12, 10, 8, 8, 9, 11 };

            // Worker availability: 0 if the worker is unavailable for a shift
            double availability[][] =
                new double[][] {
                    { 0, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1 },
                    { 1, 1, 0, 0, 1, 0, 1, 0, 1, 0, 1, 0, 0, 0 },
                    { 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
                    { 0, 0, 0, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
                    { 1, 1, 1, 1, 1, 0, 0, 1, 0, 0, 1, 0, 1, 1 },
                    { 0, 1, 1, 0, 0, 0, 1, 0, 0, 1, 1, 1, 1, 1 },
                    { 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
                    { 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
                };
        }
    }
}
// Model
GRBEnv env = new GRBEnv();
GRBModel model = new GRBModel(env);
model.set(GRB.StringAttr.ModelName, "assignment");

// Assignment variables: x[w][s] == 1 if worker w is assigned
// to shift s. Since an assignment model always produces integer
// solutions, we use continuous variables and solve as an LP.
GRBVar[][] x = new GRBVar[nWorkers][nShifts];
for (int w = 0; w < nWorkers; ++w) {
    for (int s = 0; s < nShifts; ++s) {
        x[w][s] =
            model.addVar(0, availability[w][s], pay[w],
                         Workers[w] + "." + Shifts[s]);
    }
}

// The objective is to minimize the total pay costs
model.set(GRB.IntAttr.ModelSense, GRB.MINIMIZE);

// Constraint: assign exactly shiftRequirements[s] workers
// to each shift s
for (int s = 0; s < nShifts; ++s) {
    GRBLinExpr lhs = new GRBLinExpr();
    for (int w = 0; w < nWorkers; ++w) {
        lhs.addTerm(1.0, x[w][s]);
    }
    model.addConstr(lhs, GRB.EQUAL, shiftRequirements[s], Shifts[s]);
}

// Optimize
model.optimize();
int status = model.get(GRB.IntAttr.Status);
if (status == GRB.Status.UNBOUNDED) {
    System.out.println("The model cannot be solved "
                      + "because it is unbounded");
    return;
}

if (status == GRB.Status.OPTIMAL) {
    System.out.println("The optimal objective is " +
                       model.get(GRB.DoubleAttr.ObjVal));
    return;
}

if (status != GRB.Status.INF_OR_UNBD &&
    status != GRB.Status.INFEASIBLE)
{
    System.out.println("Optimization was stopped with status " + status);
    return;
}

// Compute IIS
System.out.println("The model is infeasible; computing IIS");
model.computeIIS();
System.out.println("\nThe following constraint(s) "}
for (GRBConstr c : model.getConstrs()) {
    if (c.get(GRB.IntAttr.IISConstr) == 1) {
        System.out.println(c.get(GRB.StringAttr.ConstrName));
    }
}

// Dispose of model and environment
model.dispose();
env.dispose();

} catch (GRBException e) {
    System.out.println("Error code: " + e.getErrorCode() + ", " + e.getMessage());
}
}

Workforce2.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a particular day. If the problem cannot be solved, use IIS iteratively to find all conflicting constraints. */

import gurobi.*;
import java.util.*;

public class Workforce2 {

    public static void main(String[] args) {
        try {

            // Sample data
            // Sets of days and workers
            String Shifts[] =
            String Workers[] =

            int nShifts = Shifts.length;
            int nWorkers = Workers.length;

            // Number of workers required for each shift
            double shiftRequirements[] =
                new double[] { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

            // Amount each worker is paid to work one shift
            double pay[] = new double[] { 10, 12, 10, 8, 8, 9, 11 };

            // Worker availability: 0 if the worker is unavailable for a shift
            double availability[][] =
                new double[][] { { 0, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1 },
...
// Model
GRBEnv env = new GRBEnv();
GRBModel model = new GRBModel(env);
model.set(GRB.StringAttr.ModelName, "assignment");

// Assignment variables: x[w][s] == 1 if worker w is assigned
// to shift s. Since an assignment model always produces integer
// solutions, we use continuous variables and solve as an LP.
x = new GRBVar[nWorkers][nShifts];
for (int w = 0; w < nWorkers; ++w) {
  for (int s = 0; s < nShifts; ++s) {
    x[w][s] = model.addVar(0, availability[w][s], pay[w], GRB.CONTINUOUS,
                           Workers[w] + "." + Shifts[s]);
  }
}

// The objective is to minimize the total pay costs
model.set(GRB.IntAttr.ModelSense, GRB.MINIMIZE);

// Constraint: assign exactly shiftRequirements[s] workers
// to each shift s
for (int s = 0; s < nShifts; ++s) {
  GRBLinExpr lhs = new GRBLinExpr();
  for (int w = 0; w < nWorkers; ++w) {
    lhs.addTerm(1.0, x[w][s]);
  }
  model.addConstr(lhs, GRB.EQUAL, shiftRequirements[s], Shifts[s]);
}

// Optimize
model.optimize();
int status = model.get(GRB.IntAttr.Status);
if (status == GRB.Status.UNBOUNDED) {
  System.out.println("The model cannot be solved "
                   + "because it is unbounded");
  return;
}
if (status == GRB.Status.OPTIMAL) {
  System.out.println("The optimal objective is " +
                     model.get(GRB.DoubleAttr_ObjVal));
  return;
}
if (status != GRB.Status.INF_OR_UNBD &&
    status != GRB.Status.INFEASIBLE) {
  System.out.println("Optimization was stopped with status " + status);
  return;
}
// Do IIS
System.out.println("The model is infeasible; computing IIS");
LinkedList<String> removed = new LinkedList<String>();

// Loop until we reduce to a model that can be solved
while (true) {
    model.computeIIS();
    System.out.println("\nThe following constraint cannot be satisfied:");
    for (GRBConstr c : model.getConstrs()) {
        if (c.get(GRB.IntAttr.IISConstr) == 1) {
            System.out.println(c.get(GRB.StringAttr.ConstrName));
            // Remove a single constraint from the model
            removed.add(c.get(GRB.StringAttr.ConstrName));
            model.remove(c);
            break;
        }
    }
    System.out.println();
    model.optimize();
    status = model.get(GRB.IntAttr.Status);
    if (status == GRB.Status.UNBOUNDED) {
        System.out.println("The model cannot be solved "
                        + "because it is unbounded");
        return;
    } else if (status == GRB.Status.OPTIMAL) {
        break;
    } else if (status != GRB.Status.INF_OR_UNBD &&
               status != GRB.Status.INFEASIBLE) {
        System.out.println("Optimization was stopped with status " +
                           status);
        return;
    }
    System.out.println("\nThe following constraints were removed "
                        + "to get a feasible LP:");
    for (String s : removed) {
        System.out.print(s + ",");
    }
    System.out.println();
    // Dispose of model and environment
    model.dispose();
    env.dispose();
}

} catch (GRBException e) {
    System.out.println("Error code: " + e.getErrorCode() + ". " +
                       e.getMessage());
}
}
/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a
particular day. If the problem cannot be solved, relax the model
to determine which constraints cannot be satisfied, and how much
they need to be relaxed. */

import gurobi.*;

public class Workforce3 {

    public static void main(String[] args) {
        try {
            // Sample data
            // Sets of days and workers
            String Shifts[] =
                new String[] { "Mon1", "Tue2", "Wed3", "Thu4", "Fri5", "Sat6",
                               "Sun7", "Mon8", "Tue9", "Wed10", "Thu11", "Fri12", "Sat13",
                               "Sun14" };
            String Workers[] =

            int nShifts = Shifts.length;
            int nWorkers = Workers.length;

            // Number of workers required for each shift
            double shiftRequirements[] =
                new double[] { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

            // Amount each worker is paid to work one shift
            double pay[] =
                new double[] { 10, 12, 10, 8, 8, 9, 11 };

            // Worker availability: 0 if the worker is unavailable for a shift
            double availability[][] =
                new double[][] { 
                    { 0, 1, 1, 0, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
                    { 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0 },
                    { 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
                    { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
                    { 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1 },
                    { 1, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1 },
                    { 1, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1 },
                    { 1, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1 },
                    { 1, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1 },
                    { 1, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1 },
                    { 1, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1 },
                    { 1, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1 } };

            // Model
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env);
            model.set(GRB.StringAttr.ModelName, "assignment");

            // Assignment variables: x[w][s] == 1 if worker w is assigned
            // to shift s. Since an assignment model always produces integer
            // solutions, we use continuous variables and solve as an LP.
            GRBVar[][] x = new GRBVar[nWorkers][nShifts];
            for (int w = 0; w < nWorkers; ++w) {
                for (int s = 0; s < nShifts; ++s) {

            ...
x[w][s] =
    model.addVar(0, availability[w][s], pay[w], GRB.CONTINUOUS,
    Workers[w] + "." + Shifts[s]);
}
}

// The objective is to minimize the total pay costs
model.set(GRB.IntAttr.ModelSense, GRB.MINIMIZE);

// Constraint: assign exactly shiftRequirements[s] workers
// to each shift s
for (int s = 0; s < nShifts; ++s) {
    GRBLinExpr lhs = new GRBLinExpr();
    for (int w = 0; w < nWorkers; ++w) {
        lhs.addTerm(1.0, x[w][s]);
    }
    model.addConstr(lhs, GRB.EQUAL, shiftRequirements[s], Shifts[s]);
}

// Optimize
model.optimize();
int status = model.get(GRB.IntAttr.Status);
if (status == GRB.UNBOUNDED) {
    System.out.println("The model cannot be solved " +
    "because it is unbounded");
    return;
}
if (status == GRB.OPTIMAL) {
    System.out.println("The optimal objective is " +
    model.get(GRB.DoubleAttr.ObjVal));
    return;
}
if (status != GRB.INF_OR_UNBD &&
    status != GRB.INFEASIBLE) {
    System.out.println("Optimization was stopped with status " + status);
    return;
}

// Relax the constraints to make the model feasible
System.out.println("The model is infeasible; relaxing the constraints");
int orignumvars = model.get(GRB.IntAttr.NumVars);
model.feasRelax(0, false, false, true);
model.optimize();
status = model.get(GRB.IntAttr.Status);
if (status == GRB.INF_OR_UNBD ||
    status == GRB.INFEASIBLE ||
    status == GRB.UNBOUNDED) {
    System.out.println("The relaxed model cannot be solved " +
    "because it is infeasible or unbounded");
    return;
}
if (status != GRB.OPTIMAL) {
    System.out.println("Optimization was stopped with status " + status);
    return;
}
System.out.println("Slack values:");
GRBVar[] vars = model.getVars();
for (int i = origumvars; i < model.get(GRB.IntAttr.NumVars); ++i) {
    GRBVar sv = vars[i];
    if (sv.get(GRB.DoubleAttr.X) > 1e-6) {
        System.out.println(sv.get(GRB.StringAttr.VarName) + " = " +
                           sv.get(GRB.DoubleAttr.X));
    }
}

// Dispose of model and environment
model.dispose();
env.dispose();

} catch (GRBException e) {
    System.out.println(" Error code: " + e.getErrorCode() + ". " +
                      e.getMessage());
}
}

Workforce4.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a
particular day. We use Pareto optimization to solve the model:
first, we minimize the linear sum of the slacks. Then, we constrain
the sum of the slacks, and we minimize a quadratic objective that
tries to balance the workload among the workers. */

import gurobi.*;

public class Workforce4 {

    public static void main(String[] args) {
        try {
            // Sample data
            // Sets of days and workers
            String Shifts[] =
                new String[] { "Mon1", "Tue2", "Wed3", "Thu4", "Fri5", "Sat6",
                               "Sun7", "Mon8", "Tue9", "Wed10", "Thu11", "Fri12", "Sat13",
                               "Sun14" };
            String Workers[] =

            int nShifts = Shifts.length;
            int nWorkers = Workers.length;

            // Number of workers required for each shift
don double shiftRequirements[] =
                new double[] { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

            // Worker availability: 0 if the worker is unavailable for a shift
don double availability[][][] =
new double [][] { { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
{ 1, 1, 0, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0 },
{ 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1 },
{ 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
{ 1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 1, 0, 1, 1 },
{ 1, 1, 1, 0, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1 },
{ 1, 1, 1, 0, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1 } };  

// Model
GRBEnv env = new GRBEnv();
GRBModel model = new GRBModel(env);
model.set(GRB.StringAttr.ModelName, "assignment");

// Assignment variables: x[w][s] == 1 if worker w is assigned
// to shift s. This is no longer a pure assignment model, so we must
// use binary variables.
GRBVar [][] x = new GRBVar[nWorkers][nShifts];
for (int w = 0; w < nWorkers; ++w) {
    for (int s = 0; s < nShifts; ++s) {
        x[w][s] = model.addVar(0, availability[w][s], 0, GRB.BINARY,
                                Workers[w] + "." + Shifts[s]);
    }
}

// Slack variables for each shift constraint so that the shifts can
// be satisfied
GRBVar [] slacks = new GRBVar[nShifts];
for (int s = 0; s < nShifts; ++s) {
    slacks[s] = model.addVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                              Shifts[s] + "Slack");
}

// Variable to represent the total slack
GRBVar totSlack = model.addVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                                "totSlack");

// Variables to count the total shifts worked by each worker
GRBVar [] totShifts = new GRBVar[nWorkers];
for (int w = 0; w < nWorkers; ++w) {
    totShifts[w] = model.addVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                                 Workers[w] + "TotShifts");
}

GRBLinExpr lhs;

// Constraint: assign exactly shiftRequirements[s] workers
// to each shift s, plus the slack
for (int s = 0; s < nShifts; ++s) {
    lhs = new GRBLinExpr();
    lhs.addTerm(1.0, slacks[s]);
    for (int w = 0; w < nWorkers; ++w) {
        lhs.addTerm(1.0, x[w][s]);
    }
    model.addConstr(lhs, GRB.EQUAL, shiftRequirements[s], Shifts[s]);
// Constraint: set totSlack equal to the total slack
lhs = new GRBLinExpr();
lhs.addTerm(-1.0, totSlack);
for (int s = 0; s < nShifts; ++s) {
    lhs.addTerm(1.0, slacks[s]);
}
model.addConstr(lhs, GRB.EQUAL, 0, "totSlack");

// Constraint: compute the total number of shifts for each worker
for (int w = 0; w < nWorkers; ++w) {
    lhs = new GRBLinExpr();
    lhs.addTerm(-1.0, totShifts[w]);
    for (int s = 0; s < nShifts; ++s) {
        lhs.addTerm(1.0, x[w][s]);
    }
    model.addConstr(lhs, GRB.EQUAL, 0, "totShifts" + Workers[w]);
}

// Objective: minimize the total slack
GRBLinExpr obj = new GRBLinExpr();
obj.addTerm(1.0, totSlack);
model.setObjective(obj);

// Optimize
int status =
    solveAndPrint(model, totSlack, nWorkers, Workers, totShifts);
if (status != GRB.Status.OPTIMAL) {
    return;
}

// Constrain the slack by setting its upper and lower bounds
totSlack.set(GRB.DoubleAttr.UB, totSlack.get(GRB.DoubleAttr.X));
totSlack.set(GRB.DoubleAttr.LB, totSlack.get(GRB.DoubleAttr.X));

// Variable to count the average number of shifts worked
GRBVar avgShifts =
    model.addVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS, "avgShifts");

// Variables to count the difference from average for each worker;
// note that these variables can take negative values.
GRBVar[] diffShifts = new GRBVar[nWorkers];
for (int w = 0; w < nWorkers; ++w) {
    diffShifts[w] = model.addVar(-GRB.INFINITY, GRB.INFINITY, 0,
                                 GRB.CONTINUOUS, Workers[w] + "Diff");
}

// Constraint: compute the average number of shifts worked
lhs = new GRBLinExpr();
lhs.addTerm(-nWorkers, avgShifts);
for (int w = 0; w < nWorkers; ++w) {
    lhs.addTerm(1.0, totShifts[w]);
}
model.addConstr(lhs, GRB.EQUAL, 0, "avgShifts");
// Constraint: compute the difference from the average number of shifts
for (int w = 0; w < nWorkers; ++w) {
    lhs = new GRBLinExpr();
    lhs.addTerm(-1, diffShifts[w]);
    lhs.addTerm(-1, avgShifts);
    lhs.addTerm(1, totShifts[w]);
    model.addConstr(lhs, GRB.EQUAL, 0, Workers[w] + "Diff");
}

// Objective: minimize the sum of the square of the difference from the average number of shifts worked
GRBQuadExpr qobj = new GRBQuadExpr();
for (int w = 0; w < nWorkers; ++w) {
    qobj.addTerm(1.0, diffShifts[w], diffShifts[w]);
}
model.setObjective(qobj);

// Optimize
status =
    solveAndPrint(model, totSlack, nWorkers, Workers, totShifts);
if (status != GRB.Status.OPTIMAL) {
    return;
}

// Dispose of model and environment
model.dispose();
env.dispose();

} catch (GRBException e) {
    System.out.println("Error code: " + e.getErrorCode() + ". " +
    e.getMessage());
}

private static int solveAndPrint(GRBModel model, GRBVar totSlack, int nWorkers, String[] Workers,
    GRBVar[] totShifts) throws GRBException {

    model.optimize();
    int status = model.get(GRB.IntAttr.Status);
    if (status == GRB.Status.INF_OR_UNBD ||
        status == GRB.Status.INFEASIBLE ||
        status == GRB.Status.UNBOUNDED ) {
        System.out.println("The model cannot be solved "+
        "because it is infeasible or unbounded");
        return status;
    }
    if (status != GRB.Status.OPTIMAL) {
        System.out.println("Optimization was stopped with status "+ status);
        return status;
    }

    // Print total slack and the number of shifts worked for each worker
    System.out.println("\nTotal slack required: " +
    totSlack.get(GRB.DoubleAttr.X));
    for (int w = 0; w < nWorkers; ++w) {

System.out.println(Workers[w] + " worked " + totShifts[w].get(GRB.DoubleAttr.X) + " shifts");
}
System.out.println("\n");
return status;
}
}

Workforce5.java

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a particular day. We use multi-objective optimization to solve the model. The highest-priority objective minimizes the sum of the slacks (i.e., the total number of uncovered shifts). The secondary objective minimizes the difference between the maximum and minimum number of shifts worked among all workers. The second optimization is allowed to degrade the first objective by up to the smaller value of 10% and 2 */

import gurobi.*;

public class Workforce5 {

    public static void main(String[] args) {

        try {

            // Sample data
            // Sets of days and workers
            String Shifts[] =
            String Workers[] =

            int nShifts = Shifts.length;
            int nWorkers = Workers.length;

            // Number of workers required for each shift
            double shiftRequirements[] =
                new double[] { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

            // Worker availability: 0 if the worker is unavailable for a shift
            double availability[][] =
                new double[][] {
                    { 0, 1, 1, 0, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1 },
                    { 1, 1, 0, 0, 1, 1, 0, 0, 1, 0, 1, 0, 1, 1 },
                    { 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 1, 1 },
                    { 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
                    { 1, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 1, 1 },
                    { 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 0, 1 },
                    { 1, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 1, 0, 1 },
                    { 0, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 0, 1, 1 },
                    { 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 1, 0, 1 },
                };

            System.out.println("Workers tested = " + nWorkers + ", shifts assigned = " + nShifts + ", objective = ");
            System.out.println("" + status + ");
        }
    }
}

import gurobi.*;

public class Workforce5 {

    public static void main(String[] args) {

        try {

            // Sample data
            // Sets of days and workers
            String Shifts[] =
            String Workers[] =

            int nShifts = Shifts.length;
            int nWorkers = Workers.length;

            // Number of workers required for each shift
            double shiftRequirements[] =
                new double[] { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

            // Worker availability: 0 if the worker is unavailable for a shift
            double availability[][] =
                new double[][] {
                    { 0, 1, 1, 0, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1 },
                    { 1, 1, 0, 0, 1, 1, 0, 0, 1, 0, 1, 0, 1, 1 },
                    { 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 1, 1 },
                    { 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
                    { 1, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 1, 1 },
                    { 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 0, 1 },
                    { 1, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 1, 0, 1 },
                    { 0, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 0, 1, 1 },
                    { 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 1, 0, 1 },
                };

            System.out.println("Workers tested = " + nWorkers + ", shifts assigned = " + nShifts + ", objective = ");
            System.out.println("" + status + ");
        }
    }
}
// Create environment
GRBEnv env = new GRBEnv();

// Create initial model
GRBModel model = new GRBModel(env);
model.set(GRB.StringAttr.ModelName, "Workforce5");

// Initialize assignment decision variables:
// x[w][s] == 1 if worker w is assigned to shift s.
// This is no longer a pure assignment model, so we must
// use binary variables.
GRBVar[][] x = new GRBVar[nWorkers][nShifts];
for (int w = 0; w < nWorkers; ++w) {
    for (int s = 0; s < nShifts; ++s) {
        x[w][s] = model.addVar(0, availability[w][s], 0, GRB.BINARY,
                                Workers[w] + "." + Shifts[s]);
    }
}

// Slack variables for each shift constraint so that the shifts can
// be satisfied
GRBVar[] slacks = new GRBVar[nShifts];
for (int s = 0; s < nShifts; ++s) {
    slacks[s] = model.addVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                             Shifts[s] + "Slack");
}

// Variable to represent the total slack
GRBVar totSlack = model.addVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                                "totSlack");

// Variables to count the total shifts worked by each worker
GRBVar[] totShifts = new GRBVar[nWorkers];
for (int w = 0; w < nWorkers; ++w) {
    totShifts[w] = model.addVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                                 Workers[w] + "TotShifts");
}

GRBLinExpr lhs;

// Constraint: assign exactly shiftRequirements[s] workers
// to each shift s, plus the slack
for (int s = 0; s < nShifts; ++s) {
    lhs = new GRBLinExpr();
    lhs.addTerm(1.0, slacks[s]);
    for (int w = 0; w < nWorkers; ++w) {
        lhs.addTerm(1.0, x[w][s]);
    }
    model.addConstr(lhs, GRB.EQUAL, shiftRequirements[s], Shifts[s]);
}

// Constraint: set totSlack equal to the total slack
lhs = new GRBLinExpr();
lhs.addTerm(-1.0, totSlack);
for (int s = 0; s < nShifts; ++s) {
    lhs.addTerm(1.0, slacks[s]);
}
model.addConstr(lhs, GRB.EQUAL, 0, "totSlack");

// Constraint: compute the total number of shifts for each worker
for (int w = 0; w < nWorkers; ++w) {
    lhs = new GRBLinExpr();
    lhs.addTerm(-1.0, totShifts[w]);
    for (int s = 0; s < nShifts; ++s) {
        lhs.addTerm(1.0, x[w][s]);
    }
    model.addConstr(lhs, GRB.EQUAL, 0, "totShifts" + Workers[w]);
}

// Constraint: set minShift/maxShift variable to less <=/= to the
// number of shifts among all workers
GRBVar minShift = model.addVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS, "minShift");
GRBVar maxShift = model.addVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS, "maxShift");
model.addGenConstrMin(minShift, totShifts, GRB.INFINITY, "minShift");
model.addGenConstrMax(maxShift, totShifts, -GRB.INFINITY, "maxShift");

// Set global sense for ALL objectives
model.set(GRB.IntAttr.ModelSense, GRB.MINIMIZE);

// Set primary objective
GRBLinExpr obj0 = new GRBLinExpr();
obj0.addTerm(1.0, totSlack);
model.setObjectiveN(obj0, 0, 2, 1.0, 2.0, 0.1, "TotalSlack");

// Set secondary objective
GRBLinExpr obj1 = new GRBLinExpr();
obj1.addTerm(1.0, maxShift);
obj1.addTerm(-1.0, minShift);
model.setObjectiveN(obj1, 1, 1, 1.0, 0.0, 0.0, "Fairness");

// Save problem
model.write("Workforce5.lp");

// Optimize
int status = solveAndPrint(model, totSlack, nWorkers, Workers, totShifts);
if (status != GRB.OPTIMAL)
    return;

// Dispose of model and environment
model.dispose();
env.dispose();
}

} catch (GRBException e) {
    System.out.println("Error code: " + e.getErrorCode() + ". " + e.getMessage());
}
private static int solveAndPrint(GRBModel model, GRBVar totSlack,
int nWorkers, String[] Workers,
GRBVar[] totShifts) throws GRBException {

    model.optimize();
    int status = model.get(GRB.IntAttr.Status);
    if (status == GRB.Status.INF_OR_UNBD ||
        status == GRB.Status.INFEASIBLE ||
        status == GRB.Status.UNBOUNDED ) {
        System.out.println("The model cannot be solved "
            + "because it is infeasible or unbounded");
        return status;
    }
    if (status != GRB.Status.OPTIMAL ) {
        System.out.println("Optimization was stopped with status " + status);
        return status;
    }

    // Print total slack and the number of shifts worked for each worker
    System.out.println("\nTotal slack required: " +
        totSlack.get(GRB.DoubleAttr.X));
    for (int w = 0; w < nWorkers; ++w) {
        System.out.println("Worker[w] + " worked " +
            totShifts[w].get(GRB.DoubleAttr.X) + " shifts");
    }
    System.out.println("\n");
    return status;
}

3.4 C# Examples

This section includes source code for all of the Gurobi C# examples. The same source code can be
found in the examples/c# directory of the Gurobi distribution.

callback_cs.cs

    /* Copyright 2018, Gurobi Optimization, LLC */
    
    /*
      This example reads a model from a file, sets up a callback that
      monitors optimization progress and implements a custom
      termination strategy, and outputs progress information to the
      screen and to a log file.
    
    The termination strategy implemented in this callback stops the
    optimization of a MIP model once at least one of the following two
    conditions have been satisfied:
      1) The optimality gap is less than 10%
      2) At least 10000 nodes have been explored, and an integer feasible
         solution has been found.
    
    Note that termination is normally handled through Gurobi parameters
    (MIPGap, NodeLimit, etc.). You should only use a callback for
termination if the available parameters don’t capture your desired termination criterion.
*/

using System;
using System.IO;
using Gurobi;

class callback_cs : GRBCallback
{
    private double lastiter;
    private double lastnode;
    private GRBVar[] vars;
    private StreamWriter logfile;

    public callback_cs(GRBVar[] xvars, StreamWriter xlogfile)
    {
        lastiter = lastnode = -GRB.INFINITY;
        vars = xvars;
        logfile = xlogfile;
    }

    protected override void Callback()
    {
        try {
            if (where == GRB.Callback.POLLING) {
                // Ignore polling callback
            } else if (where == GRB.Callback.PRESOLVE) {
                // Presolve callback
                int cdels = GetIntInfo(GRB.Callback.PRE_COLDEL);
                int rdels = GetIntInfo(GRB.Callback.PRE_ROWDEL);
                if (cdels != 0 || rdels != 0) {
                    Console.WriteLine(cdels + " columns and " + rdels + " rows are removed");
                }
            } else if (where == GRB.Callback.SIMPLEX) {
                // Simplex callback
                double itcnt = GetDoubleInfo(GRB.Callback.SPX_ITRCNT);
                if (itcnt - lastiter >= 100) {
                    lastiter = itcnt;
                    double obj = GetDoubleInfo(GRB.Callback.SPX_OBJVAL);
                    int ispert = GetIntInfo(GRB.Callback.SPX_ISPERT);
                    double pinf = GetDoubleInfo(GRB.Callback.SPX_PRIMINF);
                    double dinf = GetDoubleInfo(GRB.Callback.SPX_DUALINF);
                    char ch;
                    if (ispert == 0) ch = ' ';
                    else if (ispert == 1) ch = 'S';
                    else ch = 'P';
                    Console.WriteLine(itcnt + " " + obj + ch + " "
                        + pinf + " " + dinf);
                }
            } else if (where == GRB.Callback.MIP) {
                // General MIP callback
                double nodedcnt = GetDoubleInfo(GRB.Callback.MIP_NODCNT);
                double objbst = GetDoubleInfo(GRB.Callback.MIP_OBJBST);
                double objbnd = GetDoubleInfo(GRB.Callback.MIP_OBJBND);
int solcnt = GetIntInfo(GRB.Callback.MIP_SOLCNT);
if (nodecnt - lastnode >= 100) {
    lastnode = nodecnt;
    int actnodes = (int) GetDoubleInfo(GRB.Callback.MIP_NODLFT);
    int itcnt = (int) GetDoubleInfo(GRB.Callback.MIP_ITRCNT);
    int cutcnt = GetIntInfo(GRB.Callback.MIP_CUTCNT);
    Console.WriteLine(nodecnt + " " + actnodes + " "
        + itcnt + " " + objbst + " " + objbnd + " "
        + solcnt + " " + cutcnt);
}
if (Math.Abs(objbst - objbnd) < 0.1 * (1.0 + Math.Abs(objbst))) {
    Console.WriteLine("Stop early - 10% gap achieved");
    Abort();
}
if (nodecnt >= 10000 && solcnt > 0) {
    Console.WriteLine("Stop early - 10000 nodes explored");
    Abort();
}
else if (where == GRB.Callback.MIPSOL) {
    // MIP solution callback
    int nodecnt = (int) GetDoubleInfo(GRB.Callback.MIPSOL_NODCNT);
    double obj = GetDoubleInfo(GRB.Callback.MIPSOL_OBJ);
    int solcnt = GetIntInfo(GRB.Callback.MIPSOL_SOLCNT);
    double[] x = GetSolution(vars);
    Console.WriteLine("**** New solution at node " + nodecnt
        + ", obj " + obj + ", sol " + solcnt
        + ", x[0] = " + x[0] + " ****");
} else if (where == GRB.Callback.MIPNODE) {
    // MIP node callback
    Console.WriteLine("**** New node ****");
    if (GetIntInfo(GRB.Callback.MIPNODE_STATUS) == GRB.Status.OPTIMAL) {
        double[] x = GetNodeRel(vars);
        SetSolution(vars, x);
    }
} else if (where == GRB.Callback.BARRIER) {
    // Barrier callback
    int itcnt = GetIntInfo(GRB.Callback.BARRIER_ITRCNT);
    double primobj = GetDoubleInfo(GRB.Callback.BARRIER_PRIMOBJ);
    double dualobj = GetDoubleInfo(GRB.Callback.BARRIER_DUALOBJ);
    double priminf = GetDoubleInfo(GRB.Callback.BARRIER_PRIMINF);
    double dualinf = GetDoubleInfo(GRB.Callback.BARRIER_DUALINF);
    double cmpl = GetDoubleInfo(GRB.Callback.BARRIER_COMPL);
    Console.WriteLine(itcnt + " " + primobj + " " + dualobj + " "
        + priminf + " " + dualinf + " " + cmpl);
} else if (where == GRB.Callback.MESSAGE) {
    // Message callback
    string msg = GetStringInfo(GRB.Callback.MSG_STRING);
    if (msg != null) logfile.Write(msg);
}
}
catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode);
    Console.WriteLine(e.Message);
    Console.WriteLine(e.StackTrace);
} catch (Exception e) {
    Console.WriteLine("Error during callback");
    Console.WriteLine(e.StackTrace);
static void Main(string[] args)
{
    if (args.Length < 1) {
        Console.Out.WriteLine("Usage: callback_cs filename");
        return;
    }

    StreamWriter logfile = null;

    try {
        // Create environment
        GRBEnv env = new GRBEnv();

        // Read model from file
        GRBModel model = new GRBModel(env, args[0]);

        // Turn off display and heuristics
        model.Parameters.OutputFlag = 0;
        model.Parameters.Heuristics = 0.0;

        // Open log file
        logfile = new StreamWriter("cb.log");

        // Create a callback object and associate it with the model
        GRBVar[] vars = model.GetVars();
        callback_cs cb = new callback_cs(vars, logfile);
        model.SetCallback(cb);

        // Solve model and capture solution information
        model.Optimize();

        Console.WriteLine(""elson");
        Console.WriteLine("Optimization complete");
        if (model.SolCount == 0) {
            Console.WriteLine("No solution found, optimization status = " + model.Status);
        } else {
            Console.WriteLine("Solution found, objective = " + model.ObjVal);
            string[] vnames = model.Get(GRB.StringAttr.VarName, vars);
            double[] x = model.Get(GRB.DoubleAttr.X, vars);

            for (int j = 0; j < vars.Length; j++) {
                if (x[j] != 0.0) Console.WriteLine(vnames[j] + " " + x[j]);
            }
        }

        // Dispose of model and environment
        model.Dispose();
        env.Dispose();
    } catch (GRBException e) {
}
```csharp
public static bool dense_optimize(GRBEnv env, int rows, int cols, double[] c, // linear portion of objective function double[,] Q, // quadratic portion of objective function double[,] A, // constraint matrix char[] sense, // constraint senses double[] rhs, // RHS vector double[] lb, // variable lower bounds double[] ub, // variable upper bounds char[] vtype, // variable types (continuous, binary, etc.) double[] solution) {
    bool success = false;
    try {
        GRBModel model = new GRBModel(env);

        // Add variables to the model
```
GRBVar[] vars = model.AddVars(lb, ub, null, vtype, null);

// Populate A matrix
for (int i = 0; i < rows; i++) {
    GRBLinExpr expr = new GRBLinExpr();
    for (int j = 0; j < cols; j++)
        if (A[i,j] != 0)
            expr.AddTerm(A[i,j], vars[j]); // Note: '+=' would be much slower
    model.AddConstr(expr, sense[i], rhs[i], "");
}

// Populate objective
GRBQuadExpr obj = new GRBQuadExpr();
if (Q != null) {
    for (int i = 0; i < cols; i++)
        for (int j = 0; j < cols; j++)
            if (Q[i,j] != 0)
                obj.AddTerm(Q[i,j], vars[i], vars[j]); // Note: '+=' would be much slower
    for (int j = 0; j < cols; j++)
        if (c[j] != 0)
            obj.AddTerm(c[j], vars[j]); // Note: '+=' would be much slower
    model.SetObjective(obj);
}

// Solve model
model.Optimize();

// Extract solution
if (model.Status == GRB.Status.OPTIMAL) {
    success = true;
    for (int j = 0; j < cols; j++)
        solution[j] = vars[j].X;
}

model.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}

return success;

public static void Main(String[] args) {
    try {
        GRBEnv env = new GRBEnv();

        double[] c = new double[] {1, 1, 0};
        double[,] Q = new double[,] {{1, 1, 0}, {0, 1, 1}, {0, 0, 1}};
        double[,] A = new double[,] {{1, 2, 3}, {1, 1, 0}};
        char[] sense = new char[] {'>', '>'};
double[] rhs = new double[] {4, 1};
double[] lb = new double[] {0, 0, 0};
bool success;
double[] sol = new double[3];

success = dense_optimize(env, 2, 3, c, Q, A, sense, rhs,
                          lb, null, null, sol);

if (success) {
}

// Dispose of environment
env.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}

}

diet_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* Solve the classic diet model, showing how to add constraints
to an existing model. */

using System;
using Gurobi;

class diet_cs {
    static void Main() {
        try {

            // Nutrition guidelines, based on
            // USDA Dietary Guidelines for Americans, 2005
            string[] Categories =
                new string[] { "calories", "protein", "fat", "sodium" };
            int nCategories = Categories.Length;
            double[] minNutrition = new double[] { 1800, 91, 0, 0 };
            double[] maxNutrition = new double[] { 2200, GRB.INFINITY, 65, 1779 };

            // Set of foods
            string[] Foods =
                new string[] { "hamburger", "chicken", "hot dog", "fries",
                              "macaroni", "pizza", "salad", "milk", "ice cream" };
            int nFoods = Foods.Length;
            double[] cost =
                new double[] { 2.49, 2.89, 1.50, 1.89, 2.09, 1.99, 2.49, 0.89,
                              1.59 };

            // Nutrition values for the foods
double[,] nutritionValues = new double[,] {  
{ 410, 24, 26, 730 }, // hamburger  
{ 420, 32, 10, 1190 }, // chicken  
{ 560, 20, 32, 1800 }, // hot dog  
{ 380, 4, 19, 270 }, // fries  
{ 320, 12, 10, 930 }, // macaroni  
{ 320, 15, 12, 820 }, // pizza  
{ 320, 31, 12, 1230 }, // salad  
{ 100, 8, 2.5, 125 }, // milk  
{ 330, 8, 10, 180 } // ice cream  
};

// Model
GRBEnv env = new GRBEnv();
GRBModel model = new GRBModel(env);

model.ModelName = "diet";

// Create decision variables for the nutrition information,  
// which we limit via bounds
GRBVar[] nutrition = new GRBVar[nCategories];
for (int i = 0; i < nCategories; ++i) {
    nutrition[i] = model.AddVar(minNutrition[i], maxNutrition[i], 0, GRB.CONTINUOUS, Categories[i]);
}

// Create decision variables for the foods to buy
GRBVar[] buy = new GRBVar[nFoods];
for (int j = 0; j < nFoods; ++j) {
    buy[j] = model.AddVar(0, GRB.INFINITY, cost[j], GRB.CONTINUOUS, Foods[j]);
}

// The objective is to minimize the costs
model.ModelSense = GRB.MINIMIZE;

// Nutrition constraints
for (int i = 0; i < nCategories; ++i) {
    GRBLinExpr ntot = 0.0;
    for (int j = 0; j < nFoods; ++j)
        ntot.AddTerm(nutritionValues[j,i], buy[j]);
    model.AddConstr(ntot == nutrition[i], Categories[i]);
}

// Solve
model.Optimize();
PrintSolution(model, buy, nutrition);

Console.WriteLine("\nAdding constraint: at most 6 servings of dairy");

// Solve
model.Optimize();
PrintSolution(model, buy, nutrition);
// Dispose of model and env
model.Dispose();
env.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}

private static void PrintSolution(GRBModel model, GRBVar[] buy,
                                  GRBVar[] nutrition) {
    if (model.Status == GRB.Status.OPTIMAL) {
        Console.WriteLine("\nCost: " + model.ObjVal);
        Console.WriteLine("\nBuy:");
        for (int j = 0; j < buy.Length; ++j) {
            if (buy[j].X > 0.0001) {
                Console.WriteLine(buy[j].VarName + " " + buy[j].X);
            }
        }
        Console.WriteLine("\nNutrition:");
        for (int i = 0; i < nutrition.Length; ++i) {
            Console.WriteLine(nutrition[i].VarName + " " + nutrition[i].X);
        }
    } else {
        Console.WriteLine("No solution");
    }
}

facility_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* Facility location: a company currently ships its product from 5 plants to 4 warehouses. It is considering closing some plants to reduce costs. What plant(s) should the company close, in order to minimize transportation and fixed costs?

   Based on an example from Frontline Systems:
   http://www.solver.com/disfacility.htm
   Used with permission.
*/

using System;
using Gurobi;

class facility_cs
{
    static void Main()
    {
        try {

            // Warehouse demand in thousands of units
            double[] Demand = new double[] { 15, 18, 14, 20 };

            // Plant production capacity in thousands of units
            double[] Supply = new double[] { 20, 25, 10, 15, 20 };

            // Cost of transportation per unit
            double[,] Cost = new double[,] { { 3, 4, 6, 2, 5 }, { 2, 3, 4, 1, 2 }, { 4, 5, 2, 3, 1 }, { 3, 2, 4, 5, 6 }, { 5, 6, 2, 1, 4 } };
// Plant capacity in thousands of units
double[] Capacity = new double[] { 20, 22, 17, 19, 18 };

// Fixed costs for each plant
double[] FixedCosts =
    new double[] { 12000, 15000, 17000, 13000, 16000 };

// Transportation costs per thousand units
double[,] TransCosts =
    new double[,] { { 4000, 2000, 3000, 2500, 4500 },
                    { 2500, 2600, 3400, 3000, 4000 },
                    { 1200, 1800, 2600, 4100, 3000 },
                    { 2200, 2600, 3100, 3700, 3200 } };

// Number of plants and warehouses
int nPlants = Capacity.Length;
int nWarehouses = Demand.Length;

// Model
GRBEnv env = new GRBEnv();
GRBModel model = new GRBModel(env);
model.ModelName = "facility";

// Plant open decision variables: open[p] == 1 if plant p is open.
GRBVar[] open = new GRBVar[nPlants];
for (int p = 0; p < nPlants; ++p) {
    open[p] = model.AddVar(0, 1, FixedCosts[p], GRB.BINARY, "Open" + p);
}

// Transportation decision variables: how much to transport from
// a plant p to a warehouse w
GRBVar[,] transport = new GRBVar[nWarehouses, nPlants];
for (int w = 0; w < nWarehouses; ++w) {
    for (int p = 0; p < nPlants; ++p) {
        transport[w,p] =
            model.AddVar(0, GRB.INFINITY, TransCosts[w,p], GRB.CONTINUOUS,
                          "Trans" + p + "." + w);
    }
}

// The objective is to minimize the total fixed and variable costs
model.ModelSense = GRB.MINIMIZE;

// Production constraints
// Note that the right-hand limit sets the production to zero if
// the plant is closed
for (int p = 0; p < nPlants; ++p) {
    GRBLinExpr ptot = 0.0;
    for (int w = 0; w < nWarehouses; ++w)
        ptot.AddTerm(1.0, transport[w,p]);
    model.AddConstr(ptot <= Capacity[p] * open[p], "Capacity" + p);
}

// Demand constraints
for (int w = 0; w < nWarehouses; ++w) {

GRBLinExpr dtot = 0.0;
for (int p = 0; p < nPlants; ++p)
    dtot.AddTerm(1.0, transport[w][p]);
model.AddConstr(dtot == Demand[w], "Demand" + w);
}

// Guess at the starting point: close the plant with the highest
// fixed costs; open all others

// First, open all plants
for (int p = 0; p < nPlants; ++p) {
    open[p].Start = 1.0;
}

// Now close the plant with the highest fixed cost
Console.WriteLine("Initial guess:");
double maxFixed = -GRB.INFINITY;
for (int p = 0; p < nPlants; ++p) {
    if (FixedCosts[p] > maxFixed) {
        maxFixed = FixedCosts[p];
    }
}
for (int p = 0; p < nPlants; ++p) {
    if (FixedCosts[p] == maxFixed) {
        open[p].Start = 0.0;
        Console.WriteLine("Closing plant " + p + "\n");
        break;
    }
}

// Use barrier to solve root relaxation
model.Parameters.Method = GRB.METHOD_BARRIER;

// Solve
model.Optimize();

// Print solution
Console.WriteLine("\nTOTAL COSTS: " + model.ObjVal);
Console.WriteLine("SOLUTION:");
for (int p = 0; p < nPlants; ++p) {
    if (open[p].X > 0.99) {
        Console.WriteLine("Plant " + p + " open:");
        for (int w = 0; w < nWarehouses; ++w) {
            if (transport[w][p].X > 0.0001) {
                Console.WriteLine(" Transport " +
                transport[w][p].X + " units to warehouse " + w);
            }
        }
    } else {
        Console.WriteLine("Plant " + p + " closed!");
    }
}

// Dispose of model and env
model.Dispose();
env.Dispose();
```csharp
} catch (GRBException e) {
   Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}
}

feasopt_cs.cs

/*================================================================*/
/* Copyright 2018, Gurobi Optimization, LLC */
/*================================================================*/

/* This example reads a MIP model from a file, adds artificial
 variables to each constraint, and then minimizes the sum of the
 artificial variables. A solution with objective zero corresponds
 to a feasible solution to the input model.
 We can also use FeasRelax feature to do it. In this example, we
 use minrelax=1, i.e. optimizing the returned model finds a solution
 that minimizes the original objective, but only from among those
 solutions that minimize the sum of the artificial variables. */

using Gurobi;
using System;

class feasopt_cs{
   static void Main(string[] args){
      if (args.Length < 1) {
         Console.Out.WriteLine("Usage: feasopt_cs filename");
         return;
      }

      try {
         GRBEnv env = new GRBEnv();
         GRBModel feasmodel = new GRBModel(env, args[0]);

         // Create a copy to use FeasRelax feature later */
         GRBModel feasmodel1 = new GRBModel(feasmodel);

         // Clear objective
         feasmodel.SetObjective(new GRBLinExpr());

         // Add slack variables
         GRBConstr[] c = feasmodel.GetConstrs();
         for (int i = 0; i < c.Length; ++i) {
            char sense = c[i].Sense;
            if (sense != '>') {
               GRBConstr[] constrs = new GRBConstr[] { c[i] };
               double[] coeffs = new double[] { -1 };
               feasmodel.AddVar(0.0, GRB.INFINITY, 1.0, GRB.CONTINUOUS, constrs,
                  coeffs, "ArtN_" + c[i].ConstrName);
            }
            if (sense != '<') {
               GRBConstr[] constrs = new GRBConstr[] { c[i] };
               double[] coeffs = new double[] { 1 };
               feasmodel.AddVar(0.0, GRB.INFINITY, 1.0, GRB.CONTINUOUS, constrs,
```
coeffs, "ArtP_" + c[i].ConstrName);
}

// Optimize modified model
feasmodel.Optimize();
feasmodel.Write("feasopt.lp");

// Use FeasRelax feature */
feasmodel1.FeasRelax(GRB.FEASRELAX_LINEAR, true, false, true);
feasmodel1.Write("feasopt1.lp");
feasmodel1.Optimize();

// Dispose of model and env
feasmodel1.Dispose();
feasmodel.Dispose();
env.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}

}

fixanddive_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* Implement a simple MIP heuristic. Relax the model,
sort variables based on fractionality, and fix the 25% of
the fractional variables that are closest to integer variables.
Repeat until either the relaxation is integer feasible or
linearly infeasible. */

using System;
using System.Collections.Generic;
using Gurobi;

class fixanddive_cs
{
    // Comparison class used to sort variable list based on relaxation
    // fractionality

class FractionalCompare : IComparer<GRBVar>
{
    public int Compare(GRBVar v1, GRBVar v2)
    {
        try {
            double sol1 = Math.Abs(v1.X);
            double sol2 = Math.Abs(v2.X);
            double frac1 = Math.Abs(sol1 - Math.Floor(sol1 + 0.5));
            double frac2 = Math.Abs(sol2 - Math.Floor(sol2 + 0.5));
            if (frac1 < frac2) {
                return -1;
            } else if (frac1 > frac2) {
                return 1;
            }
        } catch (GRBException e) {
            Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
        }
    }
}
return 1;
} else {
    return 0;
}
}

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}

return 0;
}

static void Main(string[] args)
{
    if (args.Length < 1) {
        Console.Out.WriteLine("Usage: fixanddive_cs filename");
        return;
    }

    try {
        // Read model
        GRBEnv env = new GRBEnv();
        GRBModel model = new GRBModel(env, args[0]);

        // Collect integer variables and relax them
        List<GRBVar> intvars = new List<GRBVar>();
        foreach (GRBVar v in model.GetVars()) {
            if (v.VType != GRB.CONTINUOUS) {
                intvars.Add(v);
                v.VType = GRB.CONTINUOUS;
            }
        }

        model.Parameters.OutputFlag = 0;
        model.Optimize();

        // Perform multiple iterations. In each iteration, identify the first
        // quartile of integer variables that are closest to an integer value
        // in the relaxation, fix them to the nearest integer, and repeat.
        for (int iter = 0; iter < 1000; ++iter) {

            // create a list of fractional variables, sorted in order of
            // increasing distance from the relaxation solution to the nearest
            // integer value
            List<GRBVar> fractional = new List<GRBVar>();
            foreach (GRBVar v in intvars) {
                double sol = Math.Abs(v.X);
                if (Math.Abs(sol - Math.Floor(sol + 0.5)) > 1e-5) {
                    fractional.Add(v);
                }
            }

            Console.WriteLine("Iteration " + iter + ", obj " +
                model.ObjVal + ", fractional " + fractional.Count);
if (fractional.Count == 0) {
    Console.WriteLine("Found feasible solution - objective " +
    model.ObjVal);
    break;
}

// Fix the first quartile to the nearest integer value
fractional.Sort(new FractionalCompare());
int nfix = Math.Max(fractional.Count / 4, 1);
for (int i = 0; i < nfix; ++i) {
    GRBVar v = fractional[i];
    double fixval = Math.Floor(v.X + 0.5);
    v.LB = fixval;
    v.UB = fixval;
    Console.WriteLine("Fix " + v.VarName +
    " to " + fixval + " (rel " + v.X + " )");
}

model.Optimize();

// Check optimization result
if (model.Status != GRB.Status.OPTIMAL) {
    Console.WriteLine("Relaxation is infeasible");
    break;
}

// Dispose of model and env
model.Dispose();
env.Dispose();
}
catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " +
    e.Message);
}
}

genconstr_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* In this example we show the use of general constraints for modeling
some common expressions. We use as an example a SAT-problem where we
want to see if it is possible to satisfy at least four (or all) clauses of the logical for

L = (x0 or ¬x1 or x2) and (x1 or ¬x2 or x3) and
(x2 or ¬x3 or x0) and (x3 or ¬x0 or x1) and
(¬x0 or ¬x1 or x2) and (¬x1 or ¬x2 or x3) and
(¬x2 or ¬x3 or x0) and (¬x3 or ¬x0 or x1)

We do this by introducing two variables for each literal (itself and its
negated value), a variable for each clause, and then two
variables for indicating if we can satisfy four, and another to identify
the minimum of the clauses (so if it one, we can satisfy all clauses)
and put these two variables in the objective.
i.e. the Objective function will be

maximize Obj0 + Obj1

Obj0 = MIN(Clause1, ..., Clause8)
Obj1 = 1 -> Clause1 + ... + Clause8 >= 4

thus, the objective value will be two if and only if we can satisfy all
clauses; one if and only if at least four clauses can be satisfied, and
zero otherwise.

using System;
using Gurobi;

class genconstr_cs {

    public const int n = 4;
    public const int NLITERALS = 4; // same as n
    public const int NCLAUSES = 8;
    public const int NOBJ = 2;

    static void Main() {
        try {
            // Example data:
            // e.g. {0, n+1, 2} means clause (x0 or -x1 or x2)
            int[,] Clauses = new int[,] {
                { 0, n+1, 2}, { 1, n+2, 3},
                { 2, n+3, 0}, { 3, n+0, 1},
                {n+0, n+1, 2}, {n+1, n+2, 3},
                {n+2, n+3, 0}, {n+3, n+0, 1}};

            int i, status;

            // Create environment
            GRBEnv env = new GRBEnv("genconstr_cs.log");

            // Create initial model
            GRBModel model = new GRBModel(env);
            model.ModelName = "genconstr_cs";

            // Initialize decision variables and objective
            GRBVar[] Lit  = new GRBVar[NLITERALS];
            GRBVar[] NotLit = new GRBVar[NLITERALS];
            for (i = 0; i < NLITERALS; i++) {
                Lit[i] = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, string.Format("X{0}", i));
                NotLit[i] = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, string.Format("notX{0}", i));
            }

            GRBVar[] Cla = new GRBVar[NCLAUSES];
        }
    }
}
for (i = 0; i < NCLAUSES; i++) {
    Cla[i] = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, string.Format("Clause{0}", i));
}

GRBVar[] Obj = new GRBVar[NOBJ];
for (i = 0; i < NOBJ; i++) {
    Obj[i] = model.AddVar(0.0, 1.0, 1.0, GRB.BINARY, string.Format("Obj{0}", i));
}

// Link Xi and notXi
GRBLinExpr lhs;
for (i = 0; i < NLITERALS; i++) {
    lhs = new GRBLinExpr();
    lhs.AddTerm(1.0, Lit[i]);
    lhs.AddTerm(1.0, NotLit[i]);
    model.AddConstr(lhs, GRB.EQUAL, 1.0, string.Format("CNSTR_X{0}", i));
}

// Link clauses and literals
for (i = 0; i < NCLAUSES; i++) {
    GRBVar[] clause = new GRBVar[3];
    for (int j = 0; j < 3; j++) {
        if (Clauses[i,j] >= n) clause[j] = NotLit[Clauses[i,j]-n];
        else clause[j] = Lit[Clauses[i,j]];}
    model.AddGenConstrOr(Cla[i], clause, string.Format("CNSTR_Clause{0}", i));
}

// Link objs with clauses
model.AddGenConstrMin(Obj[0], Cla, GRB.INFINITY, "CNSTR_Obj0");
for (i = 0; i < NCLAUSES; i++) {
    lhs = new GRBLinExpr();
    lhs.AddTerm(1.0, Cla[i]);
model.AddGenConstrIndicator(Obj[1], 1, lhs, GRB.GREATER_EQUAL, 4.0, "CNSTR_Obj1");
}

// Set global objective sense
model.ModelSense = GRB.MAXIMIZE;

// Save problem
model.Write("genconstr_cs.mps");
model.Write("genconstr_cs.lp");

// Optimize
model.Optimize();

// Status checking
status = model.Status;
if (status == GRB.Status.INF_OR_UNBD ||
    status == GRB.Status.INFEASIBLE ||
    status == GRB.Status.UNBOUNDED ) {
    Console.WriteLine("The model cannot be solved "+
    "because it is infeasible or unbounded");
    return;
}
if (status != GRB.Status.OPTIMAL) {
    Console.WriteLine("Optimization was stopped with status {0}", status);
    return;
}

// Print result
double objval = model.ObjVal;

if (objval > 1.9)
    Console.WriteLine("Logical expression is satisfiable");
else if (objval > 0.9)
    Console.WriteLine("At least four clauses can be satisfied");
else
    Console.WriteLine("Not even three clauses can be satisfied");

// Dispose of model and environment
model.Dispose();
env.Dispose();
}
}

lp_cs.cs

using System;
using Gurobi;

class lp_cs
{
    static void Main(string[] args)
    {
        if (args.Length < 1) {
            Console.Out.WriteLine("Usage: lp_cs filename");
            return;
        }

        try {
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env, args[0]);
            model.Optimize();
            int optimstatus = model.Status;
            if (optimstatus == GRB.Status.INF_OR_UNBD) {

model.Parameters.Presolve = 0;
model.Optimize();
optimstatus = model.Status;

} if (optimstatus == GRB.Status.OPTIMAL) {
    double objval = model.ObjVal;
    Console.WriteLine("Optimal objective: " + objval);
} else if (optimstatus == GRB.Status.INFEASIBLE) {
    Console.WriteLine("Model is infeasible");
    // compute and write out IIS
    model.ComputeIIS();
    model.Write("model.ilp");
} else if (optimstatus == GRB.Status.UNBOUNDED) {
    Console.WriteLine("Model is unbounded");
} else {
    Console.WriteLine("Optimization was stopped with status = "
        + optimstatus);
}

// Dispose of model and env
model.Dispose();
env.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}

}

lpmethod_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* Solve a model with different values of the Method parameter;
  show which value gives the shortest solve time. */

using System;
using Gurobi;

class lpmethod_cs
{
    static void Main(string[] args)
    {
        if (args.Length < 1) {
            Console.Out.WriteLine("Usage: lpmethod_cs filename");
            return;
        }

        try {
            // Read model
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env, args[0]);

            model.Parameters.Presolve = 0;
            model.Optimize();
            optimstatus = model.Status;

            } if (optimstatus == GRB.Status.OPTIMAL) {
                double objval = model.ObjVal;
                Console.WriteLine("Optimal objective: " + objval);
            } else if (optimstatus == GRB.Status.INFEASIBLE) {
                Console.WriteLine("Model is infeasible");
                // compute and write out IIS
                model.ComputeIIS();
                model.Write("model.ilp");
            } else if (optimstatus == GRB.Status.UNBOUNDED) {
                Console.WriteLine("Model is unbounded");
            } else {
                Console.WriteLine("Optimization was stopped with status = "
                    + optimstatus);
            }

            // Dispose of model and env
            model.Dispose();
            env.Dispose();

        } catch (GRBException e) {
            Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
        }
    }
}
// Solve the model with different values of Method
int bestMethod = -1;
double bestTime = model.Parameters.TimeLimit;
for (int i = 0; i <= 2; ++i)
{
    model.Reset();
    model.Parameters.Method = i;
    model.Optimize();
    if (model.Status == GRB.Status.OPTIMAL)
    {
        bestTime = model.Runtime;
        bestMethod = i;
        // Reduce the TimeLimit parameter to save time
        // with other methods
        model.Parameters.TimeLimit = bestTime;
    }
}

// Report which method was fastest
if (bestMethod == -1) {
    Console.WriteLine("Unable to solve this model");
} else {
    Console.WriteLine("Solved in " + bestTime
    + " seconds with Method: " + bestMethod);
}

// Dispose of model and env
model.Dispose();
env.Dispose();
}

catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}
}

lpmod_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */
/* This example reads an LP model from a file and solves it.
If the model can be solved, then it finds the smallest positive variable,
sets its upper bound to zero, and resolves the model two ways:
first with an advanced start, then without an advanced start
(i.e. 'from scratch'). */
using System;
using Gurobi;

class lpmod_cs
{
    static void Main(string[] args)
    {
        if (args.Length < 1) {
            Console.Out.WriteLine("Usage: lpmod_cs filename");
            return;
        }
try {
    // Read model and determine whether it is an LP
    GRBEnv env = new GRBEnv();
    GRBModel model = new GRBModel(env, args[0]);
    if (model.IsMIP != 0) {
        Console.WriteLine("The model is not a linear program");
        Environment.Exit(1);
    }

    model.Optimize();

    int status = model.Status;

    if ((status == GRB.Status.INF_OR_UNBD) ||
        (status == GRB.Status.INFEASIBLE) ||
        (status == GRB.Status.UNBOUNDED)) {
        Console.WriteLine("The model cannot be solved because it is "+"infeasible or unbounded");
        Environment.Exit(1);
    }

    if (status != GRB.Status.OPTIMAL) {
        Console.WriteLine("Optimization was stopped with status "+status);
        Environment.Exit(0);
    }

    // Find the smallest variable value
    double minVal = GRB.INFINITY;
    GRBVar minVar = null;
    foreach (GRBVar v in model.GetVars()) {
        double sol = v.X;
        if ((sol > 0.0001) && (sol < minVal) && (v.LB == 0.0)) {
            minVal = sol;
            minVar = v;
        }
    }

    Console.WriteLine("\n*** Setting " +
    minVar.VarName + " from " + minVal +
    " to zero ***\n");
    minVar.UB = 0.0;

    // Solve from this starting point
    model.Optimize();

    // Save iteration & time info
    double warmCount = model.IterCount;
    double warmTime = model.Runtime;

    // Reset the model and resolve
    Console.WriteLine("\n*** Resetting and solving " +"without an advanced start ***\n");
    model.Reset();
    model.Optimize();
}
double coldCount = model.IterCount;
double coldTime = model.Runtime;

Console.WriteLine("\n** Warm start: " + warmCount + " iterations, " +
warmTime + " seconds");
Console.WriteLine("** Cold start: " + coldCount + " iterations, " +
coldTime + " seconds");

// Dispose of model and env
model.Dispose();
env.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " +
e.Message);
}
}

mip1_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example formulates and solves the following simple MIP model:

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

*/

using System;
using Gurobi;

class mip1_cs
{
    static void Main()
    {
        try {
            GRBEnv env = new GRBEnv("mip1.log");
            GRBModel model = new GRBModel(env);

            // Create variables
            GRBVar x = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, "x");
            GRBVar y = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, "y");
            GRBVar z = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, "z");

            // Set objective: maximize x + y + 2 z
            model.SetObjective(x + y + 2 * z, GRB.MAXIMIZE);

            // Add constraint: x + 2 y + 3 z <= 4
            model.AddConstr(x + 2 * y + 3 * z <= 4.0, "c0");
        }
    }
}
/ Add constraint: x + y >= 1
model.AddConstr(x + y >= 1.0, "c1");

// Optimize model
model.Optimize();

Console.WriteLine(x.VarName + " " + x.X);
Console.WriteLine(y.VarName + " " + y.X);
Console.WriteLine(z.VarName + " " + z.X);

Console.WriteLine("Obj: " + model.ObjVal);

// Dispose of model and env
model.Dispose();
env.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}

mip2_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example reads a MIP model from a file, solves it and
 prints the objective values from all feasible solutions
 generated while solving the MIP. Then it creates the fixed
 model and solves that model. */

using System;
using Gurobi;

class mip2_cs {
    static void Main(string[] args) {
        if (args.Length < 1) {
            Console.Out.WriteLine("Usage: mip2_cs filename");
            return;
        }

        try {
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env, args[0]);
            if (model.IsMIP == 0) {
                Console.WriteLine("Model is not a MIP");
                return;
            }

            model.Optimize();
        }

        catch (GRBException e) {
            Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
        }
    }
}
```csharp
int optimstatus = model.Status;
double objval = 0;
if (optimstatus == GRB.Status.OPTIMAL) {
    objval = model.ObjVal;
    Console.WriteLine("Optimal objective: " + objval);
} else if (optimstatus == GRB.Status.INF_OR_UNBD) {
    Console.WriteLine("Model is infeasible or unbounded");
    return;
} else if (optimstatus == GRB.Status.INFEASIBLE) {
    Console.WriteLine("Model is infeasible");
    return;
} else if (optimstatus == GRB.Status.UNBOUNDED) {
    Console.WriteLine("Model is unbounded");
    return;
} else {
    Console.WriteLine("Optimization was stopped with status = " + optimstatus);
    return;
}

/* Iterate over the solutions and compute the objectives */

GRBVar[] vars = model.GetVars();
model.Parameters.OutputFlag = 0;

Console.WriteLine();
for (int k = 0; k < model.SolCount; ++k) {
    model.Parameters.SolutionNumber = k;
    double objn = 0.0;
    for (int j = 0; j < vars.Length; j++) {
        objn += vars[j].Obj * vars[j].Xn;
    }
    Console.WriteLine("Solution " + k + " has objective: " + objn);
}
Console.WriteLine();
model.Parameters.OutputFlag = 1;

/* Create a fixed model, turn off presolve and solve */

GRBModel fixedmodel = model.FixedModel();
fixedmodel.Parameters.Presolve = 0;
fixedmodel.Optimize();

int foptimstatus = fixedmodel.Status;

if (foptimstatus != GRB.Status.OPTIMAL) {
    Console.WriteLine("Error: fixed model isn’t optimal");
    return;
}

double fobjval = fixedmodel.ObjVal;
```
if (Math.Abs(fobjval - objval) > 1.0e-6 * (1.0 + Math.Abs(objval))) { 
    Console.WriteLine("Error: objective values are different");
    return;
}

GRBVar[] fvars = fixedmodel.GetVars();
double[] x = fixedmodel.Get(GRB.DoubleAttr.X, fvars);
string[] vnames = fixedmodel.Get(GRB.StringAttr.VarName, fvars);

for (int j = 0; j < fvars.Length; j++) {
    if (x[j] != 0.0) Console.WriteLine(vnames[j] + " " + x[j]);
}

// Dispose of models and env
fixedmodel.Dispose();
model.Dispose();
env.Dispose();
}

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}

multiobj_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* Want to cover three different sets but subject to a common budget of 
elements allowed to be used. However, the sets have different priorities to 
be covered; and we tackle this by using multi-objective optimization. */

using System;
using Gurobi;

class multiobj_cs {
    static void Main() {
        try {
            // Sample data
            int groundSetSize = 20;
            int nSubsets = 4;
            int Budget = 12;
            double[,] Set = new double[,] {
                { 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 },
                { 0, 0, 0, 0, 0, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1 },
                { 0, 0, 0, 1, 1, 0, 1, 1, 0, 0, 0, 0, 0, 1, 1, 0, 1, 1, 0, 0 },
                { 0, 0, 0, 0, 0, 1, 1, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0 }};
            int[] SetObjPriority = new int[] {3, 2, 2, 1};
            double[] SetObjWeight = new double[] {1.0, 0.25, 1.25, 1.0};
            int e, i, status, nSolutions;

            // Create environment
            GRBEnv env = new GRBEnv("multiobj_cs.log");

            // Create a MIP model
            GRBModel model = new GRBModel(env);

            // Add variables
            for (i = 0; i < nSubsets; i++) {
                for (e = 0; e < groundSetSize; e++)
                    model.AddVar(Set[i, e], 0.0, 1.0, 1.0, "X" + (i + 1) + e);

            }

            // Set objective
            model.Set(GRB.DoubleAttr.ObjN, SetObjWeight);
            model.Set(GRB.IntAttr.ObjNPriority, SetObjPriority);

            // Set network constraints
            for (i = 0; i < nSubsets; i++)
                for (j = 0; j < nSubsets; j++)
                    if (i != j) {
                        model.AddConstr(Set[i, e] - Set[j, e] + 1 <= 0,
                            "NetConstr" + i + j);
                    }

            // Set budget constraints
            for (i = 0; i < nSubsets; i++)
                model.AddConstr(GRB.Sum(Set[i, e] for (e = 0; e < groundSetSize; e)) <= Budget,
                    "BudgetConstr" + i);

            // Optimize
            model.Optimize();

            // Print results
            Console.WriteLine("Objective: " + model.ObjVal);
            for (i = 0; i < nSubsets; i++)
                Console.WriteLine("Set " + (i + 1) + ": " + model.Get(GRB.IntAttr.X, i));

        } catch (GRBException e) {
            Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
        }
    }
}

268
// Create initial model
GRBModel model = new GRBModel(env);
model.ModelName = "multiobj_cs";

// Initialize decision variables for ground set:
// x[e] == 1 if element e is chosen for the covering.
GRBVar[] Elem = model.AddVars(groundSetSize, GRB.BINARY);
for (e = 0; e < groundSetSize; e++) {
    string vname = string.Format("El{0}", e);
    Elem[e].VarName = vname;
}

// Constraint: limit total number of elements to be picked to be at most
// Budget
GRBLinExpr lhs = new GRBLinExpr();
for (e = 0; e < groundSetSize; e++) {
    lhs.AddTerm(1.0, Elem[e]);
}
model.AddConstr(lhs, GRB.LESS_EQUAL, Budget, "Budget");

// Set global sense for ALL objectives
model.ModelSense = GRB.MAXIMIZE;

// Limit how many solutions to collect
model.Parameters.PoolSolutions = 100;

// Set and configure i-th objective
for (i = 0; i < nSubsets; i++) {
    string vname = string.Format("Set{0}", i);
    GRBLinExpr objn = new GRBLinExpr();
    for (e = 0; e < groundSetSize; e++) {
        objn.AddTerm(Set[i,e], Elem[e]);
    }
    model.SetObjectiveN(objn, i, SetObjPriority[i], SetObjWeight[i],
                        1.0 + i, 0.01, vname);
}

// Save problem
model.Write("multiobj_cs.lp");

// Optimize
model.Optimize();

// Status checking
status = model.Status;

if (status == GRB.Status.INF_OR_UNBD ||
    status == GRB.Status.INFEASIBLE ||
    status == GRB.Status.UNBOUNDED)
    { Console.WriteLine("The model cannot be solved "+
                      "because it is infeasible or unbounded");
        return;
    }
if (status != GRB.Status.OPTIMAL)
    { Console.WriteLine("Optimization was stopped with status {0}", status);
        return;
    }
return;
}

// Print best selected set
Console.WriteLine("Selected elements in best solution:");
Console.Write("\t");
for (e = 0; e < groundSetSize; e++) {
    if (Elem[e].X < .9) continue;
    Console.Write("El{0} ", e);
}
Console.WriteLine();

// Print number of solutions stored
nSolutions = model.SolCount;
Console.WriteLine("Number of solutions found: {0}", nSolutions);

// Print objective values of solutions
if (nSolutions > 10) nSolutions = 10;
Console.WriteLine("Objective values for first {0} solutions:", nSolutions);
for (i = 0; i < nSubsets; i++) {
    model.Parameters.ObjNumber = i;
    Console.WriteLine("\\tSet " + i);
    for (e = 0; e < nSolutions; e++) {
        model.Parameters.SolutionNumber = e;
        Console.Write("{0,8} ", model.ObjNVal);
    }
    Console.WriteLine();
}
model.Dispose();
env.Dispose();
} catch (GRBException e) {
    Console.WriteLine("Error code = {0}", e);
    Console.WriteLine(e.Message);
}

params_cs.cs

/******************************************************************************
* Copyright 2018, Gurobi Optimization, LLC                                     *
*******************************************************************************/

using System;
using Gurobi;

class params_cs
{
    static void Main(string[] args)
    {

if (args.Length < 1) {
    Console.Out.WriteLine("Usage: params_cs filename");
    return;
}

try {
    // Read model and verify that it is a MIP
    GRBEnv env = new GRBEnv();
    GRBModel m = new GRBModel(env, args[0]);
    if (m.IsMIP == 0) {
        Console.WriteLine("The model is not an integer program");
        Environment.Exit(1);
    }

    // Set a 2 second time limit
    m.Parameters.TimeLimit = 2.0;

    // Now solve the model with different values of MIPFocus
    GRBModel bestModel = new GRBModel(m);
    bestModel.Optimize();
    for (int i = 1; i <= 3; ++i) {
        m.Reset();
        m.Parameters.MIPFocus = i;
        m.Optimize();
        if (bestModel.MIPGap > m.MIPGap) {
            GRBModel swap = bestModel;
            bestModel = m;
            m = swap;
        }
    }

    // Finally, delete the extra model, reset the time limit and
    // continue to solve the best model to optimality
    m.Dispose();
    bestModel.Parameters.TimeLimit = GRB.INFINITY;
    bestModel.Optimize();
    Console.WriteLine("Solved with MIPFocus: "+
        bestModel.Parameters.MIPFocus);
} catch (GRBException e) {
    Console.WriteLine("Error code: "+e.ErrorCode+", "+
        e.Message);
}
}

piecewise_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example considers the following separable, convex problem:

    minimize   f(x) - y + g(z)
    subject to  x + 2 y + 3 z <= 4
                x +       y >= 1
                x, y, z <= 1

*/
where \( f(u) = \exp(-u) \) and \( g(u) = 2u^2 - 4u \), for all real \( u \). It formulates and solves a simpler LP model by approximating \( f \) and \( g \) with piecewise-linear functions. Then it transforms the model into a MIP by negating the approximation for \( f \), which corresponds to a non-convex piecewise-linear function, and solves it again.

```csharp
using System;
using Gurobi;

class piecewise_cs {
    private static double f(double u) { return Math.Exp(-u); }
    private static double g(double u) { return 2 * u * u - 4 * u; }

    static void Main()
    {
        try {
            // Create environment
            GRBEnv env = new GRBEnv();
            // Create a new model
            GRBModel model = new GRBModel(env);
            // Create variables
            double lb = 0.0, ub = 1.0;
            GRBVar x = model.AddVar(lb, ub, 0.0, GRB.CONTINUOUS, "x");
            GRBVar y = model.AddVar(lb, ub, 0.0, GRB.CONTINUOUS, "y");
            GRBVar z = model.AddVar(lb, ub, 0.0, GRB.CONTINUOUS, "z");
            // Set objective for y
            model.SetObjective(-y);
            // Add piecewise-linear objective functions for x and z
            int npts = 101;
            double[] ptu = new double[npts];
            double[] ptf = new double[npts];
            double[] ptg = new double[npts];
            for (int i = 0; i < npts; i++) {
                ptu[i] = lb + (ub - lb) * i / (npts - 1);
                ptf[i] = f(ptu[i]);
                ptg[i] = g(ptu[i]);
            }
            model.SetPWLObj(x, ptu, ptf);
            model.SetPWLObj(z, ptu, ptg);
        }
    }
}```
// Add constraint: x + 2 y + 3 z <= 4
model.AddConstr(x + 2 * y + 3 * z <= 4.0, "c0");

// Add constraint: x + y >= 1
model.AddConstr(x + y >= 1.0, "c1");

// Optimize model as an LP
model.Optimize();

Console.WriteLine("IsMIP: " + model.IsMIP);

Console.WriteLine(x.VarName + " " + x.X);
Console.WriteLine(y.VarName + " " + y.X);
Console.WriteLine(z.VarName + " " + z.X);

Console.WriteLine("Obj: " + model.ObjVal);

Console.WriteLine();

// Negate piecewise-linear objective function for x
for (int i = 0; i < npts; i++) {
    ptf[i] = -ptf[i];
}

model.SetPWLObj(x, ptu, ptf);

// Optimize model as a MIP
model.Optimize();

Console.WriteLine("IsMIP: " + model.IsMIP);

Console.WriteLine(x.VarName + " " + x.X);
Console.WriteLine(y.VarName + " " + y.X);
Console.WriteLine(z.VarName + " " + z.X);

Console.WriteLine("Obj: " + model.ObjVal);

// Dispose of model and environment
model.Dispose();
env.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}

poolsearch_cs.cs
/* Copyright 2018, Gurobi Optimization, LLC */

/* We find alternative epsilon-optimal solutions to a given knapsack problem by using PoolSearchMode */

using System;
using Gurobi;

class poolsearch_cs {
    static void Main() {
        try{
            // Sample data
            int groundSetSize = 10;
            double[] objCoef = new double[] {32, 32, 15, 15, 6, 6, 1, 1, 1, 1};
            double[] knapsackCoef = new double[] {16, 16, 8, 8, 4, 4, 2, 2, 1, 1};
            double Budget = 33;
            int e, status, nSolutions;

            // Create environment
            GRBEnv env = new GRBEnv("poolsearch_cs.log");

            // Create initial model
            GRBModel model = new GRBModel(env);
            model.ModelName = "poolsearch_cs";

            // Initialize decision variables for ground set:
            // x[e] == 1 if element e is chosen
            GRBVar[] Elem = model.AddVars(groundSetSize, GRB.BINARY);
            model.Set(GRB.DoubleAttr.Obj, Elem, objCoef, 0, groundSetSize);
            for (e = 0; e < groundSetSize; e++) {
                Elem[e].VarName = string.Format("El{0}", e);
            }

            // Constraint: limit total number of elements to be picked to be at most Budget
            GRBLinExpr lhs = new GRBLinExpr();
            for (e = 0; e < groundSetSize; e++) {
                lhs.AddTerm(knapsackCoef[e], Elem[e]);
            }
            model.AddConstr(lhs, GRB.LESS_EQUAL, Budget, "Budget");

            // set global sense for ALL objectives
            model.ModelSense = GRB.MAXIMIZE;

            // Limit how many solutions to collect
            model.Parameters.PoolSolutions = 1024;

            // Limit the search space by setting a gap for the worst possible solution that will be accepted
            model.Parameters.PoolGap = 0.10;

            // do a systematic search for the k-best solutions
            model.Parameters.PoolSearchMode = 2;
        }
    }
}

274
// save problem
model.Write("poolsearch_cs.lp");

// Optimize
model.Optimize();

// Status checking
status = model.Status;

if (status == GRB.Status.INF_OR_UNBD ||
    status == GRB.Status.INFEASIBLE ||
    status == GRB.Status.UNBOUNDED)
{
    Console.WriteLine("The model cannot be solved " +
                       "because it is infeasible or unbounded");
    return;
}
if (status != GRB.Status.OPTIMAL) {
    Console.WriteLine("Optimization was stopped with status {0}", status);
    return;
}

// Print best selected set
Console.WriteLine("Selected elements in best solution:");
for (e = 0; e < groundSetSize; e++) {
    if (Elem[e].X < .9) continue;
    Console.Write("El{0} ", e);
}
Console.WriteLine();

// Print number of solutions stored
nSolutions = model.SolCount;
Console.WriteLine("Number of solutions found: {0}", nSolutions);

// Print objective values of solutions
for (e = 0; e < nSolutions; e++) {
    model.Parameters.SolutionNumber = e;
    Console.Write("{0} ", model.PoolObjVal);
    if (e%15 == 14) Console.WriteLine();
}
Console.WriteLine();

// Print fourth best set if available
if (nSolutions >= 4) {
    model.Parameters.SolutionNumber = 3;
    Console.WriteLine("Selected elements in fourth best solution:");
    for (e = 0; e < groundSetSize; e++) {
        if (Elem[e].Xn < .9) continue;
        Console.Write("El{0} ", e);
    }
    Console.WriteLine();
}
model.Dispose();
```csharp
env.Dispose();
} catch (GRBException e) {
    Console.WriteLine("Error code: {0}. {1}", e.ErrorCode, e.Message);
}
}

qcp_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */
/* This example formulates and solves the following simple QCP model:

maximize x
subject to x + y + z = 1
        x^2 + y^2 <= z^2 (second-order cone)
        x^2 <= yz (rotated second-order cone)
*/
using System;
using Gurobi;

class qcp_cs
{
    static void Main()
    {
        try {
            GRBEnv env = new GRBEnv("qcp.log");
            GRBModel model = new GRBModel(env);

            // Create variables
            GRBVar x = model.AddVar(0.0, GRB.INFINITY, 0.0, GRB.CONTINUOUS, "x");
            GRBVar y = model.AddVar(0.0, GRB.INFINITY, 0.0, GRB.CONTINUOUS, "y");
            GRBVar z = model.AddVar(0.0, GRB.INFINITY, 0.0, GRB.CONTINUOUS, "z");

            // Set objective
            GRBLinExpr obj = x;
            model.SetObjective(obj, GRB.MAXIMIZE);

            // Add linear constraint: x + y + z = 1
            model.AddConstr(x + y + z == 1.0, "c0");

            // Add second-order cone: x^2 + y^2 <= z^2
            model.AddQConstr(x*x + y*y <= z*z, "qc0");

            // Add rotated cone: x^2 <= yz
            model.AddQConstr(x*x <= y*z, "qc1");

            // Optimize model
```
model.Optimize();
Console.WriteLine(x.VarName + " " + x.X);
Console.WriteLine(y.VarName + " " + y.X);
Console.WriteLine(z.VarName + " " + z.X);
Console.WriteLine("Obj: " + model.ObjVal + " " + obj.Value);

// Dispose of model and env
model.Dispose();
env.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}

qp_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* This example formulates and solves the following simple QP model:

minimize x^2 + x*y + y^2 + y*z + z^2 + 2 x
subject to x + 2 y + 3 z >= 4
      x + y >= 1

It solves it once as a continuous model, and once as an integer model. */

using System;
using Gurobi;

class qp_cs
{
    static void Main()
    {
        try {
            GRBEnv env = new GRBEnv("qp.log");
            GRBModel model = new GRBModel(env);

            // Create variables
            GRBVar x = model.AddVar(0.0, 1.0, 0.0, GRB.CONTINUOUS, "x");
            GRBVar y = model.AddVar(0.0, 1.0, 0.0, GRB.CONTINUOUS, "y");
            GRBVar z = model.AddVar(0.0, 1.0, 0.0, GRB.CONTINUOUS, "z");

            // Set objective
            GRBQuadExpr obj = x*x + x*y + y*y + y*z + z*z + 2*x;
            model.SetObjective(obj);

            // Add constraint: x + 2 y + 3 z >= 4

        } catch (GRBException e) {
            Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
        }
    }
}
model.AddConstr(x + 2 * y + 3 * z >= 4.0, "c0");

// Add constraint: x + y >= 1
model.AddConstr(x + y >= 1.0, "c1");

// Optimize model
model.Optimize();

Console.WriteLine(x.VarName + " " + x.X);
Console.WriteLine(y.VarName + " " + y.X);
Console.WriteLine(z.VarName + " " + z.X);

Console.WriteLine("Obj: " + model.ObjVal + " " + obj.Value);

// Change variable types to integer
x.VType = GRB.INTEGER;
y.VType = GRB.INTEGER;
z.VType = GRB.INTEGER;

// Optimize model
model.Optimize();

Console.WriteLine(x.VarName + " " + x.X);
Console.WriteLine(y.VarName + " " + y.X);
Console.WriteLine(z.VarName + " " + z.X);

Console.WriteLine("Obj: " + model.ObjVal + " " + obj.Value);

// Dispose of model and env
model.Dispose();
env.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ", " + e.Message);
}

} }
class sensitivity_cs
{
    static void Main(string[] args)
    {
        if (args.Length < 1) {
            Console.Out.WriteLine("Usage: sensitivity_cs filename");
            return;
        }

        try {

            // Create environment
            GRBEnv env = new GRBEnv();

            // Read and solve model
            GRBModel model = new GRBModel(env, args[0]);

            if (model.IsMIP == 0) {
                Console.WriteLine("Model is not a MIP");
                return;
            }

            model.Optimize();

            if (model.Status != GRB.Status.OPTIMAL) {
                Console.WriteLine("Optimization ended with status " + model.Status);
                return;
            }

            // Store the optimal solution
            double origObjVal = model.ObjVal;
            GRBVar[] vars = model.GetVars();
            double[] origX = model.Get(GRB.DoubleAttr.X, vars);

            // Disable solver output for subsequent solves
            model.Parameters.OutputFlag = 0;

            // Iterate through unfixed, binary variables in model
            for (int i = 0; i < vars.Length; i++) {
                GRBVar v = vars[i];
                char vType = v.VType;

                if (v.LB == 0 && v.UB == 1
                    && (vType == GRB.BINARY || vType == GRB.INTEGER)) {

                    // Set variable to 1-X, where X is its value in optimal solution
                    if (origX[i] < 0.5) {
                        v.LB = 1.0;
                        v.Start = 1.0;
                    }
                }
            }
        }
    }
}
} else {
    v.UB = 0.0;
    v.Start = 0.0;
}

// Update MIP start for the other variables
for (int j = 0; j < vars.Length; j++) {
    if (j != i) {
        vars[j].Start = origX[j];
    }
}

// Solve for new value and capture sensitivity information
model.Optimize();

if (model.Status == GRB.Status.OPTIMAL) {
    Console.WriteLine("Objective sensitivity for variable "
    + v.VarName + " is " + (model.ObjVal - origObjVal));
} else {
    Console.WriteLine("Objective sensitivity for variable "
    + v.VarName + " is infinite");
}

// Restore the original variable bounds
v.LB = 0.0;
v.UB = 1.0;
}

// Dispose of model and environment
model.Dispose();
env.Dispose();
}

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode);
    Console.WriteLine(e.Message);
    Console.WriteLine(e.StackTrace);
}

}

SOS_C5.CS

/*----------------------------------------------------------------
 * Copyright 2018, Gurobi Optimization, LLC */

/*----------------------------------------------------------------
 * This example creates a very simple Special Ordered Set (SOS) model.
 * The model consists of 3 continuous variables, no linear constraints,
 * and a pair of SOS constraints of type 1. */

using System;
using Gurobi;
class sos_cs
{
    static void Main()
    {
        try {
            GRBEnv env = new GRBEnv();

            GRBModel model = new GRBModel(env);

            // Create variables
            double[] ub = {1, 1, 2};
            double[] obj = {-2, -1, -1};
            string[] names = {"x0", "x1", "x2"};

            GRBVar[] x = model.AddVars(null, ub, obj, null, names);

            // Add first SOS1: x0=0 or x1=0
            GRBVar[] sosv1 = {x[0], x[1]};
            double[] soswt1 = {1, 2};
            model.AddSOS(sosv1, soswt1, GRB.SOS_TYPE1);

            // Add second SOS1: x0=0 or x2=0
            GRBVar[] sosv2 = {x[0], x[2]};
            double[] soswt2 = {1, 2};
            model.AddSOS(sosv2, soswt2, GRB.SOS_TYPE1);

            // Optimize model
            model.Optimize();

            for (int i = 0; i < 3; i++)
                Console.WriteLine(x[i].VarName + " " + x[i].X);

            // Dispose of model and env
            model.Dispose();
            env.Dispose();
        } catch (GRBException e) {
            Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
        }
    }
}

sudoku_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/*
Sudoku example.

The Sudoku board is a 9x9 grid, which is further divided into a 3x3 grid */
of 3x3 grids. Each cell in the grid must take a value from 0 to 9. No two grid cells in the same row, column, or 3x3 subgrid may take the same value.

In the MIP formulation, binary variables \( x[i,j,v] \) indicate whether cell \( <i,j> \) takes value \( 'v' \). The constraints are as follows:
1. Each cell must take exactly one value (sum\_v \( x[i,j,v] = 1 \))
2. Each value is used exactly once per row (sum\_i \( x[i,j,v] = 1 \))
3. Each value is used exactly once per column (sum\_j \( x[i,j,v] = 1 \))
4. Each value is used exactly once per 3x3 subgrid (sum\_grid \( x[i,j,v] = 1 \))

Input datasets for this example can be found in examples/data/sudoku*.

```csharp
class sudoku_cs
{
    static void Main(string[] args)
    {
        int n = 9;
        int s = 3;

        if (args.Length < 1) {
            Console.Out.WriteLine("Usage: sudoku_cs filename");
            return;
        }

        try {
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env);

            // Create 3-D array of model variables
            GRBVar[,] vars = new GRBVar[n,n,n];

            for (int i = 0; i < n; i++) {
                for (int j = 0; j < n; j++) {
                    for (int v = 0; v < n; v++) {
                        string st = "G_" + i.ToString() + "_" + j.ToString() + "_" + v.ToString();
                        vars[i,j,v] = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, st);
                    }
                }
            }

            // Add constraints

            GRBLinExpr expr;

            // Each cell must take one value
            for (int i = 0; i < n; i++) {
                for (int j = 0; j < n; j++) {
```
expr = 0.0;
for (int v = 0; v < n; v++)
    expr.AddTerm(1.0, vars[i,j,v]);
string st = "V_" + i.ToString() + "_" + j.ToString();
model.AddConstr(expr == 1.0, st);

// Each value appears once per row
for (int i = 0; i < n; i++) {
    for (int v = 0; v < n; v++) {
        expr = 0.0;
        for (int j = 0; j < n; j++)
            expr.AddTerm(1.0, vars[i,j,v]);
        string st = "R_" + i.ToString() + "_" + v.ToString();
        model.AddConstr(expr == 1.0, st);
    }
}

// Each value appears once per column
for (int j = 0; j < n; j++) {
    for (int v = 0; v < n; v++) {
        expr = 0.0;
        for (int i = 0; i < n; i++)
            expr.AddTerm(1.0, vars[i,j,v]);
        string st = "C_" + j.ToString() + "_" + v.ToString();
        model.AddConstr(expr == 1.0, st);
    }
}

// Each value appears once per sub-grid
for (int v = 0; v < n; v++) {
    for (int i0 = 0; i0 < s; i0++) {
        for (int j0 = 0; j0 < s; j0++) {
            expr = 0.0;
            for (int i1 = 0; i1 < s; i1++)
                for (int j1 = 0; j1 < s; j1++) {
                    expr.AddTerm(1.0, vars[i0*s+i1,j0*s+j1,v]);
                }
            string st = "Sub_" + v.ToString() + "_" + i0.ToString()
                        + "_" + j0.ToString();
            model.AddConstr(expr == 1.0, st);
        }
    }
}

// Fix variables associated with pre-specified cells
StreamReader sr = File.OpenText(args[0]);

for (int i = 0; i < n; i++) {
    string input = sr.ReadLine();
}
for (int j = 0; j < n; j++) {
    int val = (int) input[j] - 48 - 1; // 0-based
    if (val >= 0)
        vars[i, j, val].LB = 1.0;
}

// Optimize model
model.Optimize();

// Write model to file
model.Write("sudoku.lp");

double[,] x = model.Get(GRB.DoubleAttr.X, vars);

Console.WriteLine();
for (int i = 0; i < n; i++) {
    for (int j = 0; j < n; j++) {
        for (int v = 0; v < n; v++) {
            if (x[i, j, v] > 0.5) {
                Console.Write(v + 1);
            }
        }
    }
    Console.WriteLine();
}

// Dispose of model and env
model.Dispose();
env.Dispose();
}

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ", " + e.Message);
}
}

tsp_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

// Solve a traveling salesman problem on a randomly generated set of
// points using lazy constraints. The base MIP model only includes
// 'degree-2' constraints, requiring each node to have exactly
// two incident edges. Solutions to this model may contain subtours -
// tours that don't visit every node. The lazy constraint callback
// adds new constraints to cut them off.

using System;
using Gurobi;

class tsp_cs : GRBCallback {
    private GRBVar[,] vars;
public tsp_cs(GRBVar[,] xvars) {
    vars = xvars;
}

// Subtour elimination callback. Whenever a feasible solution is found,
// find the smallest subtour, and add a subtour elimination
// constraint if the tour doesn't visit every node.

protected override void Callback() {
    try {
        if (where == GRB.Callback.MIPSOL) {
            // Found an integer feasible solution - does it visit every node?
            int n = vars.GetLength(0);
            int[] tour = findsubtour(GetSolution(vars));

            if (tour.Length < n) {
                // Add subtour elimination constraint
                GRBLinExpr expr = 0;
                for (int i = 0; i < tour.Length; i++)
                    for (int j = i + 1; j < tour.Length; j++)
                        expr.AddTerm(1.0, vars[tour[i], tour[j]]);
                AddLazy(expr <= tour.Length - 1);
            }
        }
    } catch (GRBException e) {
        Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
        Console.WriteLine(e.StackTrace);
    }
}

// Given an integer-feasible solution 'sol', return the smallest
// sub-tour (as a list of node indices).

protected static int[] findsubtour(double[,] sol) {
    int n = sol.GetLength(0);
    bool[] seen = new bool[n];
    int[] tour = new int[n];
    int bestind, bestlen;
    int i, node, len, start;

    for (i = 0; i < n; i++)
        seen[i] = false;

    start = 0;
    bestlen = n + 1;
    bestind = -1;
    node = 0;
    while (start < n) {
        for (node = 0; node < n; node++)
            if (!seen[node])
                break;
        if (node == n)
            break;
        for (len = 0; len < n; len++)
            if (len == node)
                continue;

            if (seen[node] && len < bestlen) {
                bestlen = len;
                bestind = node;
            }

            for (i = node; i < n; i++)
                seen[i] = true;
        start = node + 1;
    }

    return tour;
}
tour[start+len] = node;
seen[node] = true;
for (i = 0; i < n; i++) {
    if (sol[node, i] > 0.5 && !seen[i]) {
        node = i;
        break;
    }
}
if (i == n) {
    len++;
    if (len < bestlen) {
        bestlen = len;
        bestind = start;
    }
    start += len;
    break;
}
}
for (i = 0; i < bestlen; i++)
tour[i] = tour[bestind+i];
System.Array.Resize(ref tour, bestlen);
return tour;

// Euclidean distance between points 'i' and 'j'
protected static double distance(double[] x, double[] y, int i, int j) {
    double dx = x[i]-x[j];
    double dy = y[i]-y[j];
    return Math.Sqrt(dx*dx+dy*dy);
}

public static void Main(String[] args) {
    if (args.Length < 1) {
        Console.WriteLine("Usage: tsp_cs nnodes");
        return;
    }
    int n = Convert.ToInt32(args[0]);
    try {
        GRBEnv env = new GRBEnv();
        GRBModel model = new GRBModel(env);
        // Must set LazyConstraints parameter when using lazy constraints
        model.Parameters.LazyConstraints = 1;
        double[] x = new double[n];

double[] y = new double[n];

Random r = new Random();
for (int i = 0; i < n; i++) {
    x[i] = r.NextDouble();
    y[i] = r.NextDouble();
}

// Create variables
GRBVar[,] vars = new GRBVar[n, n];

GRBLinExpr expr = 0;
for (int i = 0; i < n; i++) {
    for (int j = 0; j <= i; j++) {
        vars[i, j] = model.AddVar(0.0, 1.0, distance(x, y, i, j),
                                 GRB.BINARY, "x"+i+"_"+j);
        vars[j, i] = vars[i, j];
    }
}

// Degree-2 constraints
for (int i = 0; i < n; i++) {
    expr = 0;
    for (int j = 0; j < n; j++)
        expr.AddTerm(1.0, vars[i, j]);
    model.AddConstr(expr == 2.0, "deg2_"+i);
}

// Forbid edge from node back to itself
for (int i = 0; i < n; i++)
    vars[i, i].UB = 0.0;

model.SetCallback(new tsp_cs(vars));
model.Optimize();

if (model.SolCount > 0) {
    int[] tour = findsubtour(model.Get(GRB_DoubleAttr.X, vars));
    Console.Write("Tour: ");
    for (int i = 0; i < tour.Length; i++)
        Console.Write(tour[i] + " ");
    Console.WriteLine();
}

// Dispose of model and environment
model.Dispose();
env.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
    Console.WriteLine(e.StackTrace);
}
}
tune_cs.cs

    /* Copyright 2018, Gurobi Optimization, LLC */
    /* This example reads a model from a file and tunes it. It then writes the best parameter settings to a file and solves the model using these parameters. */

using System;
using Gurobi;

class tune_cs
{
    static void Main(string[] args)
    {
        if (args.Length < 1) {
            Console.Out.WriteLine("Usage: tune_cs filename");
            return;
        }

        try {
            GRBEnv env = new GRBEnv();

            // Read model from file
            GRBModel model = new GRBModel(env, args[0]);

            // Set the TuneResults parameter to 1
            model.Parameters.TuneResults = 1;

            // Tune the model
            model.Tune();

            // Get the number of tuning results
            int resultcount = model.TuneResultCount;

            if (resultcount > 0) {
                // Load the tuned parameters into the model’s environment
                model.GetTuneResult(0);

                // Write the tuned parameters to a file
                model.Write("tune.prm");

                // Solve the model using the tuned parameters
                model.Optimize();
            }

            // Dispose of model and environment
            model.Dispose();
            env.Dispose();
        }
        catch (GRBException e) {
            Console.WriteLine("Error code: " + e.ErrorCode + ", " + e.Message);
        }
    }
}
/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a
particular day. If the problem cannot be solved, use IIS to find a set of
conflicting constraints. Note that there may be additional conflicts
besides what is reported via IIS. */

using System;
using Gurobi;

class workforce1_cs
{
    static void Main()
    {
        try {

            // Sample data
            // Sets of days and workers
            string[] Shifts =
                new string[] { "Mon1", "Tue2", "Wed3", "Thu4", "Fri5", "Sat6",
                    "Sun7", "Mon8", "Tue9", "Wed10", "Thu11", "Fri12", "Sat13",
                    "Sun14" };
            string[] Workers =

            int nShifts = Shifts.Length;
            int nWorkers = Workers.Length;

            // Number of workers required for each shift
            double[] shiftRequirements =
                new double[] { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

            // Amount each worker is paid to work one shift
            double[] pay = new double[] { 10, 12, 10, 8, 8, 9, 11 };

            // Worker availability: 0 if the worker is unavailable for a shift
            double[,] availability =
                new double[,] { { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
                    { 1, 1, 0, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
                    { 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
                    { 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
                    { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
                    { 1, 1, 1, 0, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
                    { 1, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 } };

            // Model
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env);

            model.ModelName = "assignment";

            // Assignment variables: x[w][s] == 1 if worker w is assigned
            // to shift s. Since an assignment model always produces integer
            // solutions, we use continuous variables and solve as an LP.

        }
    }
}

289
GRBVar[,] x = new GRBVar[nWorkers, nShifts];
for (int w = 0; w < nWorkers; ++w) {
    for (int s = 0; s < nShifts; ++s) {
        x[w,s] =
            model.AddVar(0, availability[w, s], pay[w], GRB.CONTINUOUS,
                          Workers[w] + "." + Shifts[s]);
    }
}

// The objective is to minimize the total pay costs
model.ModelSense = GRB.MINIMIZE;

// Constraint: assign exactly shiftRequirements[s] workers
// to each shift s
for (int s = 0; s < nShifts; ++s) {
    GRBLinExpr lhs = 0.0;
    for (int w = 0; w < nWorkers; ++w)
        lhs.AddTerm(1.0, x[w, s]);
    model.AddConstr(lhs == shiftRequirements[s], Shifts[s]);
}

// Optimize
model.Optimize();
int status = model.Status;
if (status == GRB.Status.UNBOUNDED) {
    Console.WriteLine("The model cannot be solved "
                       + "because it is unbounded");
    return;
}
if (status == GRB.Status.OPTIMAL) {
    Console.WriteLine("The optimal objective is " + model.ObjVal);
    return;
}
if ((status != GRB.Status.INF_OR_UNBD) &&
    (status != GRB.Status.INFEASIBLE)) {
    Console.WriteLine("Optimization was stopped with status " + status);
    return;
}

// Do IIS
Console.WriteLine("The model is infeasible; computing IIS");
model.ComputeIIS();
Console.WriteLine("\nThe following constraint(s) "
                  + "cannot be satisfied:");
foreach (GRBConstr c in model.GetConstrs()) {
    if (c.IISConstr == 1) {
        Console.WriteLine(c.ConstrName);
    }
}

// Dispose of model and env
model.Dispose();
env.Dispose();
}
catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ", " +
using System;
using System.Collections.Generic;
using Gurobi;

class workforce2_cs
{
    static void Main()
    {
        try {
            // Sample data
            // Sets of days and workers
            string[] Shifts =
            string[] Workers =

            int nShifts = Shifts.Length;
            int nWorkers = Workers.Length;

            // Number of workers required for each shift
double[] shiftRequirements =
                new double[] { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

            // Amount each worker is paid to work one shift
double[] pay = new double[] { 10, 12, 10, 8, 8, 9, 11 };

            // Worker availability: 0 if the worker is unavailable for a shift
double[,] availability =
                new double[,] { 
                    { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 }, 
                    { 1, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 1, 1 }, 
                    { 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1 }, 
                    { 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 }, 
                    { 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1 }, 
                    { 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 }, 
                };

            // Model
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env);
model.ModelName = "assignment";

// Assignment variables: x[w][s] == 1 if worker w is assigned to shift s. Since an assignment model always produces integer solutions, we use continuous variables and solve as an LP.
GRBVar[,] x = new GRBVar[nWorkers, nShifts];
for (int w = 0; w < nWorkers; ++w) {
    for (int s = 0; s < nShifts; ++s) {
        x[w, s] =
            model.AddVar(0, availability[w, s], pay[w], GRB.CONTINUOUS, Workers[w] + "." + Shifts[s]);
    }
}

// The objective is to minimize the total pay costs
model.ModelSense = GRB.MINIMIZE;

// Constraint: assign exactly shiftRequirements[s] workers to each shift s
for (int s = 0; s < nShifts; ++s) {
    GRBLinExpr lhs = 0.0;
    for (int w = 0; w < nWorkers; ++w)
        lhs.AddTerm(1.0, x[w, s]);
    model.AddConstr(lhs == shiftRequirements[s], Shifts[s]);
}

// Optimize
model.Optimize();
int status = model.Status;
if (status == GRB.Status.UNBOUNDED) {
    Console.WriteLine("The model cannot be solved " + "because it is unbounded");
    return;
}
if (status == GRB.Status.OPTIMAL) {
    Console.WriteLine("The optimal objective is "+ model.ObjVal);
    return;
}
if ((status != GRB.Status.INF_OR_UNBD) &&
    (status != GRB.Status.INFEASIBLE)) {
    Console.WriteLine("Optimization was stopped with status "+ status);
    return;
}

// Do IIS
Console.WriteLine("The model is infeasible; computing IIS");
LinkedList<string> removed = new LinkedList<string>();

// Loop until we reduce to a model that can be solved
while (true) {
    model.ComputeIIS();
    Console.WriteLine("\nThe following constraint cannot be satisfied:\n");
    foreach (GRBConstr c in model.GetConstrs()) {
        if (c.IISConstr == 1) {
            Console.WriteLine(c.ConstrName);
            // Remove a single constraint from the model
            removed.Add(c.ConstrName);
        }
    }
    if (model.Status != GRB.Status.INFEASIBLE) {
        Console.WriteLine("\nThe following constraint cannot be satisfied: ");
        foreach (GRBConstr c in model.GetConstrs()) {
            if (c.IISConstr == 1) {
                Console.WriteLine(c.ConstrName);
                // Remove a single constraint from the model
                removed.Add(c.ConstrName);
            }
        }
    }
}

removed.AddFirst(c.ConstrName);
model.Remove(c);
break;
}
}

Console.WriteLine();
model.Optimize();
status = model.Status;

if (status == GRB.Status.UNBOUNDED) {
    Console.WriteLine("The model cannot be solved "+"because it is unbounded");
    return;
}
if (status == GRB.Status.OPTIMAL) {
    break;
}
if ((status != GRB.Status.INF_OR_UNBD) &&
   (status != GRB.Status.INFEASIBLE)) {
    Console.WriteLine("Optimization was stopped with status "+
    status);
    return;
}

Console.WriteLine("\nThe following constraints were removed "+"to get a feasible LP:"");
foreach (string s in removed) {
    Console.Write(s + " ");
}
Console.WriteLine();

// Dispose of model and env
model.Dispose();
env.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ", " +
    e.Message);
}

workforce3_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a
   particular day. If the problem cannot be solved, relax the model
to determine which constraints cannot be satisfied, and how much
they need to be relaxed. */
using System;
using Gurobi;
```csharp
class workforce3_cs
{
    static void Main()
    {
        try {

            // Sample data
            // Sets of days and workers
            string[] Shifts =
            string[] Workers =

            int nShifts = Shifts.Length;
            int nWorkers = Workers.Length;

            // Number of workers required for each shift
            double[] shiftRequirements =
                new double[] { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

            // Amount each worker is paid to work one shift
            double[] pay = new double[] { 10, 12, 10, 8, 8, 9, 11 };

            // Worker availability: 0 if the worker is unavailable for a shift
            double[,] availability =
                new double[,] { { 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 1, 1, 1, 1 },
                                { 1, 1, 0, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0 },
                                { 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1 },
                                { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 },
                                { 1, 1, 1, 1, 0, 1, 0, 1, 1, 0, 1, 0, 1, 1 },
                                { 1, 1, 1, 0, 0, 1, 0, 1, 1, 0, 1, 0, 1, 1 },
                                { 1, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 } };

            // Model
            GRBEnv env = new GRBEnv();
            GRBModel model = new GRBModel(env);
            model.ModelName = "assignment";

            // Assignment variables: x[w][s] == 1 if worker w is assigned
            // to shift s. Since an assignment model always produces integer
            // solutions, we use continuous variables and solve as an LP.
            GRBVar[,] x = new GRBVar[nWorkers, nShifts];
            for (int w = 0; w < nWorkers; ++w) {
                for (int s = 0; s < nShifts; ++s) {
                    x[w, s] =
                        model.AddVar(0, availability[w, s], pay[w], GRB.CONTINUOUS, Workers[w] + "." + Shifts[s]);
                }
            }

            // The objective is to minimize the total pay costs
            model.ModelSense = GRB.MINIMIZE;
        }
    }
}
```
// Constraint: assign exactly shiftRequirements[s] workers
// to each shift s
for (int s = 0; s < nShifts; ++s) {
    GRBLinExpr lhs = 0.0;
    for (int w = 0; w < nWorkers; ++w) {
        lhs.AddTerm(1.0, x[w, s]);
    }
    model.AddConstr(lhs == shiftRequirements[s], Shifts[s]);
}

// Optimize
model.Optimize();
int status = model.Status;
if (status == GRB.Status.UNBOUNDED) {
    Console.WriteLine("The model cannot be solved "+"because it is unbounded");
    return;
} else if (status == GRB.Status.OPTIMAL) {
    Console.WriteLine("The optimal objective is " + model.ObjVal);
    return;
} else if ((status != GRB.Status.INF_OR_UNBD) && 
             (status != GRB.Status.INFEASIBLE)) {
    Console.WriteLine("Optimization was stopped with status " + status);
    return;
}

// Relax the constraints to make the model feasible
Console.WriteLine("The model is infeasible; relaxing the constraints");
int orignumvars = model.NumVars;
model.FeasRelax(0, false, false, true);
model.Optimize();
status = model.Status;
if ((status == GRB.Status.INF_OR_UNBD) || 
    (status == GRB.Status.INFEASIBLE) || 
    (status == GRB.Status.UNBOUNDED)) {
    Console.WriteLine("The relaxed model cannot be solved "+"because it is infeasible or unbounded");
    return;
}
if (status != GRB.Status.OPTIMAL) {
    Console.WriteLine("Optimization was stopped with status " + status);
    return;
}

Console.WriteLine("\nSlack values:");
GRBVar[] vars = model.GetVars();
for (int i = orignumvars; i < model.NumVars; ++i) {
    GRBVar sv = vars[i];
    if (sv.X > 1e-6) {
        Console.WriteLine(sv.VarName + " = " + sv.X);
    }
}

// Dispose of model and environment
model.Dispose();
env.Dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " + e.Message);
}
}

workforce4_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a
particular day. We use Pareto optimization to solve the model:
first, we minimize the linear sum of the slacks. Then, we constrain
the sum of the slacks, and we minimize a quadratic objective that
tries to balance the workload among the workers. */

using System;
using Gurobi;

class workforce4_cs
{
    static void Main()
    {
        try {

            // Sample data
            // Sets of days and workers
            string[] Shifts =
                new string[] { "Mon1", "Tue2", "Wed3", "Thu4", "Fri5", "Sat6",
                    "Sun7", "Mon8", "Tue9", "Wed10", "Thu11", "Fri12", "Sat13",
                    "Sun14" };
            string[] Workers =

            int nShifts = Shifts.Length;
            int nWorkers = Workers.Length;

            // Number of workers required for each shift
double[] shiftRequirements =
                new double[] { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

            // Worker availability: 0 if the worker is unavailable for a shift
double[,] availability =
                new double[,] { { 0, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1 },
                    { 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1 },
                    { 0, 0, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 },
                    { 0, 1, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1 },
                    { 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 1, 1 },
                    { 1, 1, 0, 0, 1, 0, 1, 1, 1, 0, 0, 1, 1, 1 },
                    { 1, 1, 1, 1, 0, 0, 1, 1, 1, 0, 0, 1, 1, 1 } };

            // Model

            296
GRBEnv env = new GRBEnv();
GRBModel model = new GRBModel(env);

model.ModelName = "assignment";

// Assignment variables: x[w][s] == 1 if worker w is assigned
// to shift s. This is no longer a pure assignment model, so we must
// use binary variables.
GRBVar[,] x = new GRBVar[nWorkers, nShifts];
for (int w = 0; w < nWorkers; ++w) {
    for (int s = 0; s < nShifts; ++s) {
        x[w,s] = model.AddVar(0, availability[w,s], 0, GRB.BINARY,
                               Workers[w] + "." + Shifts[s]);
    }
}

// Slack variables for each shift constraint so that the shifts can
// be satisfied
GRBVar[] slacks = new GRBVar[nShifts];
for (int s = 0; s < nShifts; ++s) {
    slacks[s] = model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                              Shifts[s] + " Slack");
}

// Variable to represent the total slack
GRBVar totSlack = model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                                "totSlack");

// Variables to count the total shifts worked by each worker
GRBVar[] totShifts = new GRBVar[nWorkers];
for (int w = 0; w < nWorkers; ++w) {
    totShifts[w] = model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                                 Workers[w] + " TotShifts");
}

GRBLinExpr lhs;

// Constraint: assign exactly shiftRequirements[s] workers
// to each shift s, plus the slack
for (int s = 0; s < nShifts; ++s) {
    lhs = new GRBLinExpr();
    lhs.AddTerm(1.0, slacks[s]);
    for (int w = 0; w < nWorkers; ++w) {
        lhs.AddTerm(1.0, x[w, s]);
    }
    model.AddConstr(lhs == shiftRequirements[s], Shifts[s]);
}

// Constraint: set totSlack equal to the total slack
lhs = new GRBLinExpr();
for (int s = 0; s < nShifts; ++s) {
    lhs.AddTerm(1.0, slacks[s]);
}
model.AddConstr(lhs == totSlack, "totSlack");
// Constraint: compute the total number of shifts for each worker
for (int w = 0; w < nWorkers; ++w) {
    lhs = new GRBLinExpr();
    for (int s = 0; s < nShifts; ++s) {
        lhs.AddTerm(1.0, x[w, s]);
    }
    model.AddConstr(lhs == totShifts[w], "totShifts" + Workers[w]);
}

// Objective: minimize the total slack
model.SetObjective(1.0*totSlack);

// Optimize
int status = solveAndPrint(model, totSlack, nWorkers, Workers, totShifts);
if (status != GRB.Status.OPTIMAL) {
    return;
}

// Constrain the slack by setting its upper and lower bounds
totSlack.UB = totSlack.X;
totSlack.LB = totSlack.X;

// Variable to count the average number of shifts worked
GRBVar avgShifts =
    model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS, "avgShifts");

// Variables to count the difference from average for each worker;
// note that these variables can take negative values.
GRBVar[] diffShifts = new GRBVar[nWorkers];
for (int w = 0; w < nWorkers; ++w) {
    diffShifts[w] = model.AddVar(-GRB.INFINITY, GRB.INFINITY, 0,
                                GRB.CONTINUOUS, Workers[w] + "Diff");
}

// Constraint: compute the average number of shifts worked
lhs = new GRBLinExpr();
for (int w = 0; w < nWorkers; ++w) {
    lhs.AddTerm(1.0, totShifts[w]);
}
model.AddConstr(lhs == nWorkers * avgShifts, "avgShifts");

// Constraint: compute the difference from the average number of shifts
for (int w = 0; w < nWorkers; ++w) {
    model.AddConstr(totShifts[w] - avgShifts == diffShifts[w],
                    Workers[w] + "Diff");
}

// Objective: minimize the sum of the square of the difference from the
// average number of shifts worked
GRBQuadExpr qobj = new GRBQuadExpr();
for (int w = 0; w < nWorkers; ++w) {
    qobj.AddTerm(1.0, diffShifts[w], diffShifts[w]);
}
model.SetObjective(qobj);
// Optimize
status = solveAndPrint(model, totSlack, nWorkers, Workers, totShifts);
if (status != GRB.Status.OPTIMAL) {
    return;
}

// Dispose of model and env
model.Dispose();
env.Dispose();
}
catch (GRBException e) {
    Console.WriteLine("Error code: " + e.ErrorCode + ". " +
                     e.Message);
}

private static int solveAndPrint(GRBModel model, GRBVar totSlack,
                                   int nWorkers, String[] Workers,
                                   GRBVar[] totShifts)
{
    model.Optimize();
    int status = model.Status;
    if ((status == GRB.Status.INF_OR_UNBD) ||
        (status == GRB.Status.INFEASIBLE) ||
        (status == GRB.Status.UNBOUNDED)) {
        Console.WriteLine("The model cannot be solved "
                         + "because it is infeasible or unbounded");
        return status;
    }
    if (status != GRB.Status.OPTIMAL) {
        Console.WriteLine("Optimization was stopped with status " + status);
        return status;
    }

    // Print total slack and the number of shifts worked for each worker
    Console.WriteLine("Total slack required: " + totSlack.X);
    for (int w = 0; w < nWorkers; ++w) {
        Console.WriteLine(Workers[w] + " worked " +
                         totShifts[w].X + " shifts");
    }
    Console.WriteLine("\n");
    return status;
}

workforce5_cs.cs

/* Copyright 2018, Gurobi Optimization, LLC */

/* Assign workers to shifts; each worker may or may not be available on a
   particular day. We use multi-objective optimization to solve the model.
   The highest-priority objective minimizes the sum of the slacks
   (i.e., the total number of uncovered shifts). The secondary objective
   minimizes the difference between the maximum and minimum number of
   shifts worked among all workers. The second optimization is allowed
de to degrade the first objective by up to the smaller value of 10% and 2 */
using System;
using Gurobi;

class workforce5_cs
{
    static void Main()
    {
        try {
            // Sample data
            // Sets of days and workers
            string[] Shifts =
            string[] Workers =

            int nShifts = Shifts.Length;
            int nWorkers = Workers.Length;

            // Number of workers required for each shift
            double[] shiftRequirements =
                new double[] { 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 };

            // Worker availability: 0 if the worker is unavailable for a shift
            double[,] availability =
                new double[,] { { 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1 },
                                { 1, 1, 0, 0, 1, 1, 0, 1, 1, 1, 1, 1 },
                                { 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1 },
                                { 0, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1 },
                                { 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1 },
                                { 1, 1, 1, 0, 0, 1, 1, 1, 1, 0, 1, 1 },
                                { 0, 0, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1 },
                                { 0, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1 } };

            // Create environment
            GRBEnv env = new GRBEnv();

            // Create initial model
            GRBModel model = new GRBModel(env);
            model.ModelName = "workforce5_cs";

            // Initialize assignment decision variables:
            // x[w][s] == 1 if worker w is assigned to shift s.
            // This is no longer a pure assignment model, so we must
            // use binary variables.
            GRBVar[,] x = new GRBVar[nWorkers, nShifts];
            for (int w = 0; w < nWorkers; ++w) {
                for (int s = 0; s < nShifts; ++s) {
                    x[w,s] =
                        model.AddVar(0, availability[w,s], 0, GRB.BINARY,
                                        string.Format("{0}.{1}", Workers[w], Shifts[s]));
                }
            }
        }
    }
}
// Slack variables for each shift constraint so that the shifts can
// be satisfied
GRBVar[] slacks = new GRBVar[nShifts];
for (int s = 0; s < nShifts; ++s) {
    slacks[s] =
        model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                      string.Format("{0} Slack", Shifts[s]));
}

// Variable to represent the total slack
GRBVar totSlack = model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                               "totSlack");

// Variables to count the total shifts worked by each worker
GRBVar[] totShifts = new GRBVar[nWorkers];
for (int w = 0; w < nWorkers; ++w) {
    totShifts[w] = model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                                string.Format("{0} TotShifts", Workers[w]));
}

GRBLinExpr lhs;

// Constraint: assign exactly shiftRequirements[s] workers
// to each shift s, plus the slack
for (int s = 0; s < nShifts; ++s) {
    lhs = new GRBLinExpr();
    lhs.AddTerm(1.0, slacks[s]);
    for (int w = 0; w < nWorkers; ++w) {
        lhs.AddTerm(1.0, x[w,s]);
    }
    model.AddConstr(lhs, GRB.EQUAL, shiftRequirements[s], Shifts[s]);
}

// Constraint: set totSlack equal to the total slack
lhs = new GRBLinExpr();
lhs.AddTerm(-1.0, totSlack);
for (int s = 0; s < nShifts; ++s) {
    lhs.AddTerm(1.0, slacks[s]);
}
model.AddConstr(lhs, GRB.EQUAL, 0, "totSlack");

// Constraint: compute the total number of shifts for each worker
for (int w = 0; w < nWorkers; ++w) {
    lhs = new GRBLinExpr();
    lhs.AddTerm(-1.0, totShifts[w]);
    for (int s = 0; s < nShifts; ++s) {
        lhs.AddTerm(1.0, x[w,s]);
    }
    model.AddConstr(lhs, GRB.EQUAL, 0, string.Format("totShifts{0}", Workers[w]));
}

// Constraint: set minShift/maxShift variable to less <=/>= to the
// number of shifts among all workers
GRBVar minShift = model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS,
                               "minShift");
GRBVar maxShift = model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS, "maxShift");
model.AddGenConstrMin(minShift, totShifts, GRB.INFINITY, "minShift");
model.AddGenConstrMax(maxShift, totShifts, -GRB.INFINITY, "maxShift");

// Set global sense for ALL objectives
model.ModelSense = GRB.MINIMIZE;

// Set primary objective
model.SetObjectiveN(totSlack, 0, 2, 1.0, 2.0, 0.1, "TotalSlack");

// Set secondary objective
model.SetObjectiveN(maxShift - minShift, 1, 1, 1.0, 0, 0, "Fairness");

// Save problem
model.Write("workforce5_cs.lp");

// Optimize
int status = solveAndPrint(model, totSlack, nWorkers, Workers, totShifts);

if (status != GRB.Status.OPTIMAL)
    return;

// Dispose of model and environment
model.Dispose();
e.dispose();

} catch (GRBException e) {
    Console.WriteLine("Error code: {0}. {1}", e.ErrorCode, e.Message);
}

private static int solveAndPrint(GRBModel model, GRBVar totSlack,
                        int nWorkers, String[] Workers,
                        GRBVar[] totShifts)
{

    model.Optimize();
    int status = model.Status;
    if (status == GRB.Status.INF_OR_UNBD ||
        status == GRB.Status.INFEASIBLE ||
        status == GRB.Status.UNBOUNDED)
    {
        Console.WriteLine("The model cannot be solved " + "because it is infeasible or unbounded");
        return status;
    }
    if (status != GRB.Status.OPTIMAL) {
        Console.WriteLine("Optimization was stopped with status {0}" , status);
        return status;
    }

    // Print total slack and the number of shifts worked for each worker
    Console.WriteLine("\nTotal slack required: {0}\", totSlack.X);
    for (int w = 0; w < nWorkers; ++w) {
        Console.WriteLine("{0} worked {1} shifts", Workers[w], totShifts[w].X);
    }
3.5 Visual Basic Examples

This section includes source code for all of the Gurobi Visual Basic examples. The same source code can be found in the examples/vb directory of the Gurobi distribution.

callback_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
'
' This example reads a model from a file, sets up a callback that
' monitors optimization progress and implements a custom
' termination strategy, and outputs progress information to the
' screen and to a log file.
'
' The termination strategy implemented in this callback stops the
' optimization of a MIP model once at least one of the following two
' conditions have been satisfied:
' 1) The optimality gap is less than 10%
' 2) At least 10000 nodes have been explored, and an integer feasible
'    solution has been found.
' Note that termination is normally handled through Gurobi parameters
' (MIPGap, NodeLimit, etc.). You should only use a callback for
' termination if the available parameters don’t capture your desired
' termination criterion.

Imports System
Imports Gurobi

Class callback_vb
    Inherits GRBCallback
    Private vars As GRBVar ()
    Private lastnode As Double
    Private lastiter As Double

    Public Sub New(ByVal xvars As GRBVar())
        vars = xvars
        lastnode = lastiter = -1
    End Sub

    Protected Overloads Overrides Sub Callback()
        Try
            If where = GRB.Callback.PRESOLVE Then
                ' Presolve callback
                Dim cdel As Integer = GetIntInfo(GRB.Callback.PRE_COLDEL)
                Dim rdels As Integer = GetIntInfo(GRB.Callback.PRE_ROWDEL)
                Console.WriteLine(cdel & " columns and " & rdels & " rows are removed"
            ElseIf where = GRB.Callback.SIMPLEX Then
                ' Simplex callback
                Dim itc As Double = GetDoubleInfo(GRB.Callback.SPX_ITRCNT)
            Else
                Return
            End If
        End Try
    End Sub
End Class
If itcnt Mod - lastiter >= 100 Then
    lastiter = itcnt
    Dim obj As Double = GetDoubleInfo(GRB.Callback.SPX_OBJVAL)
    Dim pinf As Double = GetDoubleInfo(GRB.Callback.SPX_PRIMINF)
    Dim dinf As Double = GetDoubleInfo(GRB.Callback.SPX_DUALINF)
    Dim ispert As Integer = GetIntInfo(GRB.Callback.SPX_ISPERT)
    Dim ch As Char
    If ispert = 0 Then
        ch = "c"
    ElseIf ispert = 1 Then
        ch = "S"c
    Else
        ch = "P"c
    End If
    Console.WriteLine(itcnt & " " & obj & ch & " " & pinf & " " & dinf)
End If
ElseIf where = GRB.Callback.MIP Then
    ' General MIP callback
    Dim nodecnt As Double = GetDoubleInfo(GRB.Callback.MIP_NODCNT)
    If nodecnt - lastnode >= 100 Then
        lastnode = nodecnt
        Dim objbst As Double = GetDoubleInfo(GRB.Callback.MIP_OBJBST)
        Dim objbnd As Double = GetDoubleInfo(GRB.Callback.MIP_OBJBND)
        If Math.Abs(objbst - objbnd) < 0.1 * (1.0R + Math.Abs(objbst)) Then
            Abort()
        End If
        Dim actnodes As Integer = CInt(GetDoubleInfo(GRB.Callback.MIP_NODLFT))
        Dim itcnt As Integer = CInt(GetDoubleInfo(GRB.Callback.MIP_ITRCNT))
        Dim solcnt As Integer = GetIntInfo(GRB.Callback.MIP_SOLCNT)
        Dim cutcnt As Integer = GetIntInfo(GRB.Callback.MIP_CUTCNT)
        Console.WriteLine(nodecnt & " " & actnodes & " " & itcnt & " " & _
                         objbst & " " & objbnd & " " & solcnt & " " & cutcnt)
    End If
ElseIf where = GRB.Callback.MIPSOL Then
    ' MIP solution callback
    Dim obj As Double = GetDoubleInfo(GRB.Callback.MIPSOL_OBJ)
    Dim nodecnt As Integer = CInt(GetDoubleInfo(GRB.Callback.MIPSOL_NODCNT))
    Dim x As Double() = GetSolution(vars)
    Console.WriteLine("**** New solution at node " & nodecnt & ", obj " & _
                         obj & ", x(0) = " & x(0) & ")
End If
Catch e As GRBException
    Console.WriteLine(e.StackTrace)
End Try
End Sub

Shared Sub Main(ByVal args As String())

    If args.Length < 1 Then
        Console.WriteLine("Usage: callback_vb filename")
        Return
    End If

    Try
        Dim env As New GRBEnv()
Dim model As New GRBModel(env, args(0))

Dim vars As GRBVar() = model.GetVars()

' Create a callback object and associate it with the model
model.SetCallback(New callback_vb(vars))
model.Optimize()

Dim x As Double() = model.Get(GRB.DoubleAttr.X, vars)
Dim vnames As String() = model.Get(GRB.StringAttr.VarName, vars)

For j As Integer = 0 To vars.Length - 1
    If x(j) <> 0.0 Then
        Console.WriteLine(vnames(j) & " " & x(j))
    End If
Next

' Dispose of model and env
model.Dispose()
env.Dispose()

Catch e As GRBException
    Console.WriteLine(e.StackTrace)
End Try
End Sub

End Class

dense_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
'
' This example formulates and solves the following simple QP model:
' minimize x + y + x^2 + x*y + y^2 + y*z + z^2
' subject to  x + 2 y + 3 z >= 4
'            x + y >= 1
'
' The example illustrates the use of dense matrices to store A and Q
' (and dense vectors for the other relevant data). We don't recommend
' that you use dense matrices, but this example may be helpful if you
' already have your data in this format.

Imports Gurobi

Class dense_vb
    Protected Shared Function _
        dense_optimize(env As GRBEnv, _
                        rows As Integer, _
                        cols As Integer, _
                        c As Double(), _
                        Q As Double(), _
                        A As Double(), _
                        sense As Char(), _
                        rhs As Double(), _
                        ...) As GRB_model
        dense_optimize(env, rows, cols, c, Q, A, sense, rhs)
lb As Double () , _
ub As Double () , _
vtype As Char () , _
solution As Double ()) As Boolean
Dim success As Boolean = False
Try
Dim model As New GRBModel ( env )
’ Add variables to the model
Dim vars As GRBVar () = model . AddVars ( lb , ub , Nothing , vtype , Nothing )
’ Populate A matrix
For i As Integer = 0 To rows - 1
Dim expr As New GRBLinExpr ()
For j As Integer = 0 To cols - 1
If A (i , j ) <> 0 Then
expr . AddTerm ( A (i , j ) , vars ( j ))
End If
Next
model . AddConstr ( expr , sense ( i ) , rhs ( i ) , " " )
Next
’ Populate objective
Dim obj As New GRBQuadExpr ()
If Q IsNot Nothing Then
For i As Integer = 0 To cols - 1
For j As Integer = 0 To cols - 1
If Q (i , j ) <> 0 Then
obj . AddTerm ( Q (i , j ) , vars ( i ) , vars ( j ))
End If
Next
Next
For j As Integer = 0 To cols - 1
If c ( j ) <> 0 Then
obj . AddTerm ( c ( j ) , vars ( j ))
End If
Next
model . SetObjective ( obj )
End If
’ Solve model
model . Optimize ()
’ Extract solution
If model . Status = GRB . Status . OPTIMAL Then
success = True
For j As Integer = 0 To cols - 1
solution ( j ) = vars ( j ). X

306


Next
End If
model.Dispose()

Catch e As GRBException
End Try

Return success
End Function

Public Shared Sub Main(args As String())
    Try
        Dim env As New GRBEnv()

        Dim c As Double() = New Double() {1, 1, 0}
        Dim Q As Double[,] = New Double[,] {{1, 1, 0}, {0, 1, 1}, {0, 0, 1}}
        Dim A As Double[,] = New Double[,] {{1, 2, 3}, {1, 1, 0}}
        Dim sense As Char() = New Char() {”>”C, “>”C}
        Dim rhs As Double() = New Double() {4, 1}
        Dim lb As Double() = New Double() {0, 0, 0}
        Dim success As Boolean
        Dim sol As Double() = New Double(2) {}

        success = dense_optimize(env, 2, 3, c, Q, A, sense, rhs, lb, Nothing, Nothing, sol)

        If success Then
            Console.WriteLine("x: " & sol(0) & ", y: " & sol(1) & ", z: " & sol(2))
        End If

        ' Dispose of environment
        env.Dispose()

        Catch e As GRBException
        End Try

    End Sub
End Class
diet_vb.vb

' Copyright 2018, Gurobi Optimization, LLC

' Solve the classic diet model, showing how to add constraints
' to an existing model.
Imports System
Imports Gurobi

Class diet_vb
    Shared Sub Main()
        Try

' Nutrition guidelines, based on
' USDA Dietary Guidelines for Americans, 2005
Dim Categories As String() = New String() {"calories", "protein", "fat", "sodium"}
Dim nCategories As Integer = Categories.Length
Dim minNutrition As Double() = New Double() {1800, 91, 0, 0}
Dim maxNutrition As Double() = New Double() {2200, GRB.INFINITY, 65, 1779}

' Set of foods
Dim Foods As String() = New String() {"hamburger", "chicken", "hot dog", "fries", "macaroni", "pizza", "salad", "milk", "ice cream"}
Dim nFoods As Integer = Foods.Length
Dim cost As Double() = New Double() {2.49, 2.89, 1.5R, 1.89, 2.09, 1.99, 2.49, 0.89, 1.59}

' Nutrition values for the foods
' hamburger
' chicken
' hot dog
' fries
' macaroni
' pizza
' salad
' milk
' ice cream
Dim nutritionValues As Double(,) = New Double(,) {{410, 24, 26, 730}, {420, 32, 10, 1190}, {560, 20, 32, 1800}, {380, 4, 19, 270}, {320, 12, 10, 930}, {320, 15, 12, 820}, {320, 31, 12, 1230}, {100, 8, 2.5, 125}, {330, 8, 10, 180}}

' Model
Dim env As New GRBEnv()
Dim model As New GRBModel(env)
model.ModelName = "diet"

' Create decision variables for the nutrition information, which we limit via bounds
Dim nutrition As GRBVar() = New GRBVar(nCategories - 1) {}
For i As Integer = 0 To nCategories - 1
    nutrition(i) = model.AddVar(minNutrition(i), maxNutrition(i), 0, GRB.CONTINUOUS, Categories(i))
Next

' Create decision variables for the foods to buy
Dim buy As GRBVar() = New GRBVar(nFoods - 1) {}
For j As Integer = 0 To nFoods - 1
    buy(j) = model.AddVar(0, GRB.INFINITY, cost(j), GRB.CONTINUOUS, _
' The objective is to minimize the costs
model.ModelSense = GRB.MINIMIZE

' Nutrition constraints
For i As Integer = 0 To nCategories - 1
    Dim ntot As GRBLinExpr = 0
    For j As Integer = 0 To nFoods - 1
        ntot.AddTerm(nutritionValues(j, i), buy(j))
    Next
    model.AddConstr(ntot = nutrition(i), Categories(i))
Next

' Solve
model.Optimize()
PrintSolution(model, buy, nutrition)

Console.WriteLine(vbLf & "Adding constraint: at most 6 servings of dairy")
model.AddConstr(buy(7) + buy(8) <= 6, "limit_dairy")

' Solve
model.Optimize()
PrintSolution(model, buy, nutrition)

' Dispose of model and env
model.Dispose()
env.Dispose()

Catch e As GRBException
End Try
End Sub

Private Shared Sub PrintSolution(ByVal model As GRBModel, ByVal buy As GRBVar(), _
                                ByVal nutrition As GRBVar())
    If model.Status = GRB.Status.OPTIMAL Then
        Console.WriteLine(vbLf & "Cost: " & model.ObjVal)
        Console.WriteLine(vbLf & "Buy:")
        For j As Integer = 0 To buy.Length - 1
            If buy(j).X > 0.0001 Then
                Console.WriteLine(buy(j).VarName & " " & buy(j).X)
            End If
        Next
        Console.WriteLine(vbLf & "Nutrition:")
        For i As Integer = 0 To nutrition.Length - 1
            Console.WriteLine(nutrition(i).VarName & " " & nutrition(i).X)
        Next
    Else
        Console.WriteLine("No solution")
    End If
End Sub
' Facility location: a company currently ships its product from 5 plants
to 4 warehouses. It is considering closing some plants to reduce
costs. What plant(s) should the company close, in order to minimize
transportation and fixed costs?
' Based on an example from Frontline Systems:
' http://www.solver.com/disfacility.htm
' Used with permission.

Imports System
Imports Gurobi

Class facility_vb
    Shared Sub Main()
        Try

            ' Warehouse demand in thousands of units
            Dim Demand As Double() = New Double() {15, 18, 14, 20}

            ' Plant capacity in thousands of units
            Dim Capacity As Double() = New Double() {20, 22, 17, 19, 18}

            ' Fixed costs for each plant
            Dim FixedCosts As Double() = New Double() {12000, 15000, 17000, 13000, 16000}

            ' Transportation costs per thousand units
            Dim TransCosts As Double(,) = New Double(,) {{4000, 2000, 3000, 2500, 4500},
                                                       {2500, 2600, 3400, 3000, 4000},
                                                       {1200, 1800, 2600, 4100, 3000},
                                                       {2200, 2600, 3100, 3700, 3200}}

            ' Number of plants and warehouses
            Dim nPlants As Integer = Capacity.Length
            Dim nWarehouses As Integer = Demand.Length

            ' Model
            Dim env As New GRBEnv()
            Dim model As New GRBModel(env)

            model.ModelName = "facility"

            ' Plant open decision variables: open(p) == 1 if plant p is open.
            Dim open As GRBVar() = New GRBVar(nPlants - 1) {}
            For p As Integer = 0 To nPlants - 1
                open(p) = model.AddVar(0, 1, FixedCosts(p), GRB.BINARY, "Open" & p)
            Next

            ' Transportation decision variables: how much to transport from
            ' a plant p to a warehouse w
            Dim transport As GRBVar(,) = New GRBVar(nWarehouses - 1, nPlants - 1) {}
            For w As Integer = 0 To nWarehouses - 1
                For p As Integer = 0 To nPlants - 1
                    transport(w,p) = model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS, "Transport" & w & "," & p)
                Next
            Next

        Catch ex As Exception
            Console.WriteLine(ex.Message)
For p As Integer = 0 To nPlants - 1
    transport(w, p) = model.AddVar(0, GRB.INFINITY, _
        TransCosts(w, p), GRB.CONTINUOUS, _
        "Trans" & p & "." & w)
Next
Next
'
The objective is to minimize the total fixed and variable costs
model.ModelSense = GRB.MINIMIZE
'
Production constraints
' Note that the right-hand limit sets the production to zero if
' the plant is closed
For p As Integer = 0 To nPlants - 1
    Dim ptot As GRBLinExpr = 0
    For w As Integer = 0 To nWarehouses - 1
        ptot.AddTerm(1.0, transport(w, p))
    Next
    model.AddConstr(ptot <= Capacity(p) * open(p), "Capacity" & p)
Next
'
Demand constraints
For w As Integer = 0 To nWarehouses - 1
    Dim dtot As GRBLinExpr = 0
    For p As Integer = 0 To nPlants - 1
        dtot.AddTerm(1.0, transport(w, p))
    Next
    model.AddConstr(dtot = Demand(w), "Demand" & w)
Next
'
Guess at the starting point: close the plant with the highest
' fixed costs; open all others
'
First, open all plants
For p As Integer = 0 To nPlants - 1
    open(p).Start = 1.0
Next
'
Now close the plant with the highest fixed cost
Console.WriteLine("Initial guess:")
Dim maxFixed As Double = -GRB.INFINITY
For p As Integer = 0 To nPlants - 1
    If FixedCosts(p) > maxFixed Then
        maxFixed = FixedCosts(p)
    End If
Next
For p As Integer = 0 To nPlants - 1
    If FixedCosts(p) = maxFixed Then
        open(p).Start = 0.0
        Console.WriteLine("Closing plant " & p & vbLf)
        Exit For
    End If
Next
'
Use barrier to solve root relaxation
model.Parameters.Method = GRB.METHOD_BARRIER
Solve
model.Optimize()

Print solution
Console.WriteLine(vbCrLf & "TOTAL COSTS: " & model.ObjVal)
Console.WriteLine("SOLUTION:")
For p As Integer = 0 To nPlants - 1
  If open(p).X > 0.99 Then
    Console.WriteLine("Plant " & p & " open:")
    For w As Integer = 0 To nWarehouses - 1
      If transport(w, p).X > 0.0001 Then
        Console.WriteLine(" Transport " & _
          transport(w, p).X & _
          " units to warehouse " & w)
      End If
    Next
  Else
    Console.WriteLine(" Plant " & p & " closed!")
  End If
Next

Dispose of model and env
model.Dispose()
env.Dispose()

Catch e As GRBException
End Try
End Sub

Class feasopt_vb

' Copyright 2018, Gurobi Optimization, LLC
'
' This example reads a MIP model from a file, adds artificial
' variables to each constraint, and then minimizes the sum of the
' artificial variables. A solution with objective zero corresponds
' to a feasible solution to the input model.
' We can also use FeasRelax feature to do it. In this example, we
' use minrelax=1, i.e. optimizing the returned model finds a solution
' that minimizes the original objective, but only from among those
' solutions that minimize the sum of the artificial variables.

Imports Gurobi
Imports System

Class feasopt_vb
  Shared Sub Main(ByVal args As String())
    If args.Length < 1 Then
      Console.WriteLine("Usage: feasopt_vb filename")
      Return
    End If
Try
Dim env As New GRBEnv ()
Dim feasmodel As New GRBModel ( env , args (0))
’ Create a copy to use FeasRelax feature later
Dim feasmodel1 As New GRBModel ( feasmodel )
’ Clear objective
feasmodel . SetObjective ( New GRBLinExpr ())
’ Add slack variables
Dim c As GRBConstr () = feasmodel . GetConstrs ()
For i As Integer = 0 To c . Length - 1
Dim sense As Char = c ( i ). Sense
If sense <> " >" c Then
Dim constrs As GRBConstr () = New GRBConstr () { c ( i )}
Dim coeffs As Double () = New Double () { -1}
feasmodel . AddVar (0.0 , GRB . INFINITY , 1.0 , GRB . CONTINUOUS , _
constrs , coeffs , _
" ArtN_ " & c ( i ). ConstrName )
End If
If sense <> " <" c Then
Dim constrs As GRBConstr () = New GRBConstr () { c ( i )}
Dim coeffs As Double () = New Double () {1}
feasmodel . AddVar (0.0 , GRB . INFINITY , 1.0 , GRB . CONTINUOUS , _
constrs , coeffs , _
" ArtP_ " & c ( i ). ConstrName )
End If
Next
’ Optimize modified model
feasmodel . Optimize ()
feasmodel . Write ( " feasopt . lp " )
’ Use FeasRelax feature */
feasmodel1 . FeasRelax ( GRB . FEASRELAX_LINEAR , true , false , true )
feasmodel1 . Write ( " feasopt1 . lp " )
feasmodel1 . Optimize ()
’ Dispose of model and env
feasmodel1 . Dispose ()
feasmodel . Dispose ()
env . Dispose ()
Catch e As GRBException
End Try
End Sub
End Class

fixanddive_vb.vb
’ Copyright 2018 , Gurobi Optimization , LLC
’
’ Implement a simple MIP heuristic . Relax the model ,

313


Imports System
Imports System.Collections.Generic
Imports Gurobi

Class fixanddive_vb
    ' Comparison class used to sort variable list based on relaxation
    ' fractionality

    Private Class FractionalCompare : Implements IComparer(Of GRBVar)
        Public Function Compare(ByVal v1 As GRBVar, ByVal v2 As GRBVar) As Integer -
            Implements IComparer(Of Gurobi.GRBVar).Compare
            Try
                Dim sol1 As Double = Math.Abs(v1.X)
                Dim sol2 As Double = Math.Abs(v2.X)
                Dim frac1 As Double = Math.Abs(sol1 - Math.Floor(sol1 + 0.5))
                Dim frac2 As Double = Math.Abs(sol2 - Math.Floor(sol2 + 0.5))
                If frac1 < frac2 Then
                    Return -1
                ElseIf frac1 > frac2 Then
                    Return 1
                Else
                    Return 0
                End If
            Catch e As GRBException
            End Try
            Return 0
        End Function
    End Class

    Shared Sub Main(ByVal args As String())
        If args.Length < 1 Then
            Console.WriteLine("Usage: fixanddive_vb filename")
            Return
        End If
        Try
            ' Read model
            Dim env As New GRBEnv()
            Dim model As New GRBModel(env, args(0))
            ' Collect integer variables and relax them
            Dim intvars As New List(Of GRBVar)()
            For Each v As GRBVar In model.GetVars()
                If v.VType <> GRB.CONTINUOUS Then
                    intvars.Add(v)
                    v.VType = GRB.CONTINUOUS
                End If
            Next
            ' sort variables based on fractionality, and fix the 25% of
            ' the fractional variables that are closest to integer variables.
            ' Repeat until either the relaxation is integer feasible or
            ' linearly infeasible.
        End Try
    End Sub
End Class
model.Parameters.OutputFlag = 0
model.Optimize()

' Perform multiple iterations. In each iteration, identify the first quartile of integer variables that are closest to an integer value in the relaxation, fix them to the nearest integer, and repeat.

For iter As Integer = 0 To 999

' create a list of fractional variables, sorted in order of increasing distance from the relaxation solution to the nearest integer value

Dim fractional As New List(Of GRBVar)()
For Each v As GRBVar In intvars
    Dim sol As Double = Math.Abs(v.X)
    If Math.Abs(sol - Math.Floor(sol + 0.5)) > 0.00001 Then
        fractional.Add(v)
    End If
Next

Console.WriteLine("Iteration " & iter & ", obj " & ", fractional " & fractional.Count)

If fractional.Count = 0 Then
    Console.WriteLine("Found feasible solution - objective " & ", ObjVal")
    Exit For
End If

' Fix the first quartile to the nearest integer value

fractional.Sort(New FractionalCompare())
Dim nfix As Integer = Math.Max(fractional.Count / 4, 1)
For i As Integer = 0 To nfix - 1
    Dim v As GRBVar = fractional(i)
    Dim fixval As Double = Math.Floor(v.X + 0.5)
    v.LB = fixval
    v.UB = fixval
    Console.WriteLine(" Fix " & v.VarName & " to " & fixval & " (rel " & v.X & ")")
Next

model.Optimize()

' Check optimization result

If model.Status <> GRB.Status.OPTIMAL Then
    Console.WriteLine("Relaxation is infeasible")
    Exit For
End If

Next

' Dispose of model and env
model.Dispose()
env.Dispose()
Imports Gurobi

Class genconstr_vb

Public Const n As Integer = 4
Public Const NLITERALS As Integer = 4 'same as n
Public Const NCLAUSES As Integer = 8
Public Const NOBJ As Integer = 2

Shared Sub Main()

Try

' Example data:
' e.g. {0, n+1, 2} means clause (x0 or -x1 or x2)
Dim Clauses As Integer(,) = New Integer(,) { _
    { 0, n + 1, 2}, { 1, n + 2, 3}, _

Catch e As GRBException
End Try

End Sub

End Class

genconstr_vb.vb

' Copyright 2018, Gurobi Optimization, LLC

' In this example we show the use of general constraints for modeling
' some common expressions. We use as an example a SAT-problem where we
' want to see if it is possible to satisfy at least four (or all) clauses
' of the logical for
',
' L = (x0 or -x1 or x2) and (x1 or -x2 or x3) and
' (x2 or -x3 or x0) and (x3 or -x0 or x1) and
',
' We do this by introducing two variables for each literal (itself and its
' negated value), a variable for each clause, and then two
' variables for indicating if we can satisfy four, and another to identify
' the minimum of the clauses (so if it one, we can satisfy all clauses)
' and put these two variables in the objective.
' i.e. the Objective function will be
',
' maximize Obj0 + Obj1
',
' Obj0 = MIN(Clause1, ..., Clause8)
' Obj1 = 1 -> Clause1 + ... + Clause8 >= 4
',
' thus, the objective value will be two if and only if we can satisfy all
' clauses; one if and only of at least four clauses can be satisfied, and
' zero otherwise.
',

Imports Gurobi

Class genconstr_vb

Public Const n As Integer = 4
Public Const NLITERALS As Integer = 4 'same as n
Public Const NCLAUSES As Integer = 8
Public Const NOBJ As Integer = 2

Shared Sub Main()

Try

' Example data:
' e.g. {0, n+1, 2} means clause (x0 or -x1 or x2)
Dim Clauses As Integer(,) = New Integer(,) { _
    { 0, n + 1, 2}, { 1, n + 2, 3}, _

Catch e As GRBException
End Try

End Sub

End Class

genconstr_vb.vb
Dim i As Integer, status As Integer

' Create environment
Dim env As New GRBEnv("genconstr_vb.log")

' Create initial model
Dim model As New GRBModel(env)
model.ModelName = "genconstr_vb"

' Initialize decision variables and objective
Dim Lit As GRBVar() = New GRBVar(NLITERALS - 1) {}
Dim NotLit As GRBVar() = New GRBVar(NLITERALS - 1) {}
For i = 0 To NLITERALS - 1
    Lit(i) = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, String.Format("X{0}", i))
    NotLit(i) = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, String.Format("notX{0}", i))
Next

Dim Cla As GRBVar() = New GRBVar(NCLAUSES - 1) {}
For i = 0 To NCLAUSES - 1
    Cla(i) = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, String.Format("Clause{0}", i))
Next

Dim Obj As GRBVar() = New GRBVar(NOBJ - 1) {}
For i = 0 To NOBJ - 1
    Obj(i) = model.AddVar(0.0, 1.0, 1.0, GRB.BINARY, String.Format("Obj{0}", i))
Next

' Link Xi and notXi
Dim lhs As GRBLinExpr
For i = 0 To NLITERALS - 1
    lhs = New GRBLinExpr()
    lhs.AddTerm(1.0, Lit(i))
    lhs.AddTerm(1.0, NotLit(i))
    model.AddConstr(lhs, GRB.EQUAL, 1.0, String.Format("CNSTR_X{0}", i))
Next

' Link clauses and literals
For i = 0 To NCLAUSES - 1
    Dim clause As GRBVar() = New GRBVar(2) {}
    For j As Integer = 0 To 2
        If Clauses(i, j) >= n Then
            clause(j) = NotLit(Clauses(i, j) - n)
        Else
            clause(j) = Lit(Clauses(i, j))
        End If
    Next
    model.AddGenConstrOr(Cla(i), clause, String.Format("CNSTR_Clause{0}", i))
Next

' Link objs with clauses
model.AddGenConstrMin(Obj(0), Cla, GRB.INFINITY, "CNSTR_Obj0")
lhs = New GRBLinExpr()
For i = 0 To NCLAUSES - 1
    lhs.AddTerm(1.0, Cla(i))
Next
model.AddGenConstrIndicator(Obj(1), 1, lhs, GRB.GREATER_EQUAL, 4.0, "CNSTR_Obj1")

' Set global objective sense
model.ModelSense = GRB.MAXIMIZE

' Save problem
model.Write("genconstr_vb.mps")
model.Write("genconstr_vb.lp")

' Optimize
model.Optimize()

' Status checking
status = model.Status
If status = GRB.Status.INF_OR_UNBD OrElse _
    status = GRB.Status.INFEASIBLE OrElse _
    status = GRB.Status.UNBOUNDED Then
    Console.WriteLine("The model cannot be solved " & _
        "because it is infeasible or unbounded")
    Return
End If

If status <> GRB.Status.OPTIMAL Then
    Console.WriteLine("Optimization was stopped with status {0}", status)
    Return
End If

' Print result
Dim objval As Double = model.ObjVal
If objval > 1.9 Then
    Console.WriteLine("Logical expression is satisfiable")
ElseIf objval > 0.9 Then
    Console.WriteLine("At least four clauses can be satisfied")
Else
    Console.WriteLine("Not even three clauses can be satisfied")
End If

' Dispose of model and environment
model.Dispose()
env.Dispose()

Catch e As GRBException
    Console.WriteLine("Error code: {0}. {1}", e.ErrorCode, e.Message)
End Try
End Sub
End Class

lp_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
This example reads an LP model from a file and solves it.
If the model is infeasible or unbounded, the example turns off
presolve and solves the model again. If the model is infeasible,
the example computes an Irreducible Inconsistent Subsystem (IIS),
and writes it to a file.

Imports System
Imports Gurobi

Class lp_vb
    Shared Sub Main(ByVal args As String())
        If args.Length < 1 Then
            Console.WriteLine("Usage: lp_vb filename")
            Return
        End If
        Try
            Dim env As GRBEnv = New GRBEnv("lp1.log")
            Dim model As GRBModel = New GRBModel(env, args(0))
            model.Optimize()
            Dim optimstatus As Integer = model.Status
            If optimstatus = GRB.Status.INF_OR_UNBD Then
                model.Parameters.Presolve = 0
                model.Optimize()
                optimstatus = model.Status
            End If
            If optimstatus = GRB.Status.OPTIMAL Then
                Dim objval As Double = model.ObjVal
                Console.WriteLine("Optimal objective: " & objval)
            ElseIf optimstatus = GRB.Status.INFEASIBLE Then
                Console.WriteLine("Model is infeasible")
                model.ComputeIIS()
                model.Write("model.ilp")
            ElseIf optimstatus = GRB.Status.UNBOUNDED Then
                Console.WriteLine("Model is unbounded")
            Else
                Console.WriteLine("Optimization was stopped with status = " & _
                         optimstatus)
            End If
            ' Dispose of model and env
            model.Dispose()
            env.Dispose()
        Catch e As GRBException
        End Try
    End Sub
End Class
lpmethod_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
'
' Solve a model with different values of the Method parameter;
' show which value gives the shortest solve time.

Imports System
Imports Gurobi

Class lpmethod_vb

Shared Sub Main(ByVal args As String())
    If args.Length < 1 Then
        Console.WriteLine("Usage: lpmethod_vb filename")
        Return
    End If

    Try
        ' Read model and verify that it is a MIP
        Dim env As New GRBEnv()
        Dim model As New GRBModel(env, args(0))

        ' Solve the model with different values of Method
        Dim bestMethod As Integer = -1
        Dim bestTime As Double = model.get(GRB.DoubleParam.TimeLimit)
        For i As Integer = 0 To 2
            model.Reset()
            model.Parameters.Method = i
            model.Optimize()
            If model.Status = GRB.Status.OPTIMAL Then
                bestTime = model.Runtime
                bestMethod = i
                ' Reduce the TimeLimit parameter to save time
                ' with other methods
                model.Parameters.TimeLimit = bestTime
            End If
        Next

        ' Report which method was fastest
        If bestMethod = -1 Then
            Console.WriteLine("Unable to solve this model")
        Else
            Console.WriteLine("Solved in " & bestTime & " seconds with Method: " & bestMethod)
        End If

        ' Dispose of model and env
        model.Dispose()
        env.Dispose()
    Catch e As GRBException
    End Try
End Sub
Imports System
Imports Gurobi

Class lpmod_vb
    Shared Sub Main(ByVal args As String())
        If args.Length < 1 Then
            Console.WriteLine("Usage: lpmod_vb filename")
            Return
        End If

        Try
            ' Read model and determine whether it is an LP
            Dim env As New GRBEnv()
            Dim model As New GRBModel(env, args(0))
            If model.IsMIP <> 0 Then
                Console.WriteLine("The model is not a linear program")
                Environment.Exit(1)
            End If

            model.Optimize()

            Dim status As Integer = model.Status

            If (status = GRB.Status.INF_OR_UNBD) OrElse _
                (status = GRB.Status.INFEASIBLE) OrElse _
                (status = GRB.Status.UNBOUNDED) Then
                Console.WriteLine("The model cannot be solved because it is " & _
                    "infeasible or unbounded")
                Environment.Exit(1)
            End If

            If status <> GRB.Status.OPTIMAL Then
                Console.WriteLine("Optimization was stopped with status " & status)
                Environment.Exit(0)
            End If

            ' Find the smallest variable value
            Dim minVal As Double = GRB.INFINITY
            Dim minVar As GRBVar = Nothing

            For Each v As GRBVar In model.GetVars()
                Dim sol As Double = v.X
                If (sol > 0.0001) AndAlso (sol < minVal) AndAlso _
                    _
Then
minVal = sol
minVar = v
End If
Next

Console.WriteLine(vbLf & "*** Setting " & _
      minVar.VarName & " from " & minVal & " to zero ***" & vbLf)
minVar.UB = 0

' Solve from this starting point
model.Optimize()

' Save iteration & time info
Dim warmCount As Double = model.IterCount
Dim warmTime As Double = model.Runtime

' Reset the model and resolve
Console.WriteLine(vbLf & "*** Resetting and solving " & _
      "without an advanced start ***" & vbLf)
model.Reset()
model.Optimize()

Dim coldCount As Double = model.IterCount
Dim coldTime As Double = model.Runtime

Console.WriteLine(vbLf & "*** Warm start: " & warmCount & _
      " iterations, " & warmTime & " seconds")

Console.WriteLine(vbLf & "*** Cold start: " & coldCount & _
      " iterations, " & coldTime & " seconds")

' Dispose of model and env
model.Dispose()
env.Dispose()

Catch e As GRBException
End Try

End Sub

End Class

mip1_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
'
' This example formulates and solves the following simple MIP model:
'
' maximize  x + y + 2 z
' subject to x + 2 y + 3 z <= 4
'            x + y      >= 1
' x, y, z binary

Imports System
Imports Gurobi

322
Class mip1_vb
    Shared Sub Main()
    Try
        Dim env As GRBEnv = New GRBEnv("mip1.log")
        Dim model As GRBModel = New GRBModel(env)

        ' Create variables
        Dim x As GRBVar = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, "x")
        Dim y As GRBVar = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, "y")
        Dim z As GRBVar = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, "z")

        ' Set objective: maximize x + y + 2 z
        model.SetObjective(x + y + 2 * z, GRB.MAXIMIZE)

        ' Add constraint: x + 2 y + 3 z <= 4
        model.AddConstr(x + 2 * y + 3 * z <= 4.0, "c0")

        ' Add constraint: x + y >= 1
        model.AddConstr(x + 2 * y + 3 * z <= 4.0, "c1")

        ' Optimize model
        model.Optimize()

        Console.WriteLine(x.VarName & " " & x.X)
        Console.WriteLine(y.VarName & " " & y.X)
        Console.WriteLine(z.VarName & " " & z.X)

        Console.WriteLine("Obj: " & model.ObjVal)

        ' Dispose of model and env
        model.Dispose()
        env.Dispose()
    Catch e As GRBException
    End Try
    End Sub
End Class

mip2_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
'
' This example reads a MIP model from a file, solves it and
' prints the objective values from all feasible solutions
' generated while solving the MIP. Then it creates the fixed
' model and solves that model.

Imports System
Imports Gurobi

Class mip2_vb

    Shared Sub Main(ByVal args As String())
        If args.Length < 1 Then
            Console.WriteLine("Usage: mip2_vb filename")
            Return
        End If

        Try
            Dim env As GRBEnv = New GRBEnv("lp1.log")
            Dim model As GRBModel = New GRBModel(env, args(0))

            If model.IsMIP = 0 Then
                Console.WriteLine("Model is not a MIP")
                Return
            End If

            model.Optimize()

            Dim optimstatus As Integer = model.Status

            If optimstatus = GRB.Status.INF_OR_UNBD Then
                model.Parameters.Presolve = 0
                model.Optimize()
                optimstatus = model.Status
            End If

            Dim objval As Double

            If optimstatus = GRB.Status.OPTIMAL Then
                objval = model.ObjVal
                Console.WriteLine("Optimal objective: " & objval)
            ElseIf optimstatus = GRB.Status.INFEASIBLE Then
                Console.WriteLine("Model is infeasible")
                model.ComputeIIS()
                model.Write("model.ilp")
                Return
            ElseIf optimstatus = GRB.Status.UNBOUNDED Then
                Console.WriteLine("Model is unbounded")
                Return
            Else
                Console.WriteLine("Optimization was stopped with status = " & _
                                optimstatus)
                Return
            End If

        ' Iterate over the solutions and compute the objectives
        Dim vars() As GRBVar = model.GetVars()
        model.Parameters.OutputFlag = 0

        Console.WriteLine()
        For k As Integer = 0 To model.SolCount - 1
            model.Parameters.SolutionNumber = k
            Dim objn As Double = 0.0
            ' ...
For j As Integer = 0 To vars.Length - 1
    objn += vars(j).Obj * vars(j).Xn
Next

Console.WriteLine("Solution " & k & " has objective: " & objn)
Next

Console.WriteLine()
model.Parameters.OutputFlag = 1

' Solve fixed model
Dim fixedmodel As GRBModel = model.FixedModel()
fixedmodel.Parameters.Presolve = 0
fixedmodel.Optimize()

Dim foptimstatus As Integer = fixedmodel.Status
If foptimstatus <> GRB.Status.OPTIMAL Then
    Console.WriteLine("Error: fixed model isn’t optimal")
    Return
End If

Dim fobjval As Double = fixedmodel.ObjVal
If Math.Abs(fobjval - objval) > 0.000001 * (1.0 + Math.Abs(objval)) Then
End If

Dim fvars() As GRBVar = fixedmodel.GetVars()
Dim x() As Double = fixedmodel.Get(GRB.DoubleAttr.X, fvars)
Dim vnames() As String = fixedmodel.Get(GRB.StringAttr.VarName, fvars)

For j As Integer = 0 To fvars.Length - 1
    If x(j) <> 0 Then
        Console.WriteLine(vnames(j) & " " & x(j))
    End If
Next

' Dispose of models and env
fixedmodel.Dispose()
model.Dispose()
env.Dispose()

Catch e As GRBException
End Try

End Sub

End Class

multiobj_vb.vb

' Copyright 2018, Gurobi Optimization, LLC

' Want to cover three different sets but subject to a common budget of
' elements allowed to be used. However, the sets have different priorities to
' be covered; and we tackle this by using multi-objective optimization.
Imports Gurobi

Class multiobj_vb

Shared Sub Main()

Try

' Sample data
Dim groundsetSize As Integer = 20
Dim nSubsets As Integer = 4
Dim Budget As Integer = 12

Dim [Set] As Double(,) = New Double(,) { _
  {1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0}, _
  {0, 0, 0, 0, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0}, _
  {0, 0, 0, 1, 1, 0, 1, 1, 0, 0, 0, 0, 1, 1, 0, 0}, _
  {0, 0, 0, 1, 1, 0, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0}}

Dim SetObjPriority As Integer() = New Integer() {3, 2, 2, 1}
Dim SetObjWeight As Double() = New Double() {1.0, 0.25, 1.25, 1.0}

Dim e As Integer, i As Integer, status As Integer, nSolutions As Integer

' Create environment
Dim env As New GRBEnv("multiobj_vb.log")

' Create initial model
Dim model As New GRBModel(env)
model.ModelName = "multiobj_vb"

' Initialize decision variables for ground set:
' x[e] == 1 if element e is chosen for the covering.
Dim Elem As GRBVar() = model.AddVars(groundsetSize, GRB.BINARY)
For e = 0 To groundsetSize - 1
    Dim vname As String = "El" & e.ToString()
    Elem(e).VarName = vname
Next

' Constraint: limit total number of elements to be picked to be at most
' Budget
Dim lhs As New GRBLinExpr()
For e = 0 To groundsetSize - 1
    lhs.AddTerm(1.0, Elem(e))
Next
model.AddConstr(lhs, GRB.LESS_EQUAL, Budget, "Budget")

' Set global sense for ALL objectives
model.ModelSense = GRB.MAXIMIZE

' Limit how many solutions to collect
model.Parameters.PoolSolutions = 100

' Set and configure i-th objective
For i = 0 To nSubsets - 1
    Dim vname As String = String.Format("Set{0}" , i)
    Dim objn As New GRBLinExpr()
    For e = 0 To groundsetSize - 1
        
Next

End Try

End Sub

objn.AddTerm([Set](i, e), Elem(e))

Next

model.SetObjectiveN(objn, i, SetObjPriority(i), SetObjWeight(i), _
1.0 + i, 0.01, vname)

Next

' Save problem
model.Write("multiobj_vb.lp")

' Optimize
model.Optimize()

' Status checking
status = model.Status

If status = GRB.Status.INF_OR_UNBD OrElse _
status = GRB.Status.INFEASIBLE OrElse _
status = GRB.Status.UNBOUNDED Then
    Console.WriteLine("The model cannot be solved " & _
                    "because it is infeasible or unbounded")
    Return
End If

If status <> GRB.Status.OPTIMAL Then
    Console.WriteLine("Optimization was stopped with status {0}" , status)
    Return
End If

' Print best selected set
Console.WriteLine("Selected elements in best solution:")
Console.Write(vbTab)
For e = 0 To groundSetSize - 1
    If Elem(e).X < 0.9 Then
        Continue For
    End If
    Console.Write("El{0} ", e)
Next
Console.WriteLine()

' Print number of solutions stored
nSolutions = model.SolCount
Console.WriteLine("Number of solutions found: {0}" , nSolutions)

' Print objective values of solutions
If nSolutions > 10 Then
    nSolutions = 10
End If
Console.WriteLine("Objective values for first {0} solutions:", nSolutions)
For i = 0 To nSubsets - 1
    model.Parameters.ObjNumber = i
    Console.Write(vbTab & " Set " & i)
    For e = 0 To nSolutions - 1
        model.Parameters.SolutionNumber = e
        Console.Write("{0,8}" , model.ObjNVal)
    Next
    Console.WriteLine()
Console.WriteLine()
Next
model.Dispose()
env.Dispose()

Catch e As GRBException
    Console.WriteLine("Error code = {0}", e)
    Console.WriteLine(e.Message)
End Try
End Sub
End Class

params_vb.vb

' Copyright 2018, Gurobi Optimization, LLC */

' Use parameters that are associated with a model.

' A MIP is solved for a few seconds with different sets of parameters.
' The one with the smallest MIP gap is selected, and the optimization
' is resumed until the optimal solution is found.

Imports System
Imports Gurobi

Class params_vb
    Shared Sub Main(args As String())
        If args.Length < 1 Then
            Console.Out.WriteLine("Usage: params_vb filename")
            Return
        End If

        Try
            ' Read model and verify that it is a MIP
            Dim env As New GRBEnv()
            Dim m As New GRBModel(env, args(0))
            If m.IsMIP = 0 Then
                Console.WriteLine("The model is not an integer program")
                Environment.Exit(1)
            End If

            ' Set a 2 second time limit
            m.Parameters.TimeLimit = 2.0

            ' Now solve the model with different values of MIPFocus
            Dim bestModel As New GRBModel(m)
            bestModel.Optimize()
            For i As Integer = 1 To 3
                m.Reset()
                m.Parameters.MIPFocus = i
                m.Optimize()
                If bestModel.MIPGap > m.MIPGap Then
                    Dim swap As GRBModel = bestModel
                    bestModel = m
                End If
            Next
        End Try
    End Sub
End Class
m = swap
   End If
Next
' Finally, delete the extra model, reset the time limit and
' continue to solve the best model to optimality
m.Dispose()
bModel.Parameters.TimeLimit = GRB.INFINITY
bModel.Optimize()
Console.WriteLine("Solved with MIPFocus: ", bModel.Parameters.MIPFocus)
Catch e As GRBException
Dim lb As Double = 0.0, ub As Double = 1.0

Dim x As GRBVar = model.AddVar(lb, ub, 0.0, GRB.CONTINUOUS, "x")
Dim y As GRBVar = model.AddVar(lb, ub, 0.0, GRB.CONTINUOUS, "y")
Dim z As GRBVar = model.AddVar(lb, ub, 0.0, GRB.CONTINUOUS, "z")

' Set objective for y
model.SetObjective(-y)

' Add piecewise-linear objective functions for x and z
Dim npts As Integer = 101
Dim ptu As Double() = New Double(npts - 1) {}
Dim ptf As Double() = New Double(npts - 1) {}
Dim ptg As Double() = New Double(npts - 1) {}
For i As Integer = 0 To npts - 1
    ptu(i) = lb + (ub - lb) * i / (npts - 1)
    ptf(i) = f(ptu(i))
    ptg(i) = g(ptu(i))
Next
model.SetPWLObj(x, ptu, ptf)
model.SetPWLObj(z, ptu, ptg)

' Add constraint: x + 2 y + 3 z <= 4
model.AddConstr(x + 2 * y + 3 * z <= 4.0, "c0")

' Add constraint: x + y >= 1
model.AddConstr(x + y >= 1.0, "c1")

' Optimize model as an LP
model.Optimize()

Console.WriteLine("IsMIP: " & model.IsMIP)

Console.WriteLine(x.VarName & " = " & x.X)
Console.WriteLine(y.VarName & " = " & y.X)
Console.WriteLine(z.VarName & " = " & z.X)

Console.WriteLine("Obj: " & model.ObjVal)

Console.WriteLine()

' Negate piecewise-linear objective function for x
For i As Integer = 0 To npts - 1
    ptf(i) = -ptf(i)
Next
model.SetPWLObj(x, ptu, ptf)
' Optimize model as a MIP
model.Optimize()
Console.WriteLine("IsMIP: " & model.IsMIP)

Console.WriteLine(x.VarName & " " & x.X)
Console.WriteLine(y.VarName & " " & y.X)
Console.WriteLine(z.VarName & " " & z.X)

Console.WriteLine("Obj: " & model.ObjVal)

' Dispose of model and environment
model.Dispose()
env.Dispose()
Catch e As GRBException
End Try
End Sub
End Class

poolsearch_vb.vb

' Copyright 2018, Gurobi Optimization, LLC

' We find alternative epsilon-optimal solutions to a given knapsack
' problem by using PoolSearchMode

Imports Gurobi

Class poolsearch_vb

Shared Sub Main()

Try

' Sample data
Dim groundSetSize As Integer = 10
Dim objCoef As Double() = New Double() { 32, 32, 15, 15, 6, 6, 1, 1, 1, 1}

Dim knapsackCoef As Double() = New Double() { 16, 16, 8, 8, 4, 4, 2, 2, 1, 1}

Dim Budget As Double = 33
Dim e As Integer, status As Integer, nSolutions As Integer

' Create environment
Dim env As New GRBEnv("poolsearch_vb.log")

' Create initial model
Dim model As New GRBModel(env)
model.ModelName = "poolsearch_vb"

' Initialize decision variables for ground set:
' x[e] == k if element e is chosen k-times.
Dim Elem As GRBVar() = model.AddVars(groundSetSize, GRB.BINARY)
model.Set(GRB.DoubleAttr.Obj, Elem, objCoef, 0, groundSetSize)

For e = 0 To groundSetSize - 1
    Elem(e).VarName = String.Format("El{0}" , e)
Next

' Constraint: limit total number of elements to be picked to be at most Budget
Dim lhs As New GRBLinExpr()
For e = 0 To groundSetSize - 1
    lhs.AddTerm(knapsackCoef(e), Elem(e))
Next
model.AddConstr(lhs, GRB.LESS_EQUAL, Budget, "Budget")

' set global sense for ALL objectives
model.ModelSense = GRB.MAXIMIZE

' Limit how many solutions to collect
model.Parameters.PoolSolutions = 1024

' Limit how many solutions to collect
model.Parameters.PoolGap = 0.1

' Limit how many solutions to collect
model.Parameters.PoolSearchMode = 2

' save problem
model.Write("poolsearch_vb.lp")

' Optimize
model.Optimize()

' Status checking
status = model.Status
If status = GRB.Status.INF_OR_UNBD OrElse status = GRB.Status.INFEASIBLE OrElse status = GRB.Status.UNBOUNDED Then
    Console.WriteLine("The model cannot be solved because it is infeasible or unbounded")
    Return
End If
If status <> GRB.Status.OPTIMAL Then
    Console.WriteLine("Optimization was stopped with status {0}" , status)
    Return
End If

' Print best selected set
Console.WriteLine("Selected elements in best solution:")
Console.Write(vbTab)
For e = 0 To groundSetSize - 1
    If Elem(e).X < 0.9 Then
        Console.WriteLine(vbTab
    End If
Next
Continue For
End If
Console.WriteLine("El{0} ", e)
Next
Console.WriteLine()

' Print number of solutions stored
nSolutions = model.SolCount
Console.WriteLine("Number of solutions found: ", nSolutions)

' Print objective values of solutions
For e = 0 To nSolutions - 1
    model.Parameters.SolutionNumber = e
    Console.Write("{0} ", model.PoolObjVal)
    If e Mod 15 = 14 Then
        Console.WriteLine()
    End If
Next
Console.WriteLine()
model.Dispose()
env.Dispose()

Catch e As GRBException
End Try
End Sub

End Class

qcp_vb.vb

' Copyright 2018, Gurobi Optimization, LLC

' This example formulates and solves the following simple QCP model:
'
' maximize       x
' subject to     x + y + z = 1
'                x^2 + y^2 <= z^2 (second-order cone)
'                x^2 <= yz (rotated second-order cone)

Imports Gurobi

Class qcp_vb
    Shared Sub Main()
        Try
            Dim env As New GRBEnv("qcp.log")
            Dim model As New GRBModel(env)

            ' Create variables

            Dim x As GRBVar = model.AddVar(0.0, GRB.INFINITY, 0.0, GRB.CONTINUOUS, "x")
            Dim y As GRBVar = model.AddVar(0.0, GRB.INFINITY, 0.0, GRB.CONTINUOUS, "y")
            Dim z As GRBVar = model.AddVar(0.0, GRB.INFINITY, 0.0, GRB.CONTINUOUS, "z")

            model.ModelName = "qcp_vb"
' Set objective
Dim obj As GRBLinExpr = x
model.SetObjective(obj, GRB.MAXIMIZE)

' Add linear constraint: x + y + z = 1
model.AddConstr(x + y + z = 1.0, "c0")

' Add second-order cone: x^2 + y^2 <= z^2
model.AddQConstr(x * x + y * y <= z * z, "qc0")

' Add rotated cone: x^2 <= yz
model.AddQConstr(x * x <= y * z, "qc1")

' Optimize model
model.Optimize()

Console.WriteLine(x.VarName & " " & x.X)
Console.WriteLine(y.VarName & " " & y.X)
Console.WriteLine(z.VarName & " " & z.X)


' Dispose of model and env
model.Dispose()
env.Dispose()

Catch e As GRBException
End Try
End Sub

End Class

qp_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
'
' This exampleformulates and solves the following simple QP model:
'
' minimize x^2 + x*y + y^2 + y*z + z^2 + 2 x
' subject to x + 2 y + 3 z >= 4
'           x + y >= 1
'
' It solves it once as a continuous model, and once as an integer model.
'
Imports Gurobi

Class qp_vb
    Shared Sub Main()
        Try

            ' Set objective
            Dim obj As GRBLinExpr = x
            model.SetObjective(obj, GRB.MAXIMIZE)

            ' Add linear constraint: x + y + z = 1
            model.AddConstr(x + y + z = 1.0, "c0")

            ' Add second-order cone: x^2 + y^2 <= z^2
            model.AddQConstr(x * x + y * y <= z * z, "qc0")

            ' Add rotated cone: x^2 <= yz
            model.AddQConstr(x * x <= y * z, "qc1")

            ' Optimize model
            model.Optimize()

            Console.WriteLine(x.VarName & " " & x.X)
            Console.WriteLine(y.VarName & " " & y.X)
            Console.WriteLine(z.VarName & " " & z.X)


            ' Dispose of model and env
            model.Dispose()
            env.Dispose()

            Catch e As GRBException
            End Try
        End Sub
    End Class

qp_vb.vb
Dim env As New GRBEnv("qp.log")
Dim model As New GRBModel(env)

' Create variables
Dim x As GRBVar = model.AddVar(0.0, 1.0, 0.0, GRB.CONTINUOUS, "x")
Dim y As GRBVar = model.AddVar(0.0, 1.0, 0.0, GRB.CONTINUOUS, "y")
Dim z As GRBVar = model.AddVar(0.0, 1.0, 0.0, GRB.CONTINUOUS, "z")

' Set objective
Dim obj As New GRBQuadExpr()
obj = x*x + x*y + y*y + y*z + z*z + 2*x
model.SetObjective(obj)

' Add constraint: x + 2 y + 3 z >= 4
model.AddConstr(x + 2 * y + 3 * z >= 4.0, "c0")

' Add constraint: x + y >= 1
model.AddConstr(x + y >= 1.0, "c1")

' Optimize model
model.Optimize()

Console.WriteLine(x.VarName & " " & x.X)
Console.WriteLine(y.VarName & " " & y.X)
Console.WriteLine(z.VarName & " " & z.X)


' Change variable types to integer
x.VType = GRB.INTEGER
y.VType = GRB.INTEGER
z.VType = GRB.INTEGER

' Optimize model
model.Optimize()

Console.WriteLine(x.VarName & " " & x.X)
Console.WriteLine(y.VarName & " " & y.X)
Console.WriteLine(z.VarName & " " & z.X)


' Dispose of model and env
model.Dispose()
env.Dispose()

Catch e As GRBException
```vbnet
Imports System
Imports Gurobi

Class sensitivity_vb
    Shared Sub Main(args As String())
        If args.Length < 1 Then
            Console.Out.WriteLine("Usage: sensitivity_vb filename")
            Return
        End If

        Try

            "Create environment"
            Dim env As New GRBEnv()

            "Read and solve model"
            Dim model As New GRBModel(env, args(0))
            If model.IsMIP = 0 Then
                Console.WriteLine("Model is not a MIP")
                Return
            End If

            model.Optimize()

            If model.Status <> GRB.Status.OPTIMAL Then
                Console.WriteLine("Optimization ended with status " & _
                    model.Status)
                Return
            End If

            "Store the optimal solution"
            Dim origObjVal As Double = model.ObjVal
            Dim vars As GRBVar() = model.GetVars()
            Dim origX As Double() = model.Get(GRB.DoubleAttr.X, vars)

            "Disable solver output for subsequent solves"
            model.Parameters.OutputFlag = 0
        End Try
    End Sub
End Class
```
' Iterate through unfixed, binary variables in model

For i As Integer = 0 To vars.Length - 1
    Dim v As GRBVar = vars(i)
    Dim vType As Char = v.VType

    If v.LB = 0 AndAlso v.UB = 1 AndAlso (vType = GRB.BINARY OrElse vType = GRB.INTEGER) Then
        ' Set variable to 1-X, where X is its value in optimal solution
        If origX(i) < 0.5 Then
            v.LB = 1.0
            v.Start = 1.0
        Else
            v.UB = 0.0
            v.Start = 0.0
        End If

        ' Update MIP start for the other variables
        For j As Integer = 0 To vars.Length - 1
            If j <> i Then
                vars(j).Start = origX(j)
            End If
        Next

        ' Solve for new value and capture sensitivity information
        model.Optimize()

        If model.Status = GRB.Status.OPTIMAL Then
            Console.WriteLine("Objective sensitivity for variable ", v.VarName & " is ", (model.ObjVal - origObjVal))
        Else
            Console.WriteLine("Objective sensitivity for variable ", v.VarName & " is infinite")
        End If

        ' Restore the original variable bounds
        v.LB = 0.0
        v.UB = 1.0
    End If
Next

' Dispose of model and environment
model.Dispose()
env.Dispose()
Catch e As GRBException
    Console.WriteLine("Error code: ", e.ErrorCode)
    Console.WriteLine(e.Message)
```vbnet
Imports System
Imports Gurobi

Class sos_vb
    Shared Sub Main()
        Try
            Dim env As New GRBEnv()
            Dim model As New GRBModel(env)

            ' Create variables
            Dim ub As Double() = {1, 1, 2}
            Dim obj As Double() = {-2, -1, -1}
            Dim names As String() = {"x0", "x1", "x2"}
            Dim x As GRBVar() = model.AddVars(Nothing, ub, obj, Nothing, names)

            ' Add first SOS1: x0=0 or x1=0
            Dim sosv1 As GRBVar() = {x(0), x(1)}
            Dim soswt1 As Double() = {1, 2}
            model.AddSOS(sosv1, soswt1, GRB.SOS_TYPE1)

            ' Add second SOS1: x0=0 or x2=0
            Dim sosv2 As GRBVar() = {x(0), x(2)}
            Dim soswt2 As Double() = {1, 2}
            model.AddSOS(sosv2, soswt2, GRB.SOS_TYPE1)

            ' Optimize model
            model.Optimize()

            For i As Integer = 0 To 2
                Console.WriteLine(x(i).VarName & " = " & x(i).X)
            Next

            ' Dispose of model and env
            model.Dispose()
            env.Dispose()
        End Try
    End Sub
End Class
```

This example creates a very simple Special Ordered Set (SOS) model. The model consists of 3 continuous variables, no linear constraints, and a pair of SOS constraints of type 1.
Catch e As GRBException
End Try
End Sub
End Class

sudoku_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
'
' Sudoku example.
'
' The Sudoku board is a 9x9 grid, which is further divided into a 3x3 grid
' of 3x3 grids. Each cell in the grid must take a value from 0 to 9.
' No two grid cells in the same row, column, or 3x3 subgrid may take the
' same value.
'
' In the MIP formulation, binary variables x(i,j,v) indicate whether
' cell <i,j> takes value 'v'. The constraints are as follows:
' 1. Each cell must take exactly one value (sum_v x(i,j,v) = 1)
' 2. Each value is used exactly once per row (sum_i x(i,j,v) = 1)
' 3. Each value is used exactly once per column (sum_j x(i,j,v) = 1)
' 4. Each value is used exactly once per 3x3 subgrid (sum_grid x(i,j,v) = 1)
',
' Input datasets for this example can be found in examples/data/sudoku*

Imports System
Imports System.IO
Imports Gurobi

Class sudoku_vb
    Shared Sub Main(ByVal args as String())
        Dim n As Integer = 9
        Dim s As Integer = 3

        If args.Length < 1 Then
            Console.WriteLine("Usage: sudoku_vb filename")
            Return
        End If

        Try
            Dim env As New GRBEnv()
            Dim model As New GRBModel(env)

            ' Create 3-D array of model variables
            Dim vars As GRBVar(,,) = New GRBVar(n - 1, n - 1, n - 1) {}

            For i As Integer = 0 To n - 1
                For j As Integer = 0 To n - 1
                    For v As Integer = 0 To n - 1
                        Dim st As String = "G_" & i & "." & j & "." & v
                        vars(i, j, v) = model.AddVar(0.0, 1.0, 0.0, GRB.BINARY, st)
                    Next
                Next
            Next
        End Try
    End Sub
End Class

339
' Add constraints

Dim expr As GRBLinExpr

' Each cell must take one value
For i As Integer = 0 To n - 1
    For j As Integer = 0 To n - 1
        expr = 0
        For v As Integer = 0 To n - 1
            expr.AddTerm(1.0, vars(i, j, v))
        Next
        Dim st As String = "V_{i, j} = v" & v
        model.AddConstr(expr = 1, st)
    Next
Next

' Each value appears once per row
For i As Integer = 0 To n - 1
    For v As Integer = 0 To n - 1
        expr = 0
        For j As Integer = 0 To n - 1
            expr.AddTerm(1.0, vars(i, j, v))
        Next
        Dim st As String = "R_{i, v} = r" & v
        model.AddConstr(expr = 1, st)
    Next
Next

' Each value appears once per column
For j As Integer = 0 To n - 1
    For v As Integer = 0 To n - 1
        expr = 0
        For i As Integer = 0 To n - 1
            expr.AddTerm(1.0, vars(i, j, v))
        Next
        Dim st As String = "C_{j, v} = c" & v
        model.AddConstr(expr = 1, st)
    Next
Next

' Each value appears once per sub-grid
For v As Integer = 0 To n - 1
    For i0 As Integer = 0 To s - 1
        For j0 As Integer = 0 To s - 1
            expr = 0
            For i1 As Integer = 0 To s - 1
                expr.AddTerm(1.0, vars(i0 * s + i1, j0 * s + j1, v))
            Next
            Dim st As String = "Sub_{i0, j0, v} = s" & v & "" & i0 & "" & j0
model.AddConstr(expr = 1, st)
Next
Next
Next

' Fix variables associated with pre-specified cells
Dim sr As StreamReader = File.OpenText(args(0))
For i As Integer = 0 To n - 1
Dim input As String = sr.ReadLine()
For j As Integer = 0 To n - 1
Dim val As Integer = Microsoft.VisualBasic.Asc(input(j)) - 48 - 1
' 0-based
If val >= 0 Then
vars(i, j, val).LB = 1.0
End If
Next
Next

' Optimize model
model.Optimize()

' Write model to file
model.Write("sudoku.lp")
Dim x As Double(,,) = model.Get(GRB.DoubleAttr.X, vars)
Console.WriteLine()
For i As Integer = 0 To n - 1
For j As Integer = 0 To n - 1
For v As Integer = 0 To n - 1
If x(i, j, v) > 0.5 Then
    Console.Write(v + 1)
End If
Next
Next
Console.WriteLine()
Next

' Dispose of model and env
model.Dispose()
env.Dispose()

Catch e As GRBException
End Try
End Sub
End Class
tsp_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
,
' Solve a traveling salesman problem on a randomly generated set of
points using lazy constraints. The base MIP model only includes
'degree-2' constraints, requiring each node to have exactly
two incident edges. Solutions to this model may contain subtours -
tours that don't visit every node. The lazy constraint callback
adds new constraints to cut them off.

Imports Gurobi

Class tsp_vb
Inherits GRBCallback
Private vars As GRBVar()

Public Sub New(xvars As GRBVar())
    vars = xvars
End Sub

Subtour elimination callback. Whenever a feasible solution is found,
find the smallest subtour, and add a subtour elimination constraint
if the tour doesn't visit every node.

Protected Overrides Sub Callback()
    Try
        If where = GRB.Callback.MIPSOL Then
            ' Found an integer feasible solution - does it visit every node?
            Dim n As Integer = vars.GetLength(0)
            Dim tour As Integer() = findsputour(GetSolution(vars))
            If tour.Length < n Then
                ' Add subtour elimination constraint
                Dim expr As GRBLinExpr = 0
                For i As Integer = 0 To tour.Length - 1
                    For j As Integer = i + 1 To tour.Length - 1
                        expr.AddTerm(1.0, vars(tour(i), tour(j)))
                    Next
                Next
                AddLazy(expr <= tour.Length - 1)
            End If
        End If
    Catch e As GRBException
        Console.WriteLine(e.StackTrace)
    End Try
End Sub

Given an integer-feasible solution 'sol', returns the smallest
sub-tour (as a list of node indices).

Protected Shared Function findsputour(sol As Double()) As Integer()
    Dim n As Integer = sol.GetLength(0)
    Dim seen As Boolean() = New Boolean(n - 1) {}
    Dim tour As Integer() = New Integer(n - 1) {}
    Dim bestind As Integer, bestlen As Integer
    Dim i As Integer, node As Integer, len As Integer, start As Integer
    For i = 0 To n - 1
        ...
seen(i) = False

Next

start = 0
bestlen = n+1
bestind = -1
node = 0
While start < n
    For node = 0 To n - 1
        if Not seen(node)
            Exit For
        End if
    Next
    if node = n
        Exit While
    End if
    For len = 0 To n - 1
        tour(start+len) = node
        seen(node) = true
        For i = 0 To n - 1
            if sol(node, i) > 0.5 AndAlso Not seen(i)
                node = i
                Exit For
            End If
        Next
        If i = n
            len = len + 1
            If len < bestlen
                bestlen = len
                bestind = start
            End If
            start = start + len
            Exit For
        End If
    Next
End While

For i = 0 To bestlen - 1
    tour(i) = tour(bestind+i)
Next
System.Array.Resize(tour, bestlen)

Return tour
End Function

' Euclidean distance between points 'i' and 'j'

Protected Shared Function distance(x As Double(), y As Double(), _
i As Integer, j As Integer) As Double
    Dim dx As Double = x(i) - x(j)
    Dim dy As Double = y(i) - y(j)
    Return Math.Sqrt(dx * dx + dy * dy)
End Function

Public Shared Sub Main(args As String())
If args.Length < 1 Then
    Console.WriteLine("Usage: tsp_vb nnodes")
    Return
End If

Dim n As Integer = Convert.ToInt32(args(0))

Try
    Dim env As New GRBEnv()
    Dim model As New GRBModel(env)

    ' Must set LazyConstraints parameter when using lazy constraints
    model.Parameters.LazyConstraints = 1

    Dim x As Double() = New Double(n - 1) {}
    Dim y As Double() = New Double(n - 1) {}

    Dim r As New Random()
    For i As Integer = 0 To n - 1
        x(i) = r.NextDouble()
        y(i) = r.NextDouble()
    Next

    ' Create variables
    Dim vars As GRBVar() = New GRBVar(n - 1, n - 1) {}
    For i As Integer = 0 To n - 1
        For j As Integer = 0 To i
            vars(i, j) = model.AddVar(0.0, 1.0, distance(x, y, i, j), _
                GRB.BINARY, "x" & i & "_" & j)
            vars(j, i) = vars(i, j)
        Next
    Next

    ' Degree-2 constraints
    For i As Integer = 0 To n - 1
        Dim expr As GRBLinExpr = 0
        For j As Integer = 0 To n - 1
            expr.AddTerm(1.0, vars(i, j))
        Next
        model.AddConstr(expr = 2.0, "deg2_" & i)
    Next

    ' Forbid edge from node back to itself
    For i As Integer = 0 To n - 1
        vars(i, i).UB = 0.0
    Next

    model.SetCallback(New tsp_vb(vars))
    model.Optimize()
    If model.SolCount > 0 Then
        ...
Dim tour As Integer() = findsuptour(model.Get(GRB.DoubleAttr.X, vars))

Console.WriteLine("Tour: ")
For i As Integer = 0 To tour.Length - 1
    Console.Write(tour(i) & " ")
Next
Console.WriteLine()
End If

' Dispose of model and environment
model.Dispose()
env.Dispose()

Try
    Catch e As GRBException
        Console.WriteLine(e.StackTrace)
    End Try
End Sub

End Class

tune_vb.vb

' Copyright 2018, Gurobi Optimization, LLC */
',
' This example reads a model from a file and tunes it.
' It then writes the best parameter settings to a file
' and solves the model using these parameters.
Imports System
Imports Gurobi

Class tune_vb
    Shared Sub Main(ByVal args As String())
        If args.Length < 1 Then
            Console.Out.WriteLine("Usage: tune_vb filename")
            Return
        End If

        Try
            Dim env As New GRBEnv()

            ' Read model from file
            Dim model As New GRBModel(env, args(0))

            ' Set the TuneResults parameter to 1
            model.Parameters.TuneResults = 1

            ' Tune the model
            model.Tune()

            ' Get the number of tuning results
            Dim resultcount As Integer = model.TuneResultCount

            If resultcount > 0 Then
                Dim i As Integer = 0
                Dim j As Integer = 0
                Dim k As Integer = 0
            End If
        End Try
    End Sub
End Class
' Load the tuned parameters into the model's environment
model.GetTuneResult(0)

' Write the tuned parameters to a file
model.Write("tune.prm")

' Solve the model using the tuned parameters
model.Optimize()
End If

' Dispose of model and environment
model.Dispose()
env.Dispose()

Catch e As GRBException
End Try
End Sub
End Class

workforce1_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
,
' Assign workers to shifts; each worker may or may not be available on a
' particular day. If the problem cannot be solved, use IIS to find a set of
' conflicting constraints. Note that there may be additional conflicts
' besides what is reported via IIS.

Imports System
Imports Gurobi

Class workforce1_vb
    Shared Sub Main()
        Try

            ' Sample data
            ' Sets of days and workers
            Dim Shifts As String() = New String() {"Mon1", "Tue2", "Wed3", "Thu4", 
                "Fri5", "Sat6", "Sun7", "Mon8", 
                "Tue9", "Wed10", "Thu11", 
                "Fri12", "Sat13", "Sun14"}

            Dim Workers As String() = New String() {"Amy", "Bob", "Cathy", "Dan", 
                "Ed", "Fred", "Gu"}

            Dim nShifts As Integer = Shifts.Length
            Dim nWorkers As Integer = Workers.Length

            ' Number of workers required for each shift
            Dim shiftRequirements As Double() = New Double() {3, 2, 4, 4, 5, 6, 
                5, 2, 2, 3, 4, 6, 
                7, 5}

            ' Amount each worker is paid to work one shift
            Dim pay As Double() = New Double() {10, 12, 10, 8, 8, 9, 11}

        End Try
    End Sub
End Class
' Worker availability: 0 if the worker is unavailable for a shift
Dim availability As Double(,) = New Double(,) { _
    {0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1}, _
    {1, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0, 1, 0, 0}, _
    {0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1}, _
    {0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1}, _
    {1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1}, _,
    {1, 1, 1, 0, 0, 1, 0, 1, 1, 0, 0, 1, 1, 1}, _
    {1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1}}

' Model
Dim env As New GRBEnv()
Dim model As New GRBModel(env)

model.ModelName = "assignment"

' Assignment variables: x(w)(s) == 1 if worker w is assigned to shift s. Since an assignment model always produces integer solutions, we use continuous variables and solve as an LP.
Dim x As GRBVar(,) = New GRBVar(nWorkers - 1, nShifts - 1) {}
For w As Integer = 0 To nWorkers - 1
    For s As Integer = 0 To nShifts - 1
        x(w, s) = model.AddVar(0, availability(w, s), pay(w), _
            GRB.CONTINUOUS, _
            Workers(w) & "." & Shifts(s))
    Next
Next

' The objective is to minimize the total pay costs
model.ModelSense = GRB.MINIMIZE

' Constraint: assign exactly shiftRequirements(s) workers to each shift s
For s As Integer = 0 To nShifts - 1
    Dim lhs As GRBLinExpr = 0
    For w As Integer = 0 To nWorkers - 1
        lhs.AddTerm(1.0, x(w, s))
    Next
    model.AddConstr(lhs = shiftRequirements(s), Shifts(s))
Next

' Optimize
model.Optimize()
Dim status As Integer = model.Status
If status = GRB.Status.UNBOUNDED Then
    Console.WriteLine("The model cannot be solved " & _
        "because it is unbounded")
    Exit Sub
End If
If status = GRB.Status.OPTIMAL Then
    Console.WriteLine("The optimal objective is " & model.ObjVal)
    Exit Sub
End If
If (status <> GRB.Status.INF_OR_UNBD) AndAlso _
    (status <> GRB.Status.INFEASIBLE) Then
    Console.WriteLine("Optimization was stopped with status " & status)
Exit Sub
End If

' Do IIS
Console.WriteLine("The model is infeasible; computing IIS")
model.ComputeIIS()
Console.WriteLine(vbLf & "The following constraint(s) " & _
"cannot be satisfied:")
For Each c As GRBConstr In model.GetConstrs()
    If c.IISConstr = 1 Then
        Console.WriteLine(c.ConstrName)
    End If
Next

' Dispose of model and env
model.Dispose()
env.Dispose()

Catch e As GRBException
End Try
End Sub
End Class

workforce2_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
'
' Assign workers to shifts; each worker may or may not be available on a
' particular day. If the problem cannot be solved, use IIS iteratively to
' find all conflicting constraints.

Imports System
Imports System.Collections.Generic
Imports Gurobi

Class workforce2_vb
    Shared Sub Main()
        Try

            ' Sample data
            ' Sets of days and workers
            Dim Shifts As String() = New String() {"Mon1", "Tue2", "Wed3", "Thu4", _
                "Fri5", "Sat6", "Sun7", "Mon8", _
                "Tue9", "Wed10", "Thu11", _
                "Fri12", "Sat13", "Sun14"}

            Dim Workers As String() = New String() {"Amy", "Bob", "Cathy", "Dan", _
                "Ed", "Fred", "Gu"}

            Dim nShifts As Integer = Shifts.Length
            Dim nWorkers As Integer = Workers.Length

            ' Number of workers required for each shift
            Dim shiftRequirements As Double() = New Double() {3, 2, 4, 4, 5, 6, _
                5, 2, 2, 3, 4, 6, _

            Dim model As New GRBModel(env)
            Dim obj As New GRBLinExpr()
            Dim constr As New GRBConstr()
            Dim Binder As New GRBVarBinder()

            model.AddVar("obj", 0, 0, 0, GRB.CONTINUOUS, obj)
            model.AddVar("const1", 0, 0, 0, GRB.CONTINUOUS, constr)

            model.SetParam("LogToConsole", 1)
            model.SetParam("OutputFlag", 0)
            model.SetParam("OutputFlag", 0)

            model.SetObjective(obj, GRB.MAXIMIZE)
            model.AddConstr(constr, GRB.LESS_EQUAL, 0)

            model.Set(GRB.DoubleParam.ModelStatus, GRB.OPTIMAL)
            model.Optimize()

            If model.Status = GRB.OPTIMAL Then
                Console.WriteLine("Solution found.")
            Else
                For Each c As GRBConstr In model.GetConstrs()
                    If c.IISConstr = 1 Then
                        Console.WriteLine(c.ConstrName)
                    End If
                Next

                Console.WriteLine("IIS found.")
            End If

            model.Dispose()
            env.Dispose()

            Catch e As GRBException
            End Try
        End Sub
    End Class
' Amount each worker is paid to work one shift
Dim pay As Double() = New Double() {10, 12, 10, 8, 8, 9, 11}

' Worker availability: 0 if the worker is unavailable for a shift
Dim availability As Double(,) = New Double(,) {
    {0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1},
    {1, 1, 0, 0, 1, 1, 0, 0, 1, 0, 1, 0},
    {0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1},
    {0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1},
    {1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 1},
    {1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1},
    {1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1}}

' Model
Dim env As New GRBEnv()
Dim model As New GRBModel(env)
model.ModelName = "assignment"

' Assignment variables: x(w)(s) == 1 if worker w is assigned
to shift s. Since an assignment model always produces integer
solutions, we use continuous variables and solve as an LP.
Dim x As GRBVar(,) = New GRBVar(nWorkers - 1, nShifts - 1) {}
For w As Integer = 0 To nWorkers - 1
    For s As Integer = 0 To nShifts - 1
        x(w, s) = model.AddVar(0, availability(w, s), pay(w),
            GRB.CONTINUOUS, "Workers(w) & ", & Shifts(s))
    Next
Next

' The objective is to minimize the total pay costs
model.ModelSense = GRB.MINIMIZE

' Constraint: assign exactly shiftRequirements(s) workers
to each shift s
For s As Integer = 0 To nShifts - 1
    Dim lhs As GRBLinExpr = 0
    For w As Integer = 0 To nWorkers - 1
        lhs.AddTerm(1.0, x(w, s))
    Next
    model.AddConstr(lhs = shiftRequirements(s), Shifts(s))
Next

' Optimize
model.Optimize()
Dim status As Integer = model.Status
If status = GRB.Status.UNBOUNDED Then
    Console.WriteLine("The model cannot be solved " & _
        "because it is unbounded")
    Exit Sub
End If
If status = GRB.Status.OPTIMAL Then
    Console.WriteLine("The optimal objective is " & model.ObjVal)
Exit Sub
End If

If (status <> GRB.Status.INF_OR_UNBD) AndAlso (status <> GRB.Status.INFEASIBLE) Then
    Console.WriteLine("Optimization was stopped with status " & status)
    Exit Sub
End If

' Do IIS
Console.WriteLine("The model is infeasible; computing IIS")
Dim removed As LinkedList(Of String) = New LinkedList(Of String)()

' Loop until we reduce to a model that can be solved
While True
    model.ComputeIIS()
    Console.WriteLine(vbLf & "The following constraint cannot be satisfied:"")
    For Each c As GRBConstr In model.GetConstrs()
        If c.IISConstr = 1 Then
            Console.WriteLine(c.ConstrName)
            ' Remove a single constraint from the model
            removed.AddFirst(c.ConstrName)
            model.Remove(c)
            Exit For
        End If
    Next
    Console.WriteLine()
    model.Optimize()
    status = model.Status
    If status = GRB.Status.UNBOUNDED Then
        Console.WriteLine("The model cannot be solved " & _
                         "because it is unbounded")
        Exit Sub
    End If
    If status = GRB.Status.OPTIMAL Then
        Exit While
    End If
    If (status <> GRB.Status.INF_OR_UNBD) AndAlso _
       (status <> GRB.Status.INFEASIBLE) Then
        Console.WriteLine("Optimization was stopped with status " & _
                         status)
        Exit Sub
    End If
    End While
End If

Console.WriteLine(vbLf & "The following constraints were removed " & _
                 "to get a feasible LP:"")
For Each s As String In removed
    Console.Write(s & " ")
Next

Console.WriteLine()

' Dispose of model and env
model.Dispose()
env.Dispose()

Catch e As GRBException
End Try
End Sub

class workforce3_vb

dim shifts as string() = new string() {"Mon1", "Tue2", "Wed3", "Thu4", _
    "Fri5", "Sat6", "Sun7", "Mon8", _
    "Tue9", "Wed10", "Thu11", _
    "Fri12", "Sat13", "Sun14"}
dim workers as string() = new string() {"Amy", "Bob", "Cathy", "Dan", _
    "Ed", "Fred", "Gu"}
dim nshifts as integer = shifts.length
dim nworkers as integer = workers.length

' Number of workers required for each shift
dim shiftrequirements as double() = new double() {3, 2, 4, 4, 5, 6, _
    5, 2, 2, 3, 4, 6, _
    7, 5}

' Amount each worker is paid to work one shift
dim pay as double() = new double() {10, 12, 10, 8, 8, 9, 11}

' Worker availability: 0 if the worker is unavailable for a shift
dim availability as double() = new double() { _
    {0, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1}, _
    {1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 1, 0, 1}, _
    {0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1}, _
    {0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1}, _
    {1, 1, 1, 0, 0, 1, 1, 1, 0, 0, 1, 0, 1, 1}, _
    {1, 1, 0, 0, 1, 0, 1, 0, 0, 1, 1, 1, 1, 1}, _
    {1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1}}

' Model
dim env as new grbenv()
Dim model As New GRBModel(env)

model.ModelName = "assignment"

' Assignment variables: x[w][s] == 1 if worker w is assigned to shift s. Since an assignment model always produces integer solutions, we use continuous variables and solve as an LP.
Dim x As GRBVar(,) = New GRBVar(nWorkers - 1, nShifts - 1) {}
For w As Integer = 0 To nWorkers - 1
  For s As Integer = 0 To nShifts - 1
    x(w, s) = model.AddVar(0, availability(w, s), pay(w), _
      GRB.CONTINUOUS, _ Worker(w) & "." & Shifts(s))
  Next
Next

' The objective is to minimize the total pay costs
model.ModelSense = GRB.MINIMIZE

' Constraint: assign exactly shiftRequirements[w] workers to each shift s
For s As Integer = 0 To nShifts - 1
  Dim lhs As GRBLinExpr = 0.0
  For w As Integer = 0 To nWorkers - 1
    lhs.AddTerm(1.0, x(w, s))
  Next
  model.AddConstr(lhs = shiftRequirements(s), Shifts(s))
Next

' Optimize
model.Optimize()
Dim status As Integer = model.Status
If status = GRB.Status.UNBOUNDED Then
  Console.WriteLine("The model cannot be solved " & 
    "because it is unbounded")
  Return
End If
If status = GRB.Status.OPTIMAL Then
  Console.WriteLine("The optimal objective is " & model.ObjVal)
  Return
End If
If (status <> GRB.Status.INF_OR_UNBD) AndAlso _
  (status <> GRB.Status.INFEASIBLE) Then
  Console.WriteLine("Optimization was stopped with status " & _
    status)
  Return
End If

' Relax the constraints to make the model feasible
Console.WriteLine("The model is infeasible; relaxing the constraints")
Dim orignumvars As Integer = model.NumVars
model.FeasRelax(0, False, False, True)
model.Optimize()
status = model.Status
If (status = GRB.Status.INF_OR_UNBD) OrElse _
  (status = GRB.Status.INFEASIBLE) OrElse _
Console.WriteLine("The relaxed model cannot be solved " & _
"because it is infeasible or unbounded")
Return
End If
If status <> GRB.Status.OPTIMAL Then
Console.WriteLine("Optimization was stopped with status " & status)
Return
End If
Console.WriteLine(vbCrLf & "Slack values:")
Dim vars As GRBVar() = model.GetVars()
For i As Integer = orignumvars To model.NumVars - 1
Dim sv As GRBVar = vars(i)
If sv.X > 1E-06 Then
    Console.WriteLine(sv.VarName & " = " & sv.X)
End If
Next
' Dispose of model and environment
model.Dispose()  
env.Dispose()
Catch e As GRBException
End Try
End Sub
End Class

workforce4_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
'
' Assign workers to shifts; each worker may or may not be available on a
' particular day. We use Pareto optimization to solve the model:
' first, we minimize the linear sum of the slacks. Then, we constrain
' the sum of the slacks, and we minimize a quadratic objective that
' tries to balance the workload among the workers.
Imports System
Imports Gurobi
Class workforce4_vb
    Shared Sub Main()
        Try
            ' Sample data
            ' Sets of days and workers
            Dim Shifts As String() = New String() {"Mon1", "Tue2", "Wed3", "Thu4", _
"Fri5", "Sat6", "Sun7", "Mon8", _
"Tue9", "Wed10", "Thu11", _
"Fri12", "Sat13", "Sun14"}
            Dim Workers As String() = New String() {"Amy", "Bob", "Cathy", "Dan", _
"Ed", "Fred", "Gu"}

            Dim nShifts As Integer = Shifts.Length
Dim nWorkers As Integer = Workers.Length

' Number of workers required for each shift
Dim shiftRequirements As Double() = New Double() {3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5}

' Worker availability: 0 if the worker is unavailable for a shift
Dim availability As Double(,) = New Double(,) {
{0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1},
{1, 1, 0, 0, 1, 0, 1, 0, 0, 1, 0, 1, 0, 0},
{0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1},
{0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1},
{1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 1, 1, 1},
{1, 1, 1, 0, 0, 1, 0, 1, 1, 0, 0, 1, 1, 1},
{1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1}}

' Model
Dim env As New GRBEnv()
Dim model As New GRBModel(env)

model.ModelName = "assignment"

' Assignment variables: x(w)(s) == 1 if worker w is assigned
' to shift s. This is no longer a pure assignment model, so we
' must use binary variables.
Dim x As GRBVar(,) = New GRBVar(nWorkers - 1, nShifts - 1) {}
For w As Integer = 0 To nWorkers - 1
  For s As Integer = 0 To nShifts - 1
    x(w, s) = model.AddVar(0, availability(w, s), 0, _
      GRB.BINARY, _
      Workers(w) & "." & Shifts(s))
  Next
Next

' Add a new slack variable to each shift constraint so that the
'shifts can be satisfied
Dim slacks As GRBVar() = New GRBVar(nShifts - 1) {}
For s As Integer = 0 To nShifts - 1
  slacks(s) = _
    model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS, _
     Shifts(s) & "Slack")
Next

' Variable to represent the total slack
Dim totSlack As GRBVar = model.AddVar(0, GRB.INFINITY, 0, _
  GRB.CONTINUOUS, "totSlack")

' Variables to count the total shifts worked by each worker
Dim totShifts As GRBVar() = New GRBVar(nWorkers - 1) {}
For w As Integer = 0 To nWorkers - 1
  totShifts(w) = _
    model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS, _
     Workers(w) & "TotShifts")
Next
Dim lhs As GRBLinExpr

' Constraint: assign exactly shiftRequirements(s) workers
to each shift s, plus the slack
For s As Integer = 0 To nShifts - 1
    lhs = 0
    lhs.AddTerm(1.0, slacks(s))
    For w As Integer = 0 To nWorkers - 1
        lhs.AddTerm(1.0, x(w, s))
    Next
    model.AddConstr(lhs = shiftRequirements(s), Shifts(s))
Next

' Constraint: set totSlack equal to the total slack
lhs = 0
For s As Integer = 0 To nShifts - 1
    lhs.AddTerm(1.0, slacks(s))
Next
model.AddConstr(lhs = totSlack, "totSlack")

' Constraint: compute the total number of shifts for each worker
For w As Integer = 0 To nWorkers - 1
    lhs = 0
    For s As Integer = 0 To nShifts - 1
        lhs.AddTerm(1.0, x(w, s))
    Next
    model.AddConstr(lhs = totShifts(w), "totShifts" & Workers(w))
Next

' Objective: minimize the total slack
model.SetObjective(1.0* totSlack)

' Optimize
Dim status As Integer = _
    solveAndPrint(model, totSlack, nWorkers, Workers, totShifts)
If status <> GRB.Status.OPTIMAL Then
    Exit Sub
End If

' Constrain the slack by setting its upper and lower bounds
totSlack.UB = totSlack.X
totSlack.LB = totSlack.X

' Variable to count the average number of shifts worked
Dim avgShifts As GRBVar = model.AddVar(0, GRB.INFINITY, 0, _
    GRB.CONTINUOUS, "avgShifts")

' Variables to count the difference from average for each worker;
' note that these variables can take negative values.
Dim diffShifts As GRBVar() = New GRBVar(nWorkers - 1) {}
For w As Integer = 0 To nWorkers - 1
    diffShifts(w) = _
        model.AddVar(-GRB.INFINITY, GRB.INFINITY, 0, _
            GRB.CONTINUOUS, Workers(w) & "Diff")
Next
Constraint: compute the average number of shifts worked

\[ \text{lhs} = 0 \]

For \( w \) As Integer = 0 To nWorkers - 1

\[ \text{lhs} . \text{AddTerm}(1.0, \text{totShifts}(w)) \]

Next

model . AddConstr(lhs = nWorkers * avgShifts, "avgShifts")

Constraint: compute the difference from the average number of shifts

For \( w \) As Integer = 0 To nWorkers - 1

model . AddConstr(totShifts(w) - avgShifts = diffShifts(w), _

Workers(w) & "Diff")

Next

Objective: minimize the sum of the square of the difference
from the average number of shifts worked

Dim qobj As GRBQuadExpr = New GRBQuadExpr

For \( w \) As Integer = 0 To nWorkers - 1

qobj . AddTerm(1.0 , diffShifts(w), diffShifts(w))

Next

model . SetObjective(qobj)

Optimize

status = solveAndPrint(model, totSlack, nWorkers, Workers, totShifts)

If status <> GRB.Status.OPTIMAL Then

Exit Sub

End If

Dispose of model and env
model.Dispose()

env.Dispose()

Catch e As GRBException


End Try

End Sub

Private Shared Function solveAndPrint(ByVal model As GRBModel, _

ByVal totSlack As GRBVar, _

ByVal nWorkers As Integer, _

ByVal Workers As String(), _

ByVal totShifts As GRBVar()) As Integer

model . Optimize()

Dim status As Integer = model.Status
solveAndPrint = status

If (status = GRB.Status.INF_OR_UNBD) OrElse _

(status = GRB.Status.INFEASIBLE) OrElse _

(status = GRB.Status.UNBOUNDED) Then

Console.WriteLine("The model cannot be solved because " & _

"it is infeasible or unbounded")

Exit Function

End If

If status <> GRB.Status.OPTIMAL Then

Console.WriteLine("Optimization was stopped with status " _

& status)

Exit Function

End If
' Print total slack and the number of shifts worked for each worker
Console.WriteLine(vbLf & "Total slack required: " & totSlack.X)
For w As Integer = 0 To nWorkers - 1
    Console.WriteLine(Workers(w) & " worked " & _
        totShifts(w).X & " shifts")
Next
Console.WriteLine(vbLf)
End Function
End Class

workforce5_vb.vb

' Copyright 2018, Gurobi Optimization, LLC
,
' Assign workers to shifts; each worker may or may not be available on a
' particular day. We use multi-objective optimization to solve the model.
' The highest-priority objective minimizes the sum of the slacks
' (i.e., the total number of uncovered shifts). The secondary objective
' minimizes the difference between the maximum and minimum number of
' shifts worked among all workers. The second optimization is allowed
' to degrade the first objective by up to the smaller value of 10% and 2 */
Imports System
Imports Gurobi
Class workforce5_vb
    Shared Sub Main()
        Try
            ' Sample data
            ' Sets of days and workers
            Dim Shifts As String() = New String() { _
                "Mon1", "Tue2", "Wed3", "Thu4", "Fri5", "Sat6", "Sun7", _
                "Mon8", "Tue9", "Wed10", "Thu11", "Fri12", "Sat13", "Sun14"}

            Dim Workers As String() = New String() { _

            Dim nShifts As Integer = Shifts.Length
            Dim nWorkers As Integer = Workers.Length

            ' Number of workers required for each shift
            Dim shiftRequirements As Double() = New Double() { _
                3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5}

            ' Worker availability: 0 if the worker is unavailable for a shift
            Dim availability As Double() = New Double() { _
                {0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1}, _
                {1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 1}, _
                {0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1}, _
                {0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1}, _
                {1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1}, _
' Create environment
Dim env As New GRBEnv()

' Create initial model
Dim model As New GRBModel(env)
model.ModelName = "workforce5_vb"

' Initialize assignment decision variables:
' x[w][s] == 1 if worker w is assigned to shift s.
' This is no longer a pure assignment model, so we must
' use binary variables.
Dim x As GRBVar() = New GRBVar(nWorkers - 1, nShifts - 1) {}
For w As Integer = 0 To nWorkers - 1
  For s As Integer = 0 To nShifts - 1
    x(w, s) = model.AddVar(0, availability(w, s), 0, GRB.BINARY, 
      String.Format("{0}.{1}", Workers(w), Shifts(s)))
  Next
Next

' Slack variables for each shift constraint so that the shifts can
' be satisfied
Dim slacks As GRBVar() = New GRBVar(nShifts - 1) {}
For s As Integer = 0 To nShifts - 1
  slacks(s) = model.AddVar(0, GRB_INFINITY, 0, GRB.CONTINUOUS, 
    String.Format("{0} Slack", Shifts(s)))
Next

' Variable to represent the total slack
Dim totSlack As GRBVar = model.AddVar(0, GRB_INFINITY, 0, GRB.CONTINUOUS, "totSlack")

' Variables to count the total shifts worked by each worker
Dim totShifts As GRBVar() = New GRBVar(nWorkers - 1) {}
For w As Integer = 0 To nWorkers - 1
  totShifts(w) = model.AddVar(0, GRB_INFINITY, 0, GRB.CONTINUOUS, 
    String.Format("{0} TotShifts", Workers(w)))
Next

Dim lhs As GRBLinExpr

' Constraint: assign exactly shiftRequirements[s] workers
' to each shift s, plus the slack
For s As Integer = 0 To nShifts - 1
  lhs = New GRBLinExpr()
  lhs.AddTerm(1.0, slacks(s))
  For w As Integer = 0 To nWorkers - 1
    lhs.AddTerm(1.0, x(w, s))
  Next
  model.AddConstr(lhs, GRB.EQUAL, shiftRequirements(s), Shifts(s))
Next

' Constraint: set totSlack equal to the total slack
lhs = New GRBLinExpr()
lhs.AddTerm(-1.0, totSlack)
For s As Integer = 0 To nShifts - 1
    lhs.AddTerm(1.0, slacks(s))
Next
model.AddConstr(lhs, GRB.EQUAL, 0, "totSlack")

' Constraint: compute the total number of shifts for each worker
For w As Integer = 0 To nWorkers - 1
    lhs = New GRBLinExpr()
    lhs.AddTerm(-1.0, totShifts(w))
    For s As Integer = 0 To nShifts - 1
        lhs.AddTerm(1.0, x(w, s))
    Next
    model.AddConstr(lhs, GRB.EQUAL, 0, String.Format("totShifts{0}", Workers(w)))
Next

' Constraint: set minShift/maxShift variable to less <=/= to the
' number of shifts among all workers
Dim minShift As GRBVar = model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS, "minShift")
Dim maxShift As GRBVar = model.AddVar(0, GRB.INFINITY, 0, GRB.CONTINUOUS, "maxShift")
model.AddGenConstrMin(minShift, totShifts, GRB.INFINITY, "minShift")
model.AddGenConstrMax(maxShift, totShifts, -GRB.INFINITY, "maxShift")

' Set global sense for ALL objectives
model.ModelSense = GRB.MINIMIZE

' Set primary objective
model.SetObjectiveN(totSlack, 0, 2, 1.0, 2.0, 0.1, "TotalSlack")

' Set secondary objective
model.SetObjectiveN(maxShift - minShift, 1, 1, 1.0, 0, 0, "Fairness")

' Save problem
model.Write("workforce5_vb.lp")

' Optimize
Dim status As Integer = _
    solveAndPrint(model, totSlack, nWorkers, Workers, totShifts)
If status <> GRB.Status.OPTIMAL Then
    Return
End If

' Dispose of model and environment
model.Dispose()

env.Dispose()
Catch e As GRBException
    Console.WriteLine("Error code: {0}. {1}", e.ErrorCode, e.Message)
End Try
End Sub

Private Shared Function solveAndPrint(ByVal model As GRBModel, _
    ByVal totSlack As GRBVar, _
    ByVal nWorkers As Integer, _
    ByVal Workers As String(), _)
ByVal totShifts As GRBVar() As Integer

model.Optimize()
Dim status As Integer = model.Status
If status = GRB.Status.INF_OR_UNBD OrElse _
    status = GRB.Status.INFEASIBLE OrElse _
    status = GRB.Status.UNBOUNDED Then
    Console.WriteLine("The model cannot be solved " & _
        "because it is infeasible or unbounded")
    Return status
End If
If status <> GRB.Status.OPTIMAL Then
    Console.WriteLine("Optimization was stopped with status {0}", status)
    Return status
End If

' Print total slack and the number of shifts worked for each worker
Console.WriteLine(vbLf & "Total slack required: {0}", totSlack.X)
For w As Integer = 0 To nWorkers - 1
    Console.WriteLine("{0} worked {1} shifts", Workers(w), totShifts(w).X)
Next
Console.WriteLine(vbLf)
Return status

End Function

End Class

3.6 Python Examples

This section includes source code for all of the Gurobi Python examples. The same source code can be found in the examples/python directory of the Gurobi distribution.

callback.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# This example reads a model from a file, sets up a callback that
# monitors optimization progress and implements a custom
# termination strategy, and outputs progress information to the
# screen and to a log file.
#
# The termination strategy implemented in this callback stops the
# optimization of a MIP model once at least one of the following two
# conditions have been satisfied:
# 1) The optimality gap is less than 10%
# 2) At least 10000 nodes have been explored, and an integer feasible
# solution has been found.
# Note that termination is normally handled through Gurobi parameters
# (MIPGap, NodeLimit, etc.). You should only use a callback for
# termination if the available parameters don't capture your desired
# termination criterion.

import sys
from gurobipy import *

# Define my callback function

def mycallback(model, where):
    if where == GRB.Callback.POLLING:
        # Ignore polling callback
        pass
    elif where == GRB.Callback.PRESOLVE:
        # Presolve callback
        cdels = model.cbGet(GRB.Callback.PRE_COLDEL)
        rdels = model.cbGet(GRB.Callback.PRE_ROWDEL)
        if cdels or rdels:
            print('%d columns and %d rows are removed' % (cdels, rdels))
    elif where == GRB.Callback.SIMPLEX:
        # Simplex callback
        itcnt = model.cbGet(GRB.Callback.SPX_ITRCNT)
        if itcnt - model._lastiter >= 100:
            model._lastiter = itcnt
            obj = model.cbGet(GRB.Callback.SPX_OBJVAL)
            ispert = model.cbGet(GRB.Callback.SPX_ISPERT)
            pinf = model.cbGet(GRB.Callback.SPX_PRIMINF)
            dinf = model.cbGet(GRB.Callback.SPX_DUALINF)
            if ispert == 0:
                ch = ' '
            elif ispert == 1:
                ch = 'S'
            else:
                ch = 'P'
            print('%d %g%s %g %g' % (int(itcnt), obj, ch, pinf, dinf))
    elif where == GRB.Callback.MIP:
        # General MIP callback
        nodecnt = model.cbGet(GRB.Callback.MIP_NODCNT)
        objbst = model.cbGet(GRB.Callback.MIP_OBJBST)
        objbnd = model.cbGet(GRB.Callback.MIP_OBJBND)
        solcnt = model.cbGet(GRB.Callback.MIP_SOLCNT)
        if nodecnt - model._lastnode >= 100:
            model._lastnode = nodecnt
            actnodes = model.cbGet(GRB.Callback.MIP_NODLFT)
            itcnt = model.cbGet(GRB.Callback.MIP_ITRCNT)
            cutcnt = model.cbGet(GRB.Callback.MIP_CUTCNT)
            print('%d %d %d %g %g %d %d' % (nodecnt, actnodes, 
                itcnt, objbst, objbnd, solcnt, cutcnt))
            if abs(objbst - objbnd) < 0.1 * (1.0 + abs(objbst)):
                print('Stop early - 10% gap achieved')
                model.terminate()
        if nodecnt >= 10000 and solcnt:
            print('Stop early - 10000 nodes explored')
            model.terminate()
    elif where == GRB.Callback.MIPSOL:
        # MIP solution callback
        nodecnt = model.cbGet(GRB.Callback.MIPSOL_NODCNT)
        obj = model.cbGet(GRB.Callback.MIPSOL_Obj)
        solcnt = model.cbGet(GRB.Callback.MIPSOL_SOLCNT)
        x = model.cbGetSolution(model._vars)
        print('**** New solution at node %d, obj %g, sol %d, ' \

elif where == GRB.Callback.MIPNODE:
    # MIP node callback
    print('**** New node ****

    if model.cbGet(GRB.Callback.MIPNODE_STATUS) == GRB.Status.OPTIMAL:
        x = model.cbGetNodeRel(model._vars)
        model.cbSetSolution(model.getVars(), x)

elif where == GRB.Callback.BARRIER:
    # Barrier callback
    itcnt = model.cbGet(GRB.Callback.BARRIER_ITRCNT)
    primobj = model.cbGet(GRB.Callback.BARRIER_PRIMOBJ)
    dualobj = model.cbGet(GRB.Callback.BARRIER_DUALOBJ)
    priminf = model.cbGet(GRB.Callback.BARRIER_PRIMINF)
    dualinf = model.cbGet(GRB.Callback.BARRIER_DUALINF)
    cmpl = model.cbGet(GRB.Callback.BARRIER_CMPL)
    print('%d %g %g %g %g %g' % (itcnt, primobj, dualobj, \priminf, dualinf, cmpl))

elif where == GRB.Callback.MESSAGE:
    # Message callback
    msg = model.cbGet(GRB.Callback.MSG_STRING)
    model._logfile.write(msg)

if len(sys.argv) < 2:
    print('Usage: callback.py filename')
    quit()

# Turn off display and heuristics
setParam('OutputFlag', 0)
setParam('Heuristics', 0)

# Read model from file
model = read(sys.argv[1])

# Open log file
logfile = open('cb.log', 'w')

# Pass data into my callback function
model._lastiter = -GRB.INFINITY
model._lastnode = -GRB.INFINITY
model._logfile = logfile
model._vars = model.getVars()

# Solve model and capture solution information
model.optimize(mycallback)

print('')
print('Optimization complete')
if model.SolCount == 0:
    print('No solution found, optimization status = %d' % model.Status)
else:
print('Solution found, objective = %g' % model.ObjVal)
for v in model.getVars():
    if v.X != 0.0:
        print('%.s %.g' % (v.VarName, v.X))

# Close log file
logfile.close()

custom.py

# Copyright 2018, Gurobi Optimization, LLC
# Interactive shell customization example
# Define a set of customizations for the Gurobi shell.
# Type 'from custom import *' to import them into your shell.
#
from gurobipy import *

# custom read command --- change directory as appropriate

def myread(name):
    return read('/home/jones/models/' + name)

# simple termination callback

def mycallback(model, where):
    if where == GRB.Callback.MIP:
        time = model.cbGet(GRB.Callback.RUNTIME)
        best = model.cbGet(GRB.Callback.MIP_OBJBST)
        if time > 10 and best < GRB.INFINITY:
            model.terminate()

# custom optimize() function that uses callback

def myopt(model):
    model.optimize(mycallback)
dense.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# This example formulates and solves the following simple QP model:
# minimize x + y + x^2 + x*y + y^2 + y*z + z^2
# subject to x + 2 y + 3 z >= 4
# x + y >= 1
#
# The example illustrates the use of dense matrices to store A and Q
# (and dense vectors for the other relevant data). We don’t recommend
# that you use dense matrices, but this example may be helpful if you
# already have your data in this format.

```python
import sys
from gurobipy import *

def dense_optimize(rows, cols, c, Q, A, sense, rhs, lb, ub, vtype, solution):
    model = Model()
    # Add variables to model
    vars = []
    for j in range(cols):
        vars.append(model.addVar(lb=lb[j], ub=ub[j], vtype=vtype[j]))
    # Populate A matrix
    for i in range(rows):
        expr = LinExpr()
        for j in range(cols):
            if A[i][j] != 0:
                expr += A[i][j]*vars[j]
        model.addConstr(expr, sense[i], rhs[i])
    # Populate objective
    obj = QuadExpr()
    for i in range(cols):
        for j in range(cols):
            if Q[i][j] != 0:
                obj += Q[i][j]*vars[i]*vars[j]
    for j in range(cols):
        if c[j] != 0:
            obj += c[j]*vars[j]
    model.setObjective(obj)
    # Solve
    model.optimize()
    # Write model to a file
    model.write('dense.lp')
    if model.status == GRB.Status.OPTIMAL:
        x = model.getAttr('x', vars)
        for i in range(cols):
            solution[i] = x[i]
        return True
    else:
        return False

# Put model data into dense matrices

c = [1, 1, 0]
Q = [[1, 1, 0], [0, 1, 1], [0, 0, 1]]
```

364
A = [[1, 2, 3], [1, 1, 0]]
sense = [GRB.GREATER_EQUAL, GRB.GREATER_EQUAL]
rhs = [4, 1]
lb = [0, 0, 0]
ub = [GRB.INFINITY, GRB.INFINITY, GRB.INFINITY]
vtype = [GRB.CONTINUOUS, GRB.CONTINUOUS, GRB.CONTINUOUS]
sol = [0]*3

# Optimize

success = dense_optimize(2, 3, c, Q, A, sense, rhs, lb, ub, vtype, sol)

if success:
    print('x: %g, y: %g, z: %g' % (sol[0], sol[1], sol[2]))

diet.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC
# Solve the classic diet model, showing how to add constraints
# to an existing model.

from gurobipy import *

# Nutrition guidelines, based on
# USDA Dietary Guidelines for Americans, 2005

categories, minNutrition, maxNutrition = multidict({'
    'calories': [1800, 2200],
    'protein': [91, GRB.INFINITY],
    'fat': [0, 65],
    'sodium': [0, 1779] })

foods, cost = multidict({'
    'hamburger': 2.49,
    'chicken': 2.89,
    'hot dog': 1.50,
    'fries': 1.89,
    'macaroni': 2.09,
    'pizza': 1.99,
    'salad': 2.49,
    'milk': 0.89,
    'ice cream': 1.59 })

# Nutrition values for the foods
nutritionValues = {
    ('hamburger', 'calories'): 410,
    ('hamburger', 'protein'): 24,
    ('hamburger', 'fat'): 26,
    ('hamburger', 'sodium'): 730,
    ('chicken', 'calories'): 420,
    ('chicken', 'protein'): 32,
    ('chicken', 'fat'): 10,
}
('chicken', 'sodium'): 1190,
('hot dog', 'calories'): 560,
('hot dog', 'protein'): 20,
('hot dog', 'fat'): 32,
('hot dog', 'sodium'): 1800,
('fries', 'calories'): 380,
('fries', 'protein'): 4,
('fries', 'fat'): 19,
('fries', 'sodium'): 270,
('macaroni', 'calories'): 320,
('macaroni', 'protein'): 12,
('macaroni', 'fat'): 10,
('macaroni', 'sodium'): 930,
('pizza', 'calories'): 320,
('pizza', 'protein'): 15,
('pizza', 'fat'): 12,
('pizza', 'sodium'): 820,
('salad', 'calories'): 320,
('salad', 'protein'): 31,
('salad', 'fat'): 12,
('salad', 'sodium'): 1230,
('milk', 'calories'): 100,
('milk', 'protein'): 8,
('milk', 'fat'): 2.5,
('milk', 'sodium'): 125,
('ice cream', 'calories'): 330,
('ice cream', 'protein'): 8,
('ice cream', 'fat'): 10,
('ice cream', 'sodium'): 180 }
# Using looping constructs, the preceding statement would be:
#
# for c in categories:
# m.addRange(
#     sum(nutritionValues[f,c] * buy[f] for f in foods), minNutrition[c], maxNutrition[c], c)

def printSolution():
    if m.status == GRB.Status.OPTIMAL:
        print('
Cost: %g' % m.objVal)
        print('
Buy:)
        buyx = m.getAttr('x', buy)
        for f in foods:
            if buy[f].x > 0.0001:
                print('%s %g' % (f, buyx[f]))
            else:
                print('No solution')

# Solve
m.optimize()
printSolution()

print('
Adding constraint: at most 6 servings of dairy')
m.addConstr(buy.sum(['milk','ice cream']) <= 6, "limit_dairy")

# Solve
m.optimize()
printSolution()

diet2.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Separate the model (dietmodel.py) from the data file (diet2.py), so
# that the model can be solved with different data files.
#
# Nutrition guidelines, based on
# USDA Dietary Guidelines for Americans, 2005

from gurobipy import *

categories, minNutrition, maxNutrition = multidict({'
    'calories': [1800, 2200],
    'protein': [91, GRB.INFINITY],
    'fat': [0, 65],
    'sodium': [0, 1779 ]})

foods, cost = multidict({
    'hamburger': 2.49,
    'chicken': 2.89,
    'hot dog': 1.50,
    'fries': 1.89,
    'macaroni': 2.09,
    'pizza': 1.99,}
'salad': 2.49,
'milk': 0.89,
'ice cream': 1.59 }}

# Nutrition values for the foods
nutritionValues = {
    ('hamburger', 'calories'): 410,
    ('hamburger', 'protein'): 24,
    ('hamburger', 'fat'): 26,
    ('hamburger', 'sodium'): 730,
    ('chicken', 'calories'): 420,
    ('chicken', 'protein'): 32,
    ('chicken', 'fat'): 10,
    ('chicken', 'sodium'): 1190,
    ('hot dog', 'calories'): 560,
    ('hot dog', 'protein'): 20,
    ('hot dog', 'fat'): 32,
    ('hot dog', 'sodium'): 1800,
    ('fries', 'calories'): 380,
    ('fries', 'protein'): 4,
    ('fries', 'fat'): 19,
    ('fries', 'sodium'): 270,
    ('macaroni', 'calories'): 320,
    ('macaroni', 'protein'): 12,
    ('macaroni', 'fat'): 10,
    ('macaroni', 'sodium'): 930,
    ('pizza', 'calories'): 320,
    ('pizza', 'protein'): 15,
    ('pizza', 'fat'): 12,
    ('pizza', 'sodium'): 820,
    ('salad', 'calories'): 320,
    ('salad', 'protein'): 31,
    ('salad', 'fat'): 12,
    ('salad', 'sodium'): 1230,
    ('milk', 'calories'): 100,
    ('milk', 'protein'): 8,
    ('milk', 'fat'): 2.5,
    ('milk', 'sodium'): 125,
    ('ice cream', 'calories'): 330,
    ('ice cream', 'protein'): 8,
    ('ice cream', 'fat'): 10,
    ('ice cream', 'sodium'): 180 }

import dietmodel
dietmodel.solve(categories, minNutrition, maxNutrition, foods, cost, nutritionValues)

diet3.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Use a SQLite database with the diet model (dietmodel.py). The database
# (diet.db) can be recreated using the included SQL script (diet.sql).
#
# Note that this example reads an external data file (..\data\diet.db).
# As a result, it must be run from the Gurobi examples/python directory.

```python
import os
import sqlite3
from gurobipy import *

con = sqlite3.connect(os.path.join '..', 'data', 'diet.db'))
cur = con.cursor()

cur.execute('select category, minnutrition, maxnutrition from categories')
result = cur.fetchall()
categories, minNutrition, maxNutrition = multidict(
    (cat, [minv, maxv]) for cat, minv, maxv in result)

cur.execute('select food, cost from foods')
result = cur.fetchall()
foods, cost = multidict(result)

cur.execute('select food, category, value from nutrition')
result = cur.fetchall()
nutritionValues = dict(((f, c), v) for f, c, v in result)

con.close()

import dietmodel
dietmodel.solve(categories, minNutrition, maxNutrition,
    foods, cost, nutritionValues)
```

```python
# diet4.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Read diet model data from an Excel spreadsheet (diet.xls).
# Pass the imported data into the diet model (dietmodel.py).
# Note that this example reads an external data file (..\data\diet.xls).
# As a result, it must be run from the Gurobi examples/python directory.
# This example requires Python package 'xlrd', which isn't included
# in most Python distributions. You can obtain it from

import os
import xlrd

book = xlrd.open_workbook(os.path.join("..", "data", "diet.xls"))

sh = book.sheet_by_name("Categories")
categories = []
minNutrition = {}
maxNutrition = {}
i = 1
while True:
```
```python
try:
    c = sh.cell_value(i, 0)
    categories.append(c)
    minNutrition[c] = sh.cell_value(i,1)
    maxNutrition[c] = sh.cell_value(i,2)
    i = i + 1
except IndexError:
    break

sh = book.sheet_by_name("Foods")
foods = []
cost = {}
i = 1
while True:
    try:
        f = sh.cell_value(i, 0)
        foods.append(f)
        cost[f] = sh.cell_value(i,1)
        i = i + 1
    except IndexError:
        break

sh = book.sheet_by_name("Nutrition")
nutritionValues = {}
i = 1
for food in foods:
    j = 1
    for cat in categories:
        nutritionValues[food, cat] = sh.cell_value(i,j)
        j += 1
    i += 1

import dietmodel
dietmodel.solve(categories, minNutrition, maxNutrition, foods, cost, nutritionValues)
```

---

dietmodel.py

```python
#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Solve the classic diet model. This file implements
# a function that formulates and solves the model,
# but it contains no model data. The data is
# passed in by the calling program. Run example 'diet2.py',
# 'diet3.py', or 'diet4.py' to invoke this function.

from gurobipy import *

def solve(categories, minNutrition, maxNutrition, foods, cost, nutritionValues):
    # Model
    m = Model("diet")
```
# Create decision variables for the foods to buy
buy = m.addVars(foods, name="buy")

# The objective is to minimize the costs
m.setObjective(buy.prod(cost), GRB.MINIMIZE)

# Nutrition constraints
m.addConstrs(
    (quicksum(nutritionValues[f,c] * buy[f] for f in foods) == [minNutrition[c], maxNutrition[c]]
    for c in categories), "_")

def printSolution():
    if m.status == GRB.Status.OPTIMAL:
        print("\nCost : %g" % m.objVal)
        print("\nBuy :")
        buyx = m.getAttr('x', buy)
        for f in foods:
            if buyx[f].x > 0.0001:
                print("%s %g" % (f, buyx[f]))
    else:
        print("No solution")

# Solve
m.optimize()
printSolution()

print("\nAdding constraint: at most 6 servings of dairy")
m.addConstr(buy.sum(['milk','ice cream']) <= 6, "limit_dairy")

# Solve
m.optimize()
printSolution()

facility.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Facility location: a company currently ships its product from 5 plants
# to 4 warehouses. It is considering closing some plants to reduce
# costs. What plant(s) should the company close, in order to minimize
# transportation and fixed costs?
#
# Note that this example uses lists instead of dictionaries. Since
# it does not work with sparse data, lists are a reasonable option.
#
# Based on an example from Frontline Systems:
# http://www.solver.com/disfacility.htm
# Used with permission.

from gurobipy import *

# Warehouse demand in thousands of units
demand = [15, 18, 14, 20]
# Plant capacity in thousands of units
capacity = [20, 22, 17, 19, 18]

# Fixed costs for each plant
fixedCosts = [12000, 15000, 17000, 13000, 16000]

# Transportation costs per thousand units
transCosts = [[4000, 2000, 3000, 2500, 4500],
              [2500, 2600, 3400, 3000, 4000],
              [1200, 1800, 2600, 4100, 3000],
              [2200, 2600, 3100, 3700, 3200]]

# Range of plants and warehouses
plants = range(len(capacity))
warehouses = range(len(demand))

# Model
m = Model("facility")

# Plant open decision variables: open[p] == 1 if plant p is open.
open = m.addVars(plants,
                 vtype=GRB.BINARY,
                 obj=fixedCosts,
                 name="open")

# Transportation decision variables: transport[w,p] captures the
# optimal quantity to transport to warehouse w from plant p
transport = m.addVars(warehouses, plants, obj=transCosts, name="trans")

# You could use Python looping constructs and m.addVar() to create
# these decision variables instead. The following would be equivalent
# to the preceding two statements...
#
#open = []
#for p in plants:
#    open.append(m.addVar(vtype=GRB.BINARY,
#                         obj=fixedCosts[p],
#                         name="open[%d"] % p))
#
#transport = []
#for w in warehouses:
#    transport.append([])
#for p in plants:
#    transport[w].append(m.addVar(obj=transCosts[w][p],
#                                  name="trans[%d,%d"] % (w, p))
#
# The objective is to minimize the total fixed and variable costs
m.modelSense = GRB.MINIMIZE

# Production constraints
# Note that the right-hand limit sets the production to zero if the plant
# is closed
m.addConstrs((transport.sum('*') <= capacity[p]*open[p] for p in plants),
"Capacity")

# Using Python looping constructs, the preceding would be...
#
# for p in plants:
#   m.addConstr(sum(transport[w][p] for w in warehouses) <= capacity[p] * open[p],
#               "Capacity[%d]" % p)

# Demand constraints
m.addConstrs(
    (transport.sum(w) == demand[w] for w in warehouses),
    "Demand")

# ... and the preceding would be ...
# for w in warehouses:
#   m.addConstr(sum(transport[w][p] for p in plants) == demand[w], "Demand[%d]" % w)

# Save model
m.write('facilityPY.lp')

# Guess at the starting point: close the plant with the highest fixed costs; open all others

# First, open all plants
for p in plants:
    open[p].start = 1.0

# Now close the plant with the highest fixed cost
print('Initial guess:')
maxFixed = max(fixedCosts)
for p in plants:
    if fixedCosts[p] == maxFixed:
        open[p].start = 0.0
        print('Closing plant %s' % p)
    break

print('')

# Use barrier to solve root relaxation
m.Params.method = 2

# Solve
m.optimize()

# Print solution
print('
TOTAL COSTS: %g' % m.objVal)
print('SOLUTION:')
for p in plants:
    if open[p].x > 0.99:
        print('Plant %s open' % p)
    for w in warehouses:
        if transport[w,p].x > 0:
            print('Transport %g units to warehouse %s' % 
                (transport[w,p].x, w))
        else:
            print('Plant %s closed!' % p)
feasopt.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# This example reads a MIP model from a file, adds artificial
# variables to each constraint, and then minimizes the sum of the
# artificial variables. A solution with objective zero corresponds
# to a feasible solution to the input model.
# We can also use FeasRelax feature to do it. In this example, we
# use minrelax=1, i.e. optimizing the returned model finds a solution
# that minimizes the original objective, but only from among those
# solutions that minimize the sum of the artificial variables.

import sys
from gurobipy import *

if len(sys.argv) < 2:
    print('Usage: feasopt.py filename')
    quit()

feasmodel = gurobi.read(sys.argv[1])

# create a copy to use FeasRelax feature later
feasmodel1 = feasmodel.copy()

# clear objective
feasmodel.setObjective(0.0)

# add slack variables
for c in feasmodel.getConstrs():
    sense = c.sense
    if sense != '>':
        feasmodel.addVar(obj=1.0, name="ArtN_" + c.constrName,
                          column=Column([-1], [c]))
    if sense != '<':
        feasmodel.addVar(obj=1.0, name="ArtP_" + c.constrName,
                          column=Column([1], [c]))

# optimize modified model
feasmodel.optimize()

feasmodel.write('feasopt.lp')

# use FeasRelax feature
feasmodel1.feasRelaxS(0, True, False, True);
feasmodel1.write("feasopt1.lp");
feasmodel1.optimize();

fixanddive.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Implement a simple MIP heuristic. Relax the model,
# sort variables based on fractionality, and fix the 25% of
# the fractional variables that are closest to integer variables.
# Repeat until either the relaxation is integer feasible or
# linearly infeasible.

import sys
from gurobipy import *

# Key function used to sort variables based on relaxation fractionality

def sortkey(v1):
    sol = v1.x
    return abs(sol-int(sol+0.5))

if len(sys.argv) < 2:
    print('Usage: fixanddive.py filename')
    quit()

# Read model
model = gurobi.read(sys.argv[1])

# Collect integer variables and relax them
intvars = []
for v in model.getVars():
    if v.vType != GRB.CONTINUOUS:
        intvars += [v]
    v.vType = GRB.CONTINUOUS

model.Params.outputFlag = 0
model.optimize()

# Perform multiple iterations. In each iteration, identify the first
# quartile of integer variables that are closest to an integer value in the
# relaxation, fix them to the nearest integer, and repeat.

for iter in range(1000):

    # create a list of fractional variables, sorted in order of increasing
    # distance from the relaxation solution to the nearest integer value

    fractional = []
    for v in intvars:
sol = v.x
if abs(sol - int(sol+0.5)) > 1e-5:
    fractional += [v]

fractional.sort(key=sortkey)

print('Iteration %d, obj %g, fractional %d' %
      (iter, model.objVal, len(fractional)))

if len(fractional) == 0:
    print('Found feasible solution - objective %g' % model.objVal)
    break

# Fix the first quartile to the nearest integer value
nfix = max(int(len(fractional)/4), 1)
for i in range(nfix):
    v = fractional[i]
    fixval = int(v.x+0.5)
    v.lb = fixval
    v.ub = fixval
    print('Fix %s to %g (rel %g)' % (v.varName, fixval, v.x))

model.optimize()

# Check optimization result
if model.status != GRB.Status.OPTIMAL:
    print('Relaxation is infeasible')
    break

---

genconstr.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# In this example we show the use of general constraints for modeling
# some common expressions. We use as an example a SAT-problem where we
# want to see if it is possible to satisfy at least four (or all) clauses
# of the logical for
# #
# # L = (x0 or -x1 or x2) and (x1 or -x2 or x3) and
# #  (x2 or -x3 or x0) and (x3 or -x0 or x1) and
# #  (-x0 or -x1 or x2) and (-x1 or -x2 or x3) and
# #  (-x2 or -x3 or x0) and (-x3 or -x0 or x1)
# #
# # We do this by introducing two variables for each literal (itself and its
# # negated value), a variable for each clause, and then two
# # variables for indicating if we can satisfy four, and another to identify
# # the minimum of the clauses (so if it is one, we can satisfy all clauses)
# # and put these two variables in the objective.
# # i.e. the Objective function will be
# #
# # maximize Obj0 + Obj1
# #
# Obj0 = MIN(Clause1, ..., Clause8)
# Obj1 = 1 -> Clause1 + ... + Clause8 >= 4
#
# thus, the objective value will be two if and only if we can satisfy all
# clauses; one if and only if at least four clauses can be satisfied, and
# zero otherwise.

from gurobipy import *

try:
    NLITERALS = 4
    n = NLITERALS

    # Example data:
    # e.g. {0, n+1, 2} means clause (x0 or ~x1 or x2)
    Clauses = [[0, n+1, 2],
               [1, n+2, 3],
               [2, n+3, 0],
               [3, n+0, 1],
               [n+0, n+1, 2],
               [n+1, n+2, 3],
               [n+2, n+3, 0],
               [n+3, n+0, 1]]

    # Create a new model
    model = Model("Genconstr")

    # initialize decision variables and objective
    Lit = model.addVars(NLITERALS, vtype=GRB.BINARY, name="X")
    NotLit = model.addVars(NLITERALS, vtype=GRB.BINARY, name="NotX")
    Cla = model.addVars(len(Clauses), vtype=GRB.BINARY, name="Clause")
    Obj0 = model.addVar(vtype=GRB.BINARY, name="Obj0")
    Obj1 = model.addVar(vtype=GRB.BINARY, name="Obj1")

    # Link Xi and notXi
    model.addConstrs((Lit[i] + NotLit[i] == 1.0 for i in range(NLITERALS)),
                     name="CNSTR_X")

    # Link clauses and literals
    for i, c in enumerate(Clauses):
        clause = []
        for l in c:
            if l >= n:
                clause.append(NotLit[l-n])
            else:
                clause.append(Lit[l])
        model.addConstr(Cla[i] == or_(clause), "CNSTR_Clause" + str(i))

    # Link objs with clauses
    model.addConstr(Obj0 == min_(Cla), name="CNSTR_Obj0")
    model.addConstr((Obj1 == 1) >> (Cla.sum() >= 4.0), name="CNSTR_Obj1")

    # Set optimization objective
model.setObjective(Obj0 + Obj1, GRB.MAXIMIZE)

# Save problem
model.write("genconstr.mps")
model.write("genconstr.lp")

# Optimize
model.optimize()

# Status checking
status = model.getAttr(GRB.Attr.Status)

if status == GRB.INF_OR_UNBD or status == GRB.INFEASIBLE or status == GRB.UNBOUNDED:
    print("The model cannot be solved because it is infeasible or unbounded")
    sys.exit(1)
if status != GRB.OPTIMAL:
    print("Optimization was stopped with status ", status)
    sys.exit(1)

# Print result
objval = model.getAttr(GRB.Attr.ObjVal)

if objval > 1.9:
    print("Logical expression is satisfiable")
elif objval > 0.9:
    print("At least four clauses can be satisfied")
else:
    print("Not even three clauses can be satisfied")

except GurobiError as e:
    print('Error code ' + str(e.errno) + ": " + str(e))

except AttributeError:
    print('Encountered an attribute error')

lp.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# This example reads an LP model from a file and solves it.
# If the model is infeasible or unbounded, the example turns off
# presolve and solves the model again. If the model is infeasible,
# the example computes an Irreducible Inconsistent Subsystem (IIS),
# and writes it to a file

import sys
from gurobipy import *

if len(sys.argv) < 2:
    print("Usage: lp.py filename")
    quit()
# Read and solve model

```python
model = read(sys.argv[1])
model.optimize()
```

```python
if model.status == GRB.Status.INF_OR_UNBD:
    # Turn presolve off to determine whether model is infeasible
    # or unbounded
    model.setParam(GRB.Param.Presolve, 0)
    model.optimize()
```

```python
if model.status == GRB.Status.OPTIMAL:
    print('Optimal objective: %g' % model.objVal)
    model.write('model.sol')
    exit(0)
elif model.status != GRB.Status.INFEASIBLE:
    print('Optimization was stopped with status %d' % model.status)
    exit(0)
```

```python
# Model is infeasible - compute an Irreducible Inconsistent Subsystem (IIS)
print('')
print('Model is infeasible')
model.computeIIS()
model.write("model.ilp")
print("IIS written to file 'model.ilp'")
```

-----

```
lpmethod.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Solve a model with different values of the Method parameter;
# show which value gives the shortest solve time.

import sys
from gurobipy import *

if len(sys.argv) < 2:
    print('Usage: lpmethod.py filename')
    quit()

# Read model
m = read(sys.argv[1])

# Solve the model with different values of Method
bestTime = m.Params.timeLimit
bestMethod = -1
for i in range(3):
    m.reset()
    m.Params.method = i
    m.optimize()
    if m.status == GRB.Status.OPTIMAL:
        bestTime = m.Runtime
```

379
bestMethod = i
    # Reduce the TimeLimit parameter to save time with other methods
    m.Params.timeLimit = bestTime

    # Report which method was fastest
    if bestMethod == -1:
        print('Unable to solve this model')
    else:
        print('Solved in %g seconds with Method %d' % (bestTime, bestMethod))

lpmod.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# This example reads an LP model from a file and solves it.
# If the model can be solved, then it finds the smallest positive variable,
# sets its upper bound to zero, and resolves the model two ways:
# first with an advanced start, then without an advanced start
# (i.e. 'from scratch').

import sys
from gurobipy import *

if len(sys.argv) < 2:
    print('Usage: lpmod.py filename')
    quit()

# Read model and determine whether it is an LP

model = read(sys.argv[1])
if model.isMIP == 1:
    print('The model is not a linear program')
    exit(1)

model.optimize()

status = model.status

if status == GRB.Status.INF_OR_UNBD or status == GRB.Status.INFEASIBLE or status == GRB.Status.UNBOUNDED:
    print('The model cannot be solved because it is infeasible or unbounded')
    exit(1)

if status != GRB.Status.OPTIMAL:
    print('Optimization was stopped with status %d' % status)
    exit(0)

# Find the smallest variable value
minVal = GRB.INFINITY
for v in model.getVars():
    if v.x > 0.0001 and v.x < minVal and v.lb == 0.0:
        minVal = v.x
        minVar = v
**mip1.py**

```python
print('
*** Setting %s from %g to zero ***
' % ( minVar.varName, minVal))
minVar.ub = 0.0

# Solve from this starting point
model.optimize()

# Save iteration & time info
warmCount = model.IterCount
warmTime = model.Runtime

# Reset the model and resolve
print('
*** Resetting and solving without an advanced start ***
')
model.reset()
model.optimize()

coldCount = model.IterCount
coldTime = model.Runtime

print('')
print('*** Warm start: %g iterations, %g seconds *** (%(warmCount, warmTime))
print('*** Cold start: %g iterations, %g seconds *** (%(coldCount, coldTime))
```

```python
mip1.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# This example formulates and solves the following simple MIP model:
# maximize
#   x + y + 2 z
# subject to
#   x + 2 y + 3 z <= 4
#   x + y >= 1
# x, y, z binary

from gurobipy import *

try:

    # Create a new model
    m = Model("mip1")

    # Create variables
    x = m.addVar(vtype=GRB.BINARY, name="x")
    y = m.addVar(vtype=GRB.BINARY, name="y")
    z = m.addVar(vtype=GRB.BINARY, name="z")

    # Set objective
    m.setObjective(x + y + 2 * z, GRB.MAXIMIZE)

    # Add constraint: x + 2 y + 3 z <= 4
    m.addConstr(x + 2 * y + 3 * z <= 4, "c0")

    # Add constraint: x + y >= 1
    m.addConstr(x + y >= 1, "c1")
```

381
m.optimize()

for v in m.getVars():
    print('%s %g' % (v.varName, v.x))

print('Obj: %g' % m.objVal)

except GurobiError as e:
    print('Error code ' + str(e.errno) + ': ' + str(e))

except AttributeError:
    print('Encountered an attribute error')

mip2.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# This example reads a MIP model from a file, solves it and prints
# the objective values from all feasible solutions generated while
# solving the MIP. Then it creates the associated fixed model and
# solves that model.

import sys
from gurobipy import *

if len(sys.argv) < 2:
    print('Usage: mip2.py filename')
    quit()

# Read and solve model

model = read(sys.argv[1])

if model.isMIP == 0:
    print('Model is not a MIP')
    exit(0)

model.optimize()

if model.status == GRB.Status.OPTIMAL:
    print('Optimal objective: %g' % model.objVal)
elif model.status == GRB.Status.INF_OR_UNBD:
    print('Model is infeasible or unbounded')
    exit(0)
elif model.status == GRB.Status.INFEASIBLE:
    print('Model is infeasible')
    exit(0)
elif model.status == GRB.Status.UNBOUNDED:
    print('Model is unbounded')
    exit(0)
else:
    print('Optimization ended with status %d' % model.status)
    exit(0)
# Iterate over the solutions and compute the objectives
model.Params.outputFlag = 0
print('
for k in range(model.solCount):
    model.Params.solutionNumber = k
    objn = 0
    for v in model.getVars():
        objn += v.obj * v.xn
    print(' Solution %d has objective %g' % (k, objn))
print('
model.Params.outputFlag = 1

fixed = model.fixed()
fixed.Params.presolve = 0
fixed.optimize()

if fixed.status != GRB.Status.OPTIMAL:
    print("Error: fixed model isn't optimal")
    exit(1)

diff = model.objVal - fixed.objVal

if abs(diff) > 1e-6 * (1.0 + abs(model.objVal)):
    print('Error: objective values are different')
    exit(1)

# Print values of nonzero variables
for v in fixed.getVars():
    if v.x != 0:
        print('%s %g' % (v.varName, v.x))

multiobj.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Want to cover three different sets but subject to a common budget of
# elements allowed to be used. However, the sets have different priorities to
# be covered; and we tackle this by using multi-objective optimization.

from __future__ import print_function
from gurobipy import *

try:
    # Sample data
    Groundset = range(20)
    Subsets = range(4)
    Budget = 12;
    Set = [
        [1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0],
        [0, 0, 0, 0, 0, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1],
        [0, 0, 0, 1, 1, 0, 1, 1, 0, 0, 0, 0, 0, 1, 1, 0, 1, 1, 0, 0],
        [0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0] ]
    SetObjPriority = [3, 2, 2, 1]
    SetObjWeight = [1.0, 0.25, 1.25, 1.0]
# Create initial model
model = Model('multiobj')

# Initialize decision variables for ground set:
# x[e] == 1 if element e is chosen for the covering.
Elem = model.addVars(Groundset, vtype=GRB.BINARY, name='El')

# Constraint: limit total number of elements to be picked to be at most
# Budget
model.addConstr(Elem.sum() <= Budget, name='Budget')

# Set global sense for ALL objectives
model.ModelSense = GRB.MAXIMIZE

# Limit how many solutions to collect
model.setParam(GRB.Param.PoolSolutions, 100)

# Set and configure i-th objective
for i in Subsets:
    objn = sum(Elem[k]*Set[i][k] for k in range(len(Elem)))
    model.setObjectiveN(objn, i, SetObjPriority[i], SetObjWeight[i],
                        1.0 + i, 0.01, 'Set' + str(i))

# Save problem
model.write('multiobj.lp')

# Optimize
model.optimize()

model.setParam(GRB.Param.OutputFlag, 0)

# Status checking
status = model.Status
if status == GRB.Status.INF_OR_UNBD or 
    status == GRB.Status.INFEASIBLE or 
    status == GRB.Status.UNBOUNDED:
    print('The model cannot be solved because it is infeasible or unbounded')
    sys.exit(1)

if status != GRB.Status.OPTIMAL:
    print('Optimization was stopped with status ' + str(status))
    sys.exit(1)

# Print best selected set
print('Selected elements in best solution:')
for e in Groundset:
    if Elem[e].X > 0.9:
        print(' El%d ' % e, end='')
print('')

# Print number of solutions stored
nSolutions = model.SolCount
print('Number of solutions found: ' + str(nSolutions))

# Print objective values of solutions
if nSolutions > 10:
    nSolutions = 10
print('Objective values for first ' + str(nSolutions) + ' solutions: ')
for i in Subsets:
    model.setParam(GRB.Param.ObjNumber, i)
    print('	Set %d' % i, end='')
for e in range(nSolutions):
    model.setParam(GRB.Param.SolutionNumber, e)
    print(' %6g' % model.ObjNVal, end='')
print('')

except GurobiError as e:
    print('Error code ' + str(e.errno) + ': ' + str(e))
except AttributeError as e:
    print('Encountered an attribute error: ' + str(e))

netflow.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Solve a multi-commodity flow problem. Two products ('Pencils' and 'Pens')
# are produced in 2 cities ('Detroit' and 'Denver') and must be sent to
# warehouses in 3 cities ('Boston', 'New York', and 'Seattle') to
# satisfy demand ('inflow[h,i]').
#
# Flows on the transportation network must respect arc capacity constraints
# ('capacity[i,j]'). The objective is to minimize the sum of the arc
# transportation costs ('cost[i,j]').

from gurobipy import *

# Model data

commodities = ['Pencils', 'Pens']
nodes = ['Detroit', 'Denver', 'Boston', 'New York', 'Seattle']

arcs, capacity = multidict({
    ('Detroit', 'Boston'): 100,
    ('Detroit', 'New York'): 80,
    ('Detroit', 'Seattle'): 120,
    ('Denver', 'Boston'): 120,
    ('Denver', 'New York'): 120,
    ('Denver', 'Seattle'): 120})

cost = {
    ('Pencils', 'Detroit', 'Boston'): 10,
    ('Pencils', 'Detroit', 'New York'): 20,
    ('Pencils', 'Detroit', 'Seattle'): 60,
    ('Pencils', 'Denver', 'Boston'): 40,
    ('Pencils', 'Denver', 'New York'): 40,
    ('Pencils', 'Denver', 'Seattle'): 30,
    ('Pens', 'Detroit', 'Boston'): 20,
    ('Pens', 'Detroit', 'New York'): 20,
inflow = {
('Pencils', 'Detroit'): 50,
('Pencils', 'Denver'): 60,
('Pencils', 'Boston'): -50,
('Pencils', 'New York'): -50,
('Pencils', 'Seattle'): -10,
('Pens', 'Detroit'): 60,
('Pens', 'Denver'): 40,
('Pens', 'Boston'): -40,
('Pens', 'New York'): -30,
('Pens', 'Seattle'): -30
}

# Create optimization model
m = Model('netflow')

# Create variables
flow = m.addVars(commodities, arcs, obj=cost, name="flow")

# Arc capacity constraints
m.addConstrs(
  (flow.sum('*',i,j) <= capacity[i,j] for i,j in arcs), "cap")

# Equivalent version using Python looping
# for i,j in arcs:
#   m.addConstr (sum (flow[h,i,j] for h in commodities) <= capacity[i,j],
#                 "cap[%s,%s]" % (i, j))

# Flow conservation constraints
m.addConstrs(
  (flow.sum(h,'*',j) + inflow[h,j] == flow.sum(h,j,'*')
   for h in commodities for j in nodes), "node")

# Alternate version:
# m.addConstrs(
#   (quicksum (flow[h,i,j] for i,j in arcs.select('*',j)) + inflow[h,j] ==
#    quicksum (flow[h,j,k] for j,k in arcs.select(j,'*'))
#   for h in commodities for j in nodes), "node")

# Compute optimal solution
m.optimize()

# Print solution
if m.status == GRB.Status.OPTIMAL:
    solution = m.getAttr('x', flow)
    for h in commodities:
        print('
Optimal flows for %s:' % h)
        for i,j in arcs:
            if solution[h,i,j] > 0:
                print('%s -> %s: %g' % (i, j, solution[h,i,j]))
params.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Use parameters that are associated with a model.
# A MIP is solved for a few seconds with different sets of parameters.
# The one with the smallest MIP gap is selected, and the optimization
# is resumed until the optimal solution is found.

import sys
from gurobipy import *

if len(sys.argv) < 2:
    print('Usage: params.py filename')
    quit()

# Read model and verify that it is a MIP
m = read(sys.argv[1])
if m.isMIP == 0:
    print('The model is not an integer program')
    exit(1)

# Set a 2 second time limit
m.Params.timeLimit = 2

# Now solve the model with different values of MIPFocus
bestModel = m.copy()
bestModel.optimize()
for i in range(1, 4):
    m.reset()
    m.Params.MIPFocus = i
    m.optimize()
    if bestModel.MIPGap > m.MIPGap:
        bestModel, m = m, bestModel

# Finally, delete the extra model, reset the time limit and
# continue to solve the best model to optimality
del m
bestModel.Params.timeLimit = "default"
bestModel.optimize()
print('Solved with MIPFocus: %d' % bestModel.Params.MIPFocus)

piecewise.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# This example considers the following separable, convex problem:
# minimize f(x) - y + g(z)
# subject to  x + 2 y + 3 z <= 4
# $x + y \geq 1$
# $x, y, z \leq 1$
#
# where $f(u) = \exp(-u)$ and $g(u) = 2u^2 - 4u$, for all real $u$. It
# formulates and solves a simpler LP model by approximating $f$ and
# $g$ with piecewise-linear functions. Then it transforms the model
# into a MIP by negating the approximation for $f$, which corresponds
# to a non-convex piecewise-linear function, and solves it again.

from gurobipy import *
from math import exp

def f(u):
    return exp(-u)

def g(u):
    return 2 * u * u - 4 * u

try:
    # Create a new model
    m = Model()
    # Create variables
    lb = 0.0
    ub = 1.0
    x = m.addVar(lb, ub, name='x')
    y = m.addVar(lb, ub, name='y')
    z = m.addVar(lb, ub, name='z')
    # Set objective for $y$
    m.setObjective(-y)
    # Add piecewise-linear objective functions for $x$ and $z$
    npts = 101
    ptu = []
    ptf = []
    ptg = []
    for i in range(npts):
        ptu.append(lb + (ub - lb) * i / (npts - 1))
        ptf.append(f(ptu[i]))
        ptg.append(g(ptu[i]))
    m.setPWLObj(x, ptu, ptf)
    m.setPWLObj(z, ptu, ptg)
    # Add constraint: $x + 2y + 3z \leq 4$
    m.addConstr(x + 2 * y + 3 * z <= 4, 'c0')
# Add constraint: x + y >= 1
m.addConstr(x + y >= 1, 'c1')

# Optimize model as an LP
m.optimize()

print('IsMIP: %d' % m.IsMIP)
for v in m.getVars():
    print('%s %g' % (v.VarName, v.X))
print('Obj: %g % m.ObjVal)
print('')

# Negate piecewise-linear objective function for x
for i in range(npts):
    ptf[i] = -ptf[i]

m.setPWLObj(x, ptu, ptf)

# Optimize model as a MIP
m.optimize()

print('IsMIP: %d' % m.IsMIP)
for v in m.getVars():
    print('%s %g' % (v.VarName, v.X))
print('Obj: %g % m.ObjVal)

except GurobiError as e:
    print('Error code ' + str(e.errno) + ": " + str(e))
except AttributeError:
    print('Encountered an attribute error')

poolsearch.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# We find alternative epsilon-optimal solutions to a given knapsack problem by using PoolSearchMode

try:
    # Sample data
    Groundset = range(10)
    objCoef = [32, 32, 15, 15, 6, 6, 1, 1, 1, 1]
    knapsackCoef = [16, 16, 8, 8, 4, 4, 2, 2, 1, 1]
    Budget = 33

    # Create initial model
model = Model("poolsearch")

# Create dicts for tupledict . prod () function
objCoefDict = dict(zip(Groundset, objCoef))
knapsackCoefDict = dict(zip(Groundset, knapsackCoef))

# Initialize decision variables for ground set:
# x[e] == 1 if element e is chosen
Elem = model.addVars(Groundset, vtype=GRB.BINARY, name='El')

# Set objective function
model.ModelSense = GRB.MAXIMIZE
model.setObjective(Elem.prod(objCoefDict))

# Constraint: limit total number of elements to be picked to be at most
# Budget
model.addConstr(Elem.prod(knapsackCoefDict) <= Budget, name='Budget')

# Limit how many solutions to collect
model.setParam(GRB.Param.PoolSolutions, 1024)
# Limit the search space by setting a gap for the worst possible solution that will be accepted
model.setParam(GRB.Param.PoolGap, 0.10)
# do a systematic search for the k-best solutions
model.setParam(GRB.Param.PoolSearchMode, 2)

# save problem
model.write('poolsearch.lp')

# Optimize
model.optimize()
model.setParam(GRB.Param.OutputFlag, 0)

# Status checking
status = model.Status
if status == GRB.Status.INF_OR_UNBD or 
   status == GRB.Status.INFEASIBLE or 
   status == GRB.Status.UNBOUNDED:
   print('The model cannot be solved because it is infeasible or unbounded')
sys.exit(1)

if status != GRB.Status.OPTIMAL:
   print('Optimization was stopped with status ' + str(status))
sys.exit(1)

# Print best selected set
print('Selected elements in best solution:')
print('', end='')
for e in Groundset:
   if Elem[e].X > .9:
      print(' El%d' % e, end='')
print('')

# Print number of solutions stored
nSolutions = model.SolCount
print('Number of solutions found: ' + str(nSolutions))
# Print objective values of solutions
for e in range(nSolutions):
    model.setParam(GRB.Param.SolutionNumber, e)
    print('%g % model.PoolObjVal, end=')
if e % 15 == 14:
    print('')
print('')

# print fourth best set if available
if (nSolutions >= 4):
    model.setParam(GRB.Param.SolutionNumber, 3);
    print('Selected elements in fourth best solution:')
    print('', end='')
    for e in Groundset:
        if Elem[e].Xn > .9:
            print(' El%d' % e, end='')
    print('')
except GurobiError as e:
    print('Gurobi error' + str(e.errno) + ': ' + str(e.message))
except AttributeError as e:
    print('Encountered an attribute error: ' + str(e))

portfolio.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Portfolio selection: given a sum of money to invest, one must decide how to
# spend it amongst a portfolio of financial securities. Our approach is due
# to Markowitz (1959) and looks to minimize the risk associated with the
# investment while realizing a target expected return. By varying the target,
# one can compute an 'efficient frontier', which defines the optimal portfolio
# for a given expected return.
# # Note that this example reads historical return data from a comma-separated
# file (../data/portfolio.csv). As a result, it must be run from the Gurobi
# examples/python directory.
#
# This example requires the pandas, NumPy, and Matplotlib Python packages,
# which are part of the SciPy ecosystem for mathematics, science, and
# engineering (http://scipy.org). These packages aren't included in all
# Python distributions, but are included by default with Anaconda Python.

from gurobipy import *
from math import sqrt
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt

# Import (normalized) historical return data using pandas
data = pd.DataFrame.from_csv('../data/portfolio.csv')
stocks = data.columns

# Calculate basic summary statistics for individual stocks
stock_volatility = data.std()
stock_return = data.mean()

# Create an empty model
m = Model('portfolio')

# Add a variable for each stock
vars = pd.Series(m.addVars(stocks), index=stocks)

# Objective is to minimize risk (squared). This is modeled using the
# covariance matrix, which measures the historical correlation between stocks.
sigma = data.cov()
portfolio_risk = sigma.dot(vars).dot(vars)
m.setObjective(portfolio_risk, GRB.MINIMIZE)

# Fix budget with a constraint
m.addConstr(sum(vars) == 1, 'budget')

# Optimize model to find the minimum risk portfolio
m.setParam('OutputFlag', 0)
m.optimize()

# Create an expression representing the expected return for the portfolio
portfolio_return = stock_return.dot(vars)

# Display minimum risk portfolio
print('Minimum Risk Portfolio:
')
for v in vars:
    if v.x > 0:
        print('    %s: %g' % (v.varname, v.x))

minrisk_volatility = sqrt(portfolio_risk.getValue())
print('Volatility = %g' % minrisk_volatility)

minrisk_return = portfolio_return.getValue()
print('Expected Return = %g' % minrisk_return)

# Add (redundant) target return constraint
target = m.addConstr(portfolio_return == minrisk_return, 'target')

# Solve for efficient frontier by varying target return
frontier = pd.Series()
for r in np.linspace(stock_return.min(), stock_return.max(), 100):
    target.rhs = r
    m.optimize()
    frontier.loc[sqrt(portfolio_risk.getValue())] = r

# Plot volatility versus expected return for individual stocks
ax = plt.gca()
ax.scatter(x=stock_volatility, y=stock_return, color='Blue', label='Individual Stocks')
for i, stock in enumerate(stocks):
    ax.annotate(stock, (stock_volatility[i], stock_return[i]))

# Plot volatility versus expected return for minimum risk portfolio
ax.scatter(x=minrisk_volatility, y=minrisk_return, color='DarkGreen')
ax.annotate('Minimum Risk Portfolio', (minrisk_volatility, minrisk_return), horizontalalignment='right')

# Plot efficient frontier
frontier.plot(color='DarkGreen', label='Efficient Frontier', ax=ax)

# Format and display the final plot
ax.axis([0.005, 0.06, -0.02, 0.025])
ax.set_xlabel('Volatility (standard deviation)')
ax.set_ylabel('Expected Return')
ax.legend()
ax.grid()
plt.show()

qcp.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# This example formulates and solves the following simple QCP model:
# maximize x
# subject to x + y + z = 1
# x^2 + y^2 <= z^2 (second-order cone)
# x^2 <= yz (rotated second-order cone)

from gurobipy import *

# Create a new model
m = Model("qcp")

# Create variables
x = m.addVar(name="x")
y = m.addVar(name="y")
z = m.addVar(name="z")

# Set objective: x
obj = 1.0*x
m.setObjective(obj, GRB.MAXIMIZE)

# Add constraint: x + y + z = 1
m.addConstr(x + y + z == 1, "c0")

# Add second-order cone: x^2 + y^2 <= z^2
m.addConstr(x*x + y*y <= z*z, "qc0")

# Add rotated cone: x^2 <= yz
m.addConstr(x*x <= y*z, "qc1")

m.optimize()

for v in m.getVars():
    print('%s %g' % (v.varName, v.x))

print('Obj: %g' % obj.getValue())
qp.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# This example formulates and solves the following simple QP model:
# minimize
# x^2 + x*y + y^2 + y*z + z^2 + 2 x
# subject to
#  x + 2 y + 3 z >= 4
#  x + y >= 1
#
# It solves it once as a continuous model, and once as an integer model.

from gurobipy import *

# Create a new model
m = Model("qp")

# Create variables
x = m.addVar(ub=1.0, name="x")
y = m.addVar(ub=1.0, name="y")
z = m.addVar(ub=1.0, name="z")

# Set objective: x^2 + x*y + y^2 + y*z + z^2 + 2 x
obj = x*x + x*y + y*y + y*z + z*z + 2*x
m.setObjective(obj)

# Add constraint: x + 2 y + 3 z <= 4
m.addConstr(x + 2 * y + 3 * z >= 4, "c0")

# Add constraint: x + y >= 1
m.addConstr(x + y >= 1, "c1")

m.optimize()

for v in m.getVars():
    print('%s %g' % (v.varName, v.x))

print('Obj: %g' % obj.getValue())

x.vType = GRB.INTEGER
y.vType = GRB.INTEGER
z.vType = GRB.INTEGER

m.optimize()

for v in m.getVars():
    print('%s %g' % (v.varName, v.x))

print('Obj: %g' % obj.getValue())

sensitivity.py

#!/usr/bin/python
import sys
from gurobipy import *

# Copyright 2018, Gurobi Optimization, LLC
# A simple sensitivity analysis example which reads a MIP model
# from a file and solves it. Then each binary variable is set
to 1-X, where X is its value in the optimal solution, and
# the impact on the objective function value is reported.

# Read and solve model
model = read(sys.argv[1])
if model.IsMIP == 0:
    print('Model is not a MIP')
    exit(0)
model.optimize()

if model.status != GRB.Status.OPTIMAL:
    print('Optimization ended with status %d' % model.status)
    exit(0)

# Store the optimal solution
origObjVal = model.ObjVal
for v in model.getVars():
    v._origX = v.X

# Disable solver output for subsequent solves
model.Params.outputFlag = 0

# Iterate through unfixed, binary variables in model
for v in model.getVars():
    if (v.LB == 0 and v.UB == 1 \
        and (v.VType == GRB.BINARY or v.VType == GRB.INTEGER)):
        # Set variable to 1-X, where X is its value in optimal solution

        if v._origX < 0.5:
            v.LB = v.Start = 1
        else:
            v.UB = v.Start = 0

        # Update MIP start for the other variables
        for vv in model.getVars():
            if not vv.sameAs(v):
vv.Start = vv._origX

# Solve for new value and capture sensitivity information
model.optimize()

if model.status == GRB.Status.OPTIMAL:
    print('Objective sensitivity for variable %s is %g' %
          (v.VarName, model.ObjVal - origObjVal))
else:
    print('Objective sensitivity for variable %s is infinite' %
          v.VarName)

# Restore the original variable bounds
v.LB = 0
v.UB = 1

sos.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# This example creates a very simple Special Ordered Set (SOS) model.
# The model consists of 3 continuous variables, no linear constraints,
# and a pair of SOS constraints of type 1.

from gurobipy import *

try:
    # Create a new model
    model = Model("sos")

    # Create variables
    x0 = model.addVar(ub=1.0, name="x0")
    x1 = model.addVar(ub=1.0, name="x1")
    x2 = model.addVar(ub=2.0, name="x2")

    # Set objective
    model.setObjective(2 * x0 + x1 + x2, GRB.MAXIMIZE)

    # Add first SOS: x0 = 0 or x1 = 0
    model.addSOS(GRB.SOS_TYPE1, [x0, x1], [1, 2])

    # Add second SOS: x0 = 0 or x2 = 0
    model.addSOS(GRB.SOS_TYPE1, [x0, x2], [1, 2])

    model.optimize()

    for v in model.getVars():
        print('%s %g' % (v.varName, v.x))
print('Obj: %g' % model.objVal)

except GurobiError as e:
    print('Error code ' + str(e.errno) + ': ' + str(e))

except AttributeError:
    print('Encountered an attribute error')

sudoku.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Sudoku example.

# The Sudoku board is a 9x9 grid, which is further divided into a 3x3 grid
# of 3x3 grids. Each cell in the grid must take a value from 0 to 9.
# No two grid cells in the same row, column, or 3x3 subgrid may take the
# same value.

# In the MIP formulation, binary variables x[i,j,v] indicate whether
# cell <i,j> takes exactly one value. The constraints are as follows:
#  1. Each cell must take exactly one value (sum_v x[i,j,v] = 1)
#  2. Each value is used exactly once per row (sum_i x[i,j,v] = 1)
#  3. Each value is used exactly once per column (sum_j x[i,j,v] = 1)
#  4. Each value is used exactly once per 3x3 subgrid (sum_grid x[i,j,v] = 1)

# Input datasets for this example can be found in examples/data/sudoku*.

import sys
import math
from gurobipy import *

if len(sys.argv) < 2:
    print('Usage: %s filename' % sys.argv[0])
    quit()

f = open(sys.argv[1])

grid = f.read().split()

n = len(grid[0])
s = int(math.sqrt(n))

# Create our 3-D array of model variables

model = Model('sudoku')

vars = model.addVars(n, n, n, vtype=GRB.BINARY, name='G')

# Fix variables associated with cells whose values are pre-specified

for i in range(n):
for j in range(n):
    if grid[i][j] != '.':
        v = int(grid[i][j]) - 1
        vars[i,j,v].LB = 1

# Each cell must take one value
model.addConstrs((vars.sum(i,j,'*') == 1
    for i in range(n)
    for j in range(n)), name='V')

# Each value appears once per row
model.addConstrs((vars.sum(i,'*',v) == 1
    for i in range(n)
    for v in range(n)), name='R')

# Each value appears once per column
model.addConstrs((vars.sum('*',j,v) == 1
    for j in range(n)
    for v in range(n)), name='C')

# Each value appears once per subgrid
model.addConstrs((
    quicksum(vars[i,j,v] for i in range(i0*s, (i0+1)*s)
      for j in range(j0*s, (j0+1)*s)) == 1
    for v in range(n)
    for i0 in range(s)
    for j0 in range(s)), name='Sub')

model.optimize()
model.write('sudoku.lp')

print('Solution:')

# Retrieve optimization result
solution = model.getAttr('X', vars)
for i in range(n):
    sol = ''
    for j in range(n):
        for v in range(n):
            if solution[i,j,v] > 0.5:
                sol += str(v+1)
    print(sol)
tsp.py

#!/usr/bin/python
# Copyright 2018, Gurobi Optimization, LLC

# Solve a traveling salesman problem on a randomly generated set of
# points using lazy constraints. The base MIP model only includes
# ‘degree-2’ constraints, requiring each node to have exactly
# two incident edges. Solutions to this model may contain subtours -
# tours that don’t visit every city. The lazy constraint callback
# adds new constraints to cut them off.

import sys
import math
import random
import itertools
from gurobipy import *

# Callback - use lazy constraints to eliminate sub-tours

def subtourelim(model, where):
    if where == GRB.Callback.MIPSOL:
        # make a list of edges selected in the solution
        vals = model.cbGetSolution(model._vars)
        selected = tuplelist((i,j) for i,j in model._vars.keys() if vals[i,j] > 0.5)
        # find the shortest cycle in the selected edge list
        tour = subtour(selected)
        if len(tour) < n:
            # add subtour elimination constraint for every pair of cities in tour
            model.cbLazy(quicksum(model._vars[i,j] for i,j in itertools.combinations(tour, 2)) <= len(tour)-1)

# Given a tuplelist of edges, find the shortest subtour

def subtour(edges):
    unvisited = list(range(n))
    cycle = range(n+1) # initial length has 1 more city
    while unvisited:
        thiscycle = []
        neighbors = unvisited
        while neighbors:
            current = neighbors[0]
            thiscycle.append(current)
            unvisited.remove(current)
            neighbors = [j for i,j in edges.select(current,'*') if j in unvisited]
        if len(cycle) > len(thiscycle):
            cycle = thiscycle
    return cycle

# Parse argument

if len(sys.argv) < 2:
    print('Usage: tsp.py npoints')
    exit(1)

n = int(sys.argv[1])


# Create n random points

```python
random.seed(1)
points = [(random.randint(0,100),random.randint(0,100)) for i in range(n)]
```

# Dictionary of Euclidean distance between each pair of points

```python
dist = {(i,j) :
    math.sqrt(sum((points[i][k]-points[j][k])**2 for k in range(2))
    for i in range(n) for j in range(i)}
```

```python
m = Model()
```

# Create variables

```python
vars = m.addVars(dist.keys(), obj=dist, vtype=GRB.BINARY, name='e')
for i,j in vars.keys():
    vars[j,i] = vars[i,j] # edge in opposite direction
```

# You could use Python looping constructs and m.addVar() to create
# these decision variables instead. The following would be equivalent
# to the preceding m.addVars() call...

```python
# vars = tupledict()
# for i,j in dist.keys():
#     vars[i,j] = m.addVar(obj=dist[i,j], vtype=GRB.BINARY,
#     name='e[%d,%d]'%(i,j))
```

# Add degree-2 constraint

```python
m.addConstrs(vars.sum(i,'*') == 2 for i in range(n))
```

# Using Python looping constructs, the preceding would be...

```python
# for i in range(n):
#     m.addConstr(sum(vars[i,j] for j in range(n)) == 2)
```

# Optimize model

```python
m._vars = vars
m.Params.lazyConstraints = 1
m.optimize(subtourelim)
```

```python
vals = m.getAttr('x', vars)
selected = tuplelist((i,j) for i,j in vals.keys() if vals[i,j] > 0.5)
tour = subtour(selected)
assert len(tour) == n
```

```python
print('')
print('Optimal tour: %s' % str(tour))
print('Optimal cost: %g' % m.objVal)
print('')
```

400
tune.py

#!/usr/bin/python
# Copyright 2018, Gurobi Optimization, LLC
# This example reads a model from a file and tunes it.
# It then writes the best parameter settings to a file
# and solves the model using these parameters.

import sys
from gurobipy import *

if len(sys.argv) < 2:
    print('Usage: tune.py filename')
    quit()

# Read the model
model = read(sys.argv[1])

# Set the TuneResults parameter to 1
model.Params.tuneResults = 1

# Tune the model
model.tune()

if model.tuneResultCount > 0:
    # Load the best tuned parameters into the model
    model.getTuneResult(0)

    # Write tuned parameters to a file
    model.write('tune.prm')

    # Solve the model using the tuned parameters
    model.optimize()

workforce1.py

#!/usr/bin/python
# Copyright 2018, Gurobi Optimization, LLC
# Assign workers to shifts; each worker may or may not be available on a
# particular day. If the problem cannot be solved, use IIS to find a set of
# conflicting constraints. Note that there may be additional conflicts besides
# what is reported via IIS.

from gurobipy import *

# Number of workers required for each shift
shifts, shiftRequirements = multidict({
    "Mon1": 3,
    "Tue2": 2,
    "Wed3": 4,
    "Thu4": 4,
    "Fri5": 5,
})
"Fri5": 5,
"Sat6": 6,
"Sun7": 5,
"Mon8": 2,
"Tue9": 2,
"Wed10": 3,
"Thu11": 4,
"Fri12": 6,
"Sat13": 7,
"Sun14": 5 }

# Amount each worker is paid to work one shift
workers, pay = multidict({
"Amy": 10,
"Bob": 12,
"Cathy": 10,
"Dan": 8,
"Ed": 8,
"Fred": 9,
"Gu": 11 })

# Worker availability
availability = tuplelist((
('Amy', 'Tue2'), ('Amy', 'Wed3'), ('Amy', 'Fri5'), ('Amy', 'Sun7'),
('Amy', 'Tue9'), ('Amy', 'Wed10'), ('Amy', 'Thu11'), ('Amy', 'Fri12'),
('Amy', 'Sat13'), ('Amy', 'Sun14'), ('Bob', 'Mon1'), ('Bob', 'Tue2'),
('Bob', 'Fri5'), ('Bob', 'Sat6'), ('Bob', 'Mon8'), ('Bob', 'Thu11'),
('Bob', 'Sat13'), ('Cathy', 'Wed3'), ('Cathy', 'Thu4'), ('Cathy', 'Fri5'),
('Cathy', 'Sun7'), ('Cathy', 'Mon8'), ('Cathy', 'Tue9'), ('Cathy', 'Wed10'),
('Cathy', 'Thu11'), ('Cathy', 'Fri12'), ('Cathy', 'Sat13'),
('Cathy', 'Sun14'), ('Dan', 'Tue2'), ('Dan', 'Wed3'), ('Dan', 'Fri5'),
('Dan', 'Sat6'), ('Dan', 'Mon8'), ('Dan', 'Tue9'), ('Dan', 'Wed10'),
('Dan', 'Thu11'), ('Dan', 'Fri12'), ('Dan', 'Sat13'), ('Dan', 'Sun14'),
('Ed', 'Mon1'), ('Ed', 'Tue2'), ('Ed', 'Wed3'), ('Ed', 'Thu4'),
('Ed', 'Fri5'), ('Ed', 'Sun7'), ('Ed', 'Mon8'), ('Ed', 'Tue9'),
('Ed', 'Thu11'), ('Ed', 'Sat13'), ('Ed', 'Sun14'), ('Fred', 'Mon1'),
('Fred', 'Tue2'), ('Fred', 'Wed3'), ('Fred', 'Sat6'), ('Fred', 'Mon8'),
('Fred', 'Tue9'), ('Fred', 'Fri12'), ('Fred', 'Sat13'), ('Fred', 'Sun14'),
('Gu', 'Mon1'), ('Gu', 'Tue2'), ('Gu', 'Wed3'), ('Gu', 'Fri5'),
('Gu', 'Sat6'), ('Gu', 'Sun7'), ('Gu', 'Mon8'), ('Gu', 'Tue9'),
('Gu', 'Wed10'), ('Gu', 'Thu11'), ('Gu', 'Fri12'), ('Gu', 'Sat13'),
('Gu', 'Sun14')
))

# Model
m = Model("assignment")

# Assignment variables: x[w,s] == 1 if worker w is assigned to shift s.
# Since an assignment model always produces integer solutions, we use
# continuous variables and solve as an LP.
x = m.addVars(availability, ub=1, name="x")

# The objective is to minimize the total pay costs
m.setObjective(quicksum(pay[w] * x[w,s] for w,s in availability), GRB.MINIMIZE)

# Constraints: assign exactly shiftRequirements[s] workers to each shift s
reqCts = m.addConstrs((x.sum('s'), s) == shiftRequirements[s] for s in shifts), "_")

# Using Python looping constructs, the preceding statement would be...
#
# reqCts = {}
# for s in shifts:
#    reqCts[s] = m.addConstr(
#        quicksum(x[w,s] for w,s in availability.select('s', s)) ==
#        shiftRequirements[s], s)

# Save model
m.write('workforce1.lp')

# Optimize
m.optimize()
status = m.status
if status == GRB.Status.UNBOUNDED:
    print('The model cannot be solved because it is unbounded')
    exit(0)
if status == GRB.Status.OPTIMAL:
    print('The optimal objective is %f' % m.objVal)
    exit(0)
if status != GRB.Status.INF_OR_UNBD and status != GRB.Status.INFEASIBLE:
    print('Optimization was stopped with status %d' % status)
    exit(0)

# do IIS
print('The model is infeasible; computing IIS')
m.computeIIS()
if m.IISMinimal:
    print('IIS is minimal
')
else:
    print('IIS is not minimal
')
print('
The following constraint(s) cannot be satisfied: ')
for c in m.getConstrs():
    if c.IISConstr:
        print('%s' % c.constrName)

workforce2.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Assign workers to shifts; each worker may or may not be available on a
# particular day. If the problem cannot be solved, use IIS iteratively to
# find all conflicting constraints.
from gurobipy import *

# Number of workers required for each shift
shifts, shiftRequirements = multidict({
    "Mon1": 3,
    "Tue2": 2,
    "Wed3": 4,
})
"Thu4": 4,
"Fri5": 5,
"Sat6": 6,
"Sun7": 5,
"Mon8": 2,
"Tue9": 2,
"Wed10": 3,
"Thu11": 4,
"Fri12": 6,
"Sat13": 7,
"Sun14": 5
})

# Amount each worker is paid to work one shift
workers, pay = multidict({
    "Amy": 10,
    "Bob": 12,
    "Cathy": 10,
    "Dan": 8,
    "Ed": 8,
    "Fred": 9,
    "Gu": 11
})

# Worker availability
availability = tuplelist([
    ("Amy", "Tue2"), ("Amy", "Wed3"), ("Amy", "Fri5"), ("Amy", "Sun7"),
    ("Amy", "Tue9"), ("Amy", "Wed10"), ("Amy", "Thu11"), ("Amy", "Fri12"),
    ("Amy", "Sat13"), ("Amy", "Sun14"), ("Bob", "Mon1"), ("Bob", "Tue2"),
    ("Bob", "Fri5"), ("Bob", "Sat6"), ("Bob", "Mon8"), ("Bob", "Thu11"),
    ("Bob", "Sat13"), ("Cathy", "Wed3"), ("Cathy", "Thu4"), ("Cathy", "Fri5"),
    ("Cathy", "Sun7"), ("Cathy", "Mon8"), ("Cathy", "Tue9"), ("Cathy", "Wed10"),
    ("Cathy", "Thu11"), ("Cathy", "Fri12"), ("Cathy", "Sat13"),
    ("Cathy", "Sun14"), ("Dan", "Tue2"), ("Dan", "Wed3"), ("Dan", "Fri5"),
    ("Dan", "Sat6"), ("Dan", "Mon8"), ("Dan", "Tue9"), ("Dan", "Wed10"),
    ("Dan", "Thu11"), ("Dan", "Fri12"), ("Dan", "Sat13"), ("Dan", "Sun14"),
    ("Ed", "Mon1"), ("Ed", "Tue2"), ("Ed", "Wed3"), ("Ed", "Thu4"),
    ("Ed", "Fri5"), ("Ed", "Sun7"), ("Ed", "Mon8"), ("Ed", "Tue9"),
    ("Ed", "Thu11"), ("Ed", "Sat13"), ("Ed", "Sun14"), ("Fred", "Mon1"),
    ("Fred", "Tue2"), ("Fred", "Wed3"), ("Fred", "Sat6"), ("Fred", "Mon8"),
    ("Fred", "Tue9"), ("Fred", "Fri12"), ("Fred", "Sat13"), ("Fred", "Sun14"),
    ("Gu", "Mon1"), ("Gu", "Tue2"), ("Gu", "Wed3"), ("Gu", "Fri5"),
    ("Gu", "Sat6"), ("Gu", "Sun7"), ("Gu", "Mon8"), ("Gu", "Tue9"),
    ("Gu", "Wed10"), ("Gu", "Thu11"), ("Gu", "Fri12"), ("Gu", "Sat13"),
    ("Gu", "Sun14")
])

# Model
m = Model("assignment")

# Assignment variables: x[w,s] == 1 if worker w is assigned to shift s.
# Since an assignment model always produces integer solutions, we use
# continuous variables and solve as an LP.
x = m.addVars(availability, ub=1, name="x")

# The objective is to minimize the total pay costs
m.setObjective(quicksum(pay[w]*x[w,s] for w,s in availability), GRB.MINIMIZE)
# Constraint: assign exactly shiftRequirements[s] workers to each shift s
reqCts = m.addConstrs((x.sum('*', s) == shiftRequirements[s] for s in shifts), "_")

# Optimize
m.optimize()
status = m.status
if status == GRB.Status.UNBOUNDED:
    print('The model cannot be solved because it is unbounded')
    exit(0)
if status == GRB.Status.OPTIMAL:
    print('The optimal objective is %g' % m.objVal)
    exit(0)
if status != GRB.Status.INF_OR_UNBD and status != GRB.Status.INFEASIBLE:
    print('Optimization was stopped with status %d' % status)
    exit(0)

# do IIS
print('The model is infeasible; computing IIS')
removed = []

# Loop until we reduce to a model that can be solved
while True:
    m.computeIIS()
    print('The following constraint cannot be satisfied: ')
    for c in m.getConstrs():
        if c.IISConstr:
            print('%s' % c.constrName)
            # Remove a single constraint from the model
            removed.append(str(c.constrName))
            m.remove(c)
            break
    print('')
    m.optimize()
    status = m.status
    if status == GRB.Status.UNBOUNDED:
        print('The model cannot be solved because it is unbounded')
        exit(0)
    if status == GRB.Status.OPTIMAL:
        break
    if status != GRB.Status.INF_OR_UNBD and status != GRB.Status.INFEASIBLE:
        print('Optimization was stopped with status %d' % status)
        exit(0)

print('The following constraints were removed to get a feasible LP:')
print(removed)

workforce3.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC
# Assign workers to shifts; each worker may or may not be available on a particular day. If the problem cannot be solved, relax the model to determine which constraints cannot be satisfied, and how much they need to be relaxed.

```python
from gurobipy import *

# Number of workers required for each shift
shifts, shiftRequirements = multidict({
    "Mon1": 3,
    "Tue2": 2,
    "Wed3": 4,
    "Thu4": 4,
    "Fri5": 5,
    "Sat6": 6,
    "Sun7": 5,
    "Mon8": 2,
    "Tue9": 2,
    "Wed10": 3,
    "Thu11": 4,
    "Fri12": 6,
    "Sat13": 7,
    "Sun14": 5
})

# Amount each worker is paid to work one shift
workers, pay = multidict({
    "Amy": 10,
    "Bob": 12,
    "Cathy": 10,
    "Dan": 8,
    "Ed": 8,
    "Fred": 9,
    "Gu": 11
})

# Worker availability
availability = tuplelist([
    ('Amy', 'Tue2'), ('Amy', 'Wed3'), ('Amy', 'Fri5'), ('Amy', 'Sun7'),
    ('Amy', 'Tue9'), ('Amy', 'Wed10'), ('Amy', 'Thu11'), ('Amy', 'Fri12'),
    ('Amy', 'Sat13'), ('Amy', 'Sun14'), ('Bob', 'Mon1'), ('Bob', 'Thu2'),
    ('Bob', 'Fri5'), ('Bob', 'Sat6'), ('Bob', 'Mon8'), ('Bob', 'Thu11'),
    ('Bob', 'Sat13'), ('Cathy', 'Wed3'), ('Cathy', 'Thu4'), ('Cathy', 'Fri5'),
    ('Cathy', 'Sun7'), ('Cathy', 'Mon8'), ('Cathy', 'Tue9'), ('Cathy', 'Wed10'),
    ('Cathy', 'Thu11'), ('Cathy', 'Fri12'), ('Cathy', 'Sat13'),
    ('Cathy', 'Sun14'), ('Dan', 'Tue2'), ('Dan', 'Wed3'), ('Dan', 'Fri5'),
    ('Dan', 'Sat6'), ('Dan', 'Mon8'), ('Dan', 'Tue9'), ('Dan', 'Wed10'),
    ('Dan', 'Thu11'), ('Dan', 'Fri12'), ('Dan', 'Sat13'), ('Dan', 'Sun14'),
    ('Ed', 'Mon1'), ('Ed', 'Tue2'), ('Ed', 'Wed3'), ('Ed', 'Thu4'),
    ('Ed', 'Fri5'), ('Ed', 'Sun7'), ('Ed', 'Mon8'), ('Ed', 'Tue9'),
    ('Ed', 'Thu11'), ('Ed', 'Sat13'), ('Ed', 'Sun14'), ('Fred', 'Mon1'),
    ('Fred', 'Tue2'), ('Fred', 'Wed3'), ('Fred', 'Sat6'), ('Fred', 'Mon8'),
    ('Fred', 'Tue9'), ('Fred', 'Fri12'), ('Fred', 'Sat13'), ('Fred', 'Sun14'),
    ('Gu', 'Mon1'), ('Gu', 'Tue2'), ('Gu', 'Wed3'), ('Gu', 'Fri5'),
    ('Gu', 'Sat6'), ('Gu', 'Sun7'), ('Gu', 'Mon8'), ('Gu', 'Tue9'),
    ('Gu', 'Wed10'), ('Gu', 'Thu11'), ('Gu', 'Fri12'), ('Gu', 'Sat13'),
    ('Gu', 'Sun14')
])
```
# Model
m = Model("assignment")

# Assignment variables: x[w,s] == 1 if worker w is assigned to shift s.
# Since an assignment model always produces integer solutions, we use
# continuous variables and solve as an LP.
x = m.addVars(availability, ub=1, name="x")

# The objective is to minimize the total pay costs
m.setObjective(quicksum(pay[w]*x[w,s] for w,s in availability), GRB.MINIMIZE)

# Constraint: assign exactly shiftRequirements[s] workers to each shift s
reqCts = m.addConstrs((x.sum('*', s) == shiftRequirements[s] for s in shifts), "__")

# Optimize
m.optimize()
status = m.status
if status == GRB.Status.UNBOUNDED:
    print('The model cannot be solved because it is unbounded')
    exit(0)
if status == GRB.Status.OPTIMAL:
    print('The optimal objective is %g' % m.objVal)
    exit(0)
if status != GRB.Status.INF_OR_UNBD and status != GRB.Status.INFEASIBLE:
    print('Optimization was stopped with status %d' % status)
    exit(0)

# Relax the constraints to make the model feasible
print('The model is infeasible; relaxing the constraints')
orignumvars = m.NumVars
m.feasRelaxS(0, False, False, True)
m.optimize()
status = m.status
if status in (GRB.Status.INF_OR_UNBD, GRB.Status.INFEASIBLE, GRB.Status.UNBOUNDED):
    print('The relaxed model cannot be solved because it is infeasible or unbounded')
    exit(1)
if status != GRB.Status.OPTIMAL:
    print('Optimization was stopped with status %d' % status)
    exit(1)

print('nSlack values:')
slacks = m.getVars()[orignumvars:]
for sv in slacks:
    if sv.X > 1e-6:
        print('%s = %g' % (sv.VarName, sv.X))

workforce4.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC
# Assign workers to shifts; each worker may or may not be available on a particular day. We use lexicographic optimization to solve the model: first, we minimize the linear sum of the slacks. Then, we constrain the sum of the slacks, and we minimize a quadratic objective that tries to balance the workload among the workers.

```python
from gurobipy import *

# Number of workers required for each shift
shifts , shiftRequirements = multidict({
    "Mon1": 3,
    "Tue2": 2,
    "Wed3": 4,
    "Thu4": 4,
    "Fri5": 5,
    "Sat6": 6,
    "Sun7": 5,
    "Mon8": 2,
    "Tue9": 2,
    "Wed10": 3,
    "Thu11": 4,
    "Fri12": 6,
    "Sat13": 7,
    "Sun14": 5 })

# Amount each worker is paid to work one shift
workers , pay = multidict({
    "Amy": 10,
    "Bob": 12,
    "Cathy": 10,
    "Dan": 8,
    "Ed": 8,
    "Fred": 9,
    "Gu": 11 })

# Worker availability
availability = tuplelist([
    ("Amy", "Tue2"), ("Amy", "Wed3"), ("Amy", "Fri5"), ("Amy", "Sun7"),
    ("Amy", "Tue9"), ("Amy", "Wed10"), ("Amy", "Thu11"), ("Amy", "Fri12"),
    ("Amy", "Sat13"), ("Amy", "Sun14"), ("Bob", "Mon1"), ("Bob", "Tue2"),
    ("Bob", "Fri5"), ("Bob", "Sat6"), ("Bob", "Mon8"), ("Bob", "Thu11"),
    ("Bob", "Sat13"), ("Cathy", "Wed3"), ("Cathy", "Thu4"), ("Cathy", "Fri5"),
    ("Cathy", "Sun7"), ("Cathy", "Mon8"), ("Cathy", "Tue9"), ("Cathy", "Wed10"),
    ("Cathy", "Thu11"), ("Cathy", "Fri12"), ("Cathy", "Sat13"),
    ("Cathy", "Sun14"), ("Dan", "Tue2"), ("Dan", "Wed3"), ("Dan", "Fri5"),
    ("Dan", "Sat6"), ("Dan", "Mon8"), ("Dan", "Tue9"), ("Dan", "Wed10"),
    ("Dan", "Thu11"), ("Dan", "Fri12"), ("Dan", "Sat13"), ("Dan", "Sun14"),
    ("Ed", "Mon1"), ("Ed", "Tue2"), ("Ed", "Wed3"), ("Ed", "Thu4"),
    ("Ed", "Fri5"), ("Ed", "Sun7"), ("Ed", "Mon8"), ("Ed", "Tue9"),
    ("Ed", "Thu11"), ("Ed", "Sat13"), ("Ed", "Sun14"), ("Fred", "Mon1"),
    ("Fred", "Tue2"), ("Fred", "Wed3"), ("Fred", "Sat6"), ("Fred", "Mon8"),
    ("Fred", "Tue9"), ("Fred", "Fri12"), ("Fred", "Sat13"), ("Fred", "Sun14"),
    ("Gu", "Mon1"), ("Gu", "Tue2"), ("Gu", "Wed3"), ("Gu", "Fri5"),
    ("Gu", "Sat6"), ("Gu", "Sun7"), ("Gu", "Mon8"), ("Gu", "Tue9"),
    ("Gu", "Wed10"), ("Gu", "Thu11"), ("Gu", "Fri12"), ("Gu", "Sat13"),
    ("Gu", "Sun14")
])```
# Model
m = Model("assignment")

# Assignment variables: x[w,s] == 1 if worker w is assigned to shift s.
# This is no longer a pure assignment model, so we must use binary variables.
x = m.addVars(availability, vtype=GRB.BINARY, name="x")

# Slack variables for each shift constraint so that the shifts can
# be satisfied
slacks = m.addVars(shifts, name="Slack")

# Variable to represent the total slack
totSlack = m.addVar(name="totSlack")

# Variables to count the total shifts worked by each worker
totShifts = m.addVars(workers, name="TotShifts")

# Constraint: assign exactly shiftRequirements[s] workers to each shift s,
# plus the slack
reqCts = m.addConstrs((slacks[s] + x.sum('*', s) == shiftRequirements[s]
    for s in shifts), "_")

# Constraint: set totSlack equal to the total slack
m.addConstr(totSlack == slacks.sum(), "totSlack")

# Constraint: compute the total number of shifts for each worker
m.addConstrs((totShifts[w] == x.sum(w) for w in workers), "totShifts")

# Objective: minimize the total slack
# Note that this replaces the previous ‘pay’ objective coefficients
m.setObjective(totSlack)

# Optimize
def solveAndPrint():
m.optimize()
    status = m.status
    if status == GRB.Status.INF_OR_UNBD or status == GRB.Status.INFEASIBLE 
        or status == GRB.Status.UNBOUNDED:
        print('The model cannot be solved because it is infeasible or \n        unbounded')
        exit(1)
    if status != GRB.Status.OPTIMAL:
        print('Optimization was stopped with status %d' % status)
        exit(0)

    # Print total slack and the number of shifts worked for each worker
    print('')
    print('Total slack required: %g' % totSlack.x)
    for w in workers:
        print('%s worked %g shifts' % (w, totShifts[w].x))
        print('')
solveAndPrint()

# Constrain the slack by setting its upper and lower bounds
totSlack.ub = totSlack.x
totSlack.lb = totSlack.x

# Variable to count the average number of shifts worked
avgShifts = m.addVar(name="avgShifts")

# Variables to count the difference from average for each worker;
# note that these variables can take negative values.
diffShifts = m.addVars(workers, lb=-GRB.INFINITY, name="Diff")

# Constraint: compute the average number of shifts worked
m.addConstr(len(workers) * avgShifts == totShifts.sum(), "avgShifts")

# Constraint: compute the difference from the average number of shifts
m.addConstrs((diffShifts[w] == totShifts[w] - avgShifts for w in workers), "Diff")

# Objective: minimize the sum of the square of the difference from the
# average number of shifts worked
m.setObjective(quicksum(diffShifts[w]*diffShifts[w] for w in workers))

# Optimize
solveAndPrint()

workforce5.py

#!/usr/bin/python

# Copyright 2018, Gurobi Optimization, LLC

# Assign workers to shifts; each worker may or may not be available on a
# particular day. We use multi-objective optimization to solve the model.
# The highest-priority objective minimizes the sum of the slacks
# (i.e., the total number of uncovered shifts). The secondary objective
# minimizes the difference between the maximum and minimum number of
# shifts worked among all workers. The second optimization is allowed
# to degrade the first objective by up to the smaller value of 10% and 2 */

from gurobipy import *

try:
    # Sample data
    # Sets of days and workers
    Shifts = [ "Mon1", "Tue2", "Wed3", "Thu4", "Fri5", "Sat6",
              "Sun7", "Mon8", "Tue9", "Wed10", "Thu11", "Fri12", "Sat13",
              "Sun14" ]

    # Number of workers required for each shift
    S = [ 3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5 ]
    shiftRequirements = { s : S[i] for i,s in enumerate(Shifts) }

    # Worker availability: 0 if the worker is unavailable for a shift
A = [ [ 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1 ],
      [ 1, 1, 0, 0, 1, 1, 0, 1, 0, 0, 1, 0, 1, 0 ],
      [ 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1 ],
      [ 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 ],
      [ 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 0, 1, 0, 1 ],
      [ 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 0, 1, 0, 1 ],
      [ 0, 1, 1, 1, 0, 1, 1, 0, 1, 1, 0, 1, 1, 1 ],
      [ 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 ] ]

availability = { (w,s) : A[j][i] for i,s in enumerate(Shifts)
      for j,w in enumerate(Workers) }

# Create initial model
model = Model("workforce5")

# Initialize assignment decision variables:
# x[w][s] == 1 if worker w is assigned to shift s.
# This is no longer a pure assignment model, so we must
# use binary variables.
x = model.addVars(availability.keys(), ub=availability, vtype=GRB.BINARY,
      name='x')

# Slack variables for each shift constraint so that the shifts can
# be satisfied
slacks = model.addVars(Shifts, name='Slack')

# Variable to represent the total slack
totSlack = model.addVar(name='totSlack')

# Variables to count the total shifts worked by each worker
totShifts = model.addVars(Workers, name='TotShifts')

# Constraint: assign exactly shiftRequirements[s] workers
# to each shift s, plus the slack
model.addConstrs((x.sum('*',s) + slacks[s] == shiftRequirements[s] for s in Shifts),
      name='shiftRequirement')

# Constraint: set totSlack equal to the total slack
model.addConstr(totSlack == slacks.sum(), name='totSlack')

# Constraint: compute the total number of shifts for each worker
model.addConstrs((totShifts[w] == x.sum(w,'*') for w in Workers),
      name='totShifts')

# Constraint: set minShift/maxShift variable to less/greater than the
# number of shifts among all workers
minShift = model.addVar(name='minShift')
maxShift = model.addVar(name='maxShift')
model.addGenConstrMin(minShift, totShifts, name='minShift')
model.addGenConstrMax(maxShift, totShifts, name='maxShift')

# Set global sense for ALL objectives
model.ModelSense = GRB.MINIMIZE

# Set up primary objective
model.setObjectiveN(totSlack, index=0, priority=2, abstol=2.0, reltol=0.1,
      name='TotalSlack')
# Set up secondary objective
model.setObjectiveN(maxShift - minShift, index=1, priority=1,
                        name='Fairness')

# Save problem
model.write('workforce5.lp')

# Optimize
model.optimize()

status = model.Status
if status == GRB.Status.INF_OR_UNBD or /
    status == GRB.Status.INFEASIBLE or /
    status == GRB.Status.UNBOUNDED:
    print('The model cannot be solved because it is infeasible or unbounded')
    sys.exit(0)

if status != GRB.Status.OPTIMAL:
    print('Optimization was stopped with status ' + str(status))
    sys.exit(0)

# Print total slack and the number of shifts worked for each worker
print('')
print('Total slack required: ' + str(totSlack.X))
for w in Workers:
    print(w + ' worked ' + str(totShifts[w].X) + ' shifts')
    print('')
except GurobiError as e:
    print('Error code ' + str(e.errno) + ': ' + str(e))
except AttributeError as e:
    print('Encountered an attribute error: ' + str(e))

3.7 MATLAB Examples

This section includes source code for all of the Gurobi MATLAB examples. The same source code can be found in the examples/matlab directory of the Gurobi distribution.

diet.m

function diet()
    % Copyright 2018, Gurobi Optimization, LLC
    %
    % Solve the classic diet model

    % Nutrition guidelines, based on
    % USDA Dietary Guidelines for Americans, 2005
    
    ncategories = 4;
categories = {'calories'; 'protein'; 'fat'; 'sodium'};
    % minNutrition maxNutrition
categorynutrition = [ 1800 2200;  % calories
nfoods = 9;
foods = {'hamburger';
'chicken';
'hot dog';
'fries';
'macaroni';
'pizza';
'salad';
'milk';
'ice cream'};

foodcost = [2.49; % hamburger
2.89; % chicken
1.50; % hot dog
1.89; % fries
2.09; % macaroni
1.99; % pizza
2.49; % salad
0.89; % milk
1.59]; % ice cream

nutritionValues = [ 410 24 26 730; % hamburger
420 32 10 1190; % chicken
560 20 32 1800; % hot dog
380 4 19 270; % fries
320 12 10 930; % macaroni
320 15 12 820; % pizza
320 31 12 1230; % salad
100 8 2.5 125; % milk
330 8 10 180]; % ice cream

nutritionValues = sparse(nutritionValues);
model.modelName = 'diet';

function printSolution(result)
    if strcmp(result.status, 'OPTIMAL')
        buy = result.x(1:nfoods);
        nutrition = result.x(nfoods+1:nfoods+ncategories);
        fprintf('
Cost : %f
', result.objval);
        fprintf('
Buy :
')
        for f =1:nfoods
            if buy(f) > 0.0001
                fprintf('%10 s %g
', foods{f}, buy(f));
end
end
fprintf('\nNutrition:\n')
for c=1:ncategories
    fprintf('%10s %g\n', categories{c}, nutrition(c));
else
    fprintf('No solution\n');
end

end

% Solve
results = gurobi(model);
printSolution(results);

fprintf('\nAdding constraint at most 6 servings of dairy\n')
milk = find(strcmp('milk ', foods));
icecream = find(strcmp('ice cream', foods));
model.A(end+1,:) = sparse([1; 1], [milk; icecream], 1, ... 1, nfoods + ncategories);
model.rhs(end+1) = 6;
model.sense(end+1) = '<';

% Solve
results = gurobi(model);
printSolution(results)
end

facility.m

function facility()

% Copyright 2018, Gurobi Optimization, LLC
%
% Facility location: a company currently ships its product from 5 plants
to 4 warehouses. It is considering closing some plants to reduce
% costs. What plant(s) should the company close, in order to minimize
% transportation and fixed costs?
%
% Note that this example uses lists instead of dictionaries. Since
% it does not work with sparse data, lists are a reasonable option.
%
% Based on an example from Frontline Systems:
% http://www.solver.com/disfacility.htm
% Used with permission.
%
% define primitive data
nPlants = 5;
nWarehouses = 4;
% Warehouse demand in thousands of units
Demand = [15; 18; 14; 20];
% Plant capacity in thousands of units
Capacity = [20; 22; 17; 19; 18];
% Fixed costs for each plant
FixedCosts = [12000; 15000; 17000; 13000; 16000];
% Transportation costs per thousand units
TransCosts = [
    4000; 2000; 3000; 2500; 4500;
    2500; 2600; 3400; 3000; 4000;
    1200; 1800; 2600; 4100; 3000;
    2200; 2600; 3100; 3700; 3200];

% Index helper function
flowidx = @(w, p) nPlants * w + p;

% Build model
model.modelname = 'facility';
model.modelsense = 'min';

% Set data for variables
ncol = nPlants + nPlants * nWarehouses;
model.lb = zeros(ncol, 1);
model.ub = [ones(nPlants, 1); inf(nPlants * nWarehouses, 1)];
model.obj = [FixedCosts; TransCosts];
model.vtype = [repmat('B', nPlants, 1); repmat('C', nPlants * nWarehouses, 1)];

for p = 1:nPlants
    model.varnames{p} = sprintf('Open%d', p);
end

for w = 1:nWarehouses
    for p = 1:nPlants
        v = flowidx(w, p);
        model.varnames{v} = sprintf('Trans%d,%d', w, p);
    end
end

% Set data for constraints and matrix
nrow = nPlants + nWarehouses;
model.A = sparse(nrow, ncol);
model.rhs = [zeros(nPlants, 1); Demand];
model.sense = [repmat('<', nPlants, 1); repmat('=', nWarehouses, 1)];

% Production constraints
for p = 1:nPlants
    for w = 1:nWarehouses
        model.A(p, p) = -Capacity(p);
        model.A(p, flowidx(w, p)) = 1.0;
    end
    model.constrnames{p} = sprintf('Capacity%d', p);
end

% Demand constraints
for w = 1:nWarehouses
    for p = 1:nPlants
        model.A(nPlants+w, flowidx(w, p)) = 1.0;
    end
    model.constrnames{nPlants+w} = sprintf('Demand%d', w);
end

% Save model
gurobi_write(model,'facility_m.lp');

% Guess at the starting point: close the plant with the highest fixed costs; open all others first open all plants
model.start = [ones(nPlants, 1); inf(nPlants * nWarehouses, 1)];
[-, idx] = max(FixedCosts);
model.start(idx) = 0;

% Set parameters
params.method = 2;

% Optimize
res = gurobi(model, params);

% Print solution
if strcmp(res.status, 'OPTIMAL')
    fprintf('
Total Costs: %g
', res.objval);
    fprintf('solution:
');
    for p = 1:nPlants
        if res.x(p) > 0.99
            fprintf('Plant %d open:
', p);
        end
        for w = 1:nWarehouses
            if res.x(flowidx(w, p)) > 0.0001
                fprintf(' Transport %g units to warehouse %d
', res.x(flowidx(w, p)), w);
            end
        end
    end
else
    fprintf('
 No solution
');
end

function feasopt(filename)
% % Copyright 2018, Gurobi Optimization, LLC
% % This example reads a MIP model from a file, adds artificial variables to each constraint, and then minimizes the sum of the artificial variables. A solution with objective zero corresponds to a feasible solution to the input model. % We can also use FeasRelax feature to do it. In this example, we use minrelax=1, i.e. optimizing the returned model finds a solution that minimizes the original objective, but only from among those solutions that minimize the sum of the artificial variables.

% Read model
fprintf('Reading model %s', filename);
model = gurobi_read(filename);
params.logfile = 'feasopt.log';
result1 = gurobi(model, params);
[rows, cols] = size(model.A);

% Create penalties, only linear constraints are allowed to be relaxed
penalties.rhs = ones(rows, 1);
result = gurobi_feasrelax(model, 0, true, penalties, params);
gurobi_write(result.model, 'feasopt1.lp');

% clear objective
model.obj = zeros(cols, 1);

nvar = cols;
for c = 1:rows
    if model.sense(c) ~= '>
        nvar = nvar + 1;
        model.A(c, nvar) = -1;
        model.obj(nvar) = 1;
        model.vtype(nvar) = 'C';
        model.varnames(nvar) = strcat('ArtN_ ', model.constrnames(c));
        model.lb(nvar) = 0;
        model.ub(nvar) = inf;
    end
    if model.sense(c) ~= '<
        nvar = nvar + 1;
        model.A(c, nvar) = 1;
        model.obj(nvar) = 1;
        model.vtype(nvar) = 'C';
        model.varnames(nvar) = strcat('ArtP_ ', model.constrnames(c));
        model.lb(nvar) = 0;
        model.ub(nvar) = inf;
    end
end
gurobi_write(model, 'feasopt2.lp');
result2 = gurobi(model, params);
end

fixanddive.m

function fixanddive(filename)
%
% Copyright 2018, Gurobi Optimization, LLC
%
% Implement a simple MIP heuristic. Relax the model,
% sort variables based on fractionality, and fix the 25% of
% the fractional variables that are closest to integer variables.
% Repeat until either the relaxation is integer feasible or
% linearly infeasible.
%
% Read model
fprintf('Reading model %s\n', filename);
model = gurobi_read(filename);
cols = size(model.A, 2);
ivars = find(model.vtype == 'C');
if length(ivars) <= 0
    fprintf('All variables of the model are continuous, nothing to do\n');
    return;
end

% save vtype and set all variables to continuous
vtype = model.vtype;
model.vtype = repmat('C', cols, 1);

params.OutputFlag = 0;
result = gurobi(model, params);

% Perform multiple iterations. In each iteration, identify the first
% quartile of integer variables that are closest to an integer value
% in the relaxation, fix them to the nearest integer, and repeat.

frac = zeros(cols, 1);
for iter = 1:1000
    % See if status is optimal
    if ~strcmp(result.status, 'OPTIMAL')
        fprintf('Model status is %s\n', result.status);
        fprintf('Can not keep fixing variables\n');
        break;
    end
    % collect fractionality of integer variables
    fracs = 0;
    for j = 1:cols
        if vtype(j) == 'C'
            frac(j) = 1; % indicating not integer variable
        else
            t = result.x(j);
            t = t - floor(t);
            if t > 0.5
                t = t - 0.5;
            end
            if t > 1e-5
                frac(j) = t;
                fracs = fracs + 1;
            else
                frac(j) = 1; % indicating not fractional
            end
        end
    end
    fprintf(' Iteration %d, obj %g, fractional %d\n', iter, result.objval, fracs);
    if fracs == 0
        fprintf('Found feasible solution - objective %g\n', result.objval);
        break;
    end
end

% sort variables based on fractionality
[-, I] = sort(frac);
% fix the first quartile to the nearest integer value
nfix = max(fracs/4, 1);
for i = 1:nfix
  j = I(i);
  t = floor(result.x(j) + 0.5);
  model.lb(j) = t;
  model.ub(j) = t;
end

% use warm start basis and reoptimize
model.vbasis = result.vbasis;
model.cbasis = result.cbasis;
result = gurobi(model, params);
end

% Copyright 2018, Gurobi Optimization, LLC
%
% In this example we show the use of general constraints for modeling
% some common expressions. We use as an example a SAT problem where we
% want to see if it is possible to satisfy at least four (or all) clauses
% of the logical for
% % L = (x1 or ~x2 or x3) and (x2 or ~x3 or x4) and
% % (x3 or ~x4 or x1) and (x4 or ~x1 or x2) and
% % (~x1 or ~x2 or x3) and (~x2 or ~x3 or x4) and
% % (~x3 or ~x4 or x1) and (~x4 or ~x1 or x2)
% % We do this by introducing two variables for each literal (itself and its
% % negated value), a variable for each clause, and then two
% % variables for indicating if we can satisfy four, and another to identify
% % the minimum of the clauses (so if it one, we can satisfy all clauses)
% % and put these two variables in the objective.
% % i.e. the Objective function will be
% % % maximize Obj1 + Obj2
% % % Obj1 = MIN(Clause2, ... , Clause8)
% % % Obj2 = 2 -> Clause2 + ... + Clause8 >= 4
% % thus, the objective value will be two if and only if we can satisfy all
% % clauses; one if and only if at least four clauses can be satisfied, and
% % zero otherwise.
%
% define primitive data
n = 4;
nLiterals = 4;
nClauses = 8;
nObj = 2;
nVars = 2 * nLiterals + nClauses + nObj;
Clauses = [
% Create model
model.modelname = 'genconstr';
model.modelsense = 'max';

% Set-up data for variables and constraints
model.vtype = repmat ('B', nVars , 1);
model.ub = ones (nVars , 1);
model.obj = [zeros (2*nLiterals + nClauses, 1); ones (nObj , 1)];
model.A = sparse (nLiterals, nVars);
model.rhs = ones (nLiterals, 1);
model.sense = repmat ('=', nLiterals , 1);
for j = 1: nLiterals
    model.varnames{j} = sprintf ('X%d', j);
    model.varnames{nLiterals+j} = sprintf ('notX%d', j);
end
for j = 1: nClauses
    model.varnames{2*nLiterals+j} = sprintf ('Clause%d', j);
end
for j = 1: nObj
    model.varnames{2*nLiterals+nClauses+j} = sprintf ('Obj%d', j);
end

% Link Xi and notXi
for i = 1: nLiterals
    model.A(i, i) = 1;
    model.A(i, nLiterals+i) = 1;
    model.constrnames{i} = sprintf ('CNSTR_X%d', i);
end

% Link clauses and literals
for i = 1: nClauses
    model.genconor(i).resvar = 2 * nLiterals + i;
    model.genconor(i).vars = Clauses(i:i,1:3);
    model.genconor(i).name = sprintf ('CNSTR_Clause%d', i);
end

% Link objs with clauses
model.genconmin.resvar = 2 * nLiterals + nClauses + 1;
for i = 1: nClauses
    model.genconmin.vars(i) = 2 * nLiterals + i;
end
model.genconmin.name = 'CNSTR_Obj1';

model.genconind.binvar = 2 * nLiterals + nClauses + 2;
model.genconind.binval = 1;
model.genconind.a = [zeros (2*nLiterals,1); ones (nClauses,1); zeros (nObj,1)];
model.genconind.sense = '>';
model.genconind.rhs = 4;
model.genconind.name = 'CNSTR_Obj2';

420
% Save model
gurobi_write(model, 'genconstr_m.lp');

% Optimize
params.logfile = 'genconstr.log';
result = gurobi(model, params);

% Check optimization status
if strcmp(result.status, 'OPTIMAL')
    if result.objval > 1.9
        fprintf('Logical expression is satisfiable\n');
    else
        if result.objval > 0.9
            fprintf('At least four clauses are satisfiable\n');
        else
            fprintf('At most three clauses may be satisfiable\n');
        end
    end
else
    fprintf('Optimization failed\n');
end

intlinprog.m

function [x,fval,exitflag,output] = intlinprog(f,intcon,A,b,Aeq,beq,lb,ub,x0,options)
% Copyright 2018, Gurobi Optimization, LLC
%
% INTLINPROG A mixed integer programming (MIP) example using the
% Gurobi MATLAB interface
%
% This example is based on the intlinprog interface defined in the
% MATLAB Optimization Toolbox. The Optimization Toolbox
% is a registered trademark of The Math Works, Inc.
%
% x = INTLINPROG(f,intcon,A,b) solves the MIP problem:
%
% minimize f'*x
% subject to A*x <= b,
% x(j) integer, where j is in the vector
% intcon of integer constraints.
% For large problems, you can pass A as a sparse matrix and b as a
% sparse vector.
%
% x = INTLINPROG(f,intcon,A,b,Aeq,beq) solves the MIP problem:
%
% minimize f'*x
% subject to A*x <= b,
% Aeq*x == beq,
% x(j) integer, where j is in the vector
% intcon of integer constraints.
% For large problems, you can pass Aeq as a sparse matrix and beq as a
% sparse vector. You can set A=[] and b=[] if no inequalities exist.
%
% x = INTLINPROG(f, intcon, A, b, Aeq, beq, lb, ub) solves the MIP problem:
% minimize f'*x
% subject to A*x <= b,
% Aeq*x == beq,
% lb <= x <= ub,
% x(j) integer, where j is in the vector intcon of integer constraints.
%
% You can set lb(j) = -inf, if x(j) has no lower bound, and ub(j) = inf,
% if x(j) has no upper bound. You can set Aeq=[] and beq=[] if no
% equalities exist.
% x = INTLINPROG(f, intcon, A, b, Aeq, beq, lb, ub, X0) solves the problem above
% with MIP start set to X0.
% You can set lb=[] or ub=[] if no bounds exist.
% x = INTLINPROG(f, intcon, A, b, Aeq, beq, lb, ub, x0, OPTIONS) solves the
% problem above given the specified OPTIONS. Only a subset of possible
% options have any effect:
% OPTIONS.Display 'off' or 'none' disables output,
% OPTIONS.MaxTime time limit in seconds,
% OPTIONS.MaxFeasiblePoints MIP feasible solution limit,
% OPTIONS.RelativeGapTolerance relative MIP optimality gap,
% OPTIONS.AbsoluteGapTolerance absolute MIP optimality gap.
% x = INTLINPROG(PROBLEM) solves PROBLEM, which is a structure that must
% have solver name 'intlinprog' in PROBLEM.solver. You can also specify
% any of the input arguments above using fields PROBLEM.f, PROBLEM.A, ...
%
% [x, fval] = INTLINPROG(f, intcon, A, b) returns the objective value at the
% solution. That is, fval = f'*x.
% [x, fval, exitflag] = INTLINPROG(f, intcon, A, b) returns an exitflag
% containing the status of the optimization. The values for exitflag and
% the corresponding status codes are:
% 2 stopped prematurely, integer feasible point found
% 1 converged to a solution
% 0 stopped prematurely, no integer feasible point found
% -2 no feasible point found
% -3 problem is unbounded
% [x, fval, exitflag, OUTPUT] = INTLINPROG(f, intcon, A, b) returns information
% about the optimization. OUTPUT is a structure with the following fields:
% OUTPUT.message Gurobi status code
% OUTPUT.relativegap relative MIP optimality gap
% OUTPUT.absolugegap absolute MIP optimality gap
% OUTPUT.numnodes number of branch-and-cut nodes explored
% OUTPUT.constrviolation maximum violation for constraints and bounds
%
% Initialize missing arguments
if nargin == 1
    if isa(f,'struct') && isfield(f,'solver') && strcmpi(f.solver,'intlinprog')
        [f.intcon,A,b,Aeq,beq,lb,ub,x0,options] = probstruct2args(f);
    else
        error('PROBLEM should be a structure with valid fields');
    end
elseif nargin < 4 || nargin > 10
    error('INTLINPROG: the number of input arguments is wrong');
else
    options = struct();
    if nargin == 9
        if isa(x0,'struct') || isa(x0,'optim.options.SolverOptions')
            options = x0; % x0 was omitted and options were passed instead
            x0 = [];
        end
    end
    x0 = [];
    if nargin < 8
        ub = [];
        if nargin < 7
            lb = [];
            if nargin < 6
                beq = [];
                if nargin < 5
                    Aeq = [];
                end
            end
        end
    end
end

% build Gurobi model
model.obj = f;
model.A = [sparse(A); sparse(Aeq)]; % A must be sparse
n = size(model.A, 2);
model.vtype = repmat('C', n, 1);
model.vtype(intcon) = 'I';
model.sense = [repmat('<', size(A,1),1); repmat('=',size(Aeq,1),1)];
model.rhs = full([b(:); beq(:)]); % rhs must be dense
if ~isempty(x0)
    model.start = x0;
end
if ~isempty(lb)
    model.lb = lb;
else
    model.lb = -inf(n,1); % default lb for MATLAB is -inf
end
if ~isempty(ub)
    model.ub = ub;
end

% Extract relevant Gurobi parameters from (subset of) options
params = struct();
if isfield(options,'Display') || isa(options,'optim.options.SolverOptions')
if any(strcmp(options.Display,{'off','none'}))
    params.OutputFlag = 0;
end
endif

if isfield(options,'MaxTime') || isa(options,'optim.options.SolverOptions')
    params.TimeLimit = options.MaxTime;
end

if isfield(options,'MaxFeasiblePoints') ... 
    || isa(options,'optim.options.SolverOptions')
    params.SolutionLimit = options.MaxFeasiblePoints;
end

if isfield(options,'RelativeGapTolerance') ... 
    || isa(options,'optim.options.SolverOptions')
    params.MIPGap = options.RelativeGapTolerance;
end

if isfield(options,'AbsoluteGapTolerance') ... 
    || isa(options,'optim.options.SolverOptions')
    params.MIPGapAbs = options.AbsoluteGapTolerance;
end

% Solve model with Gurobi
result = gurobi(model, params);

% Resolve model if status is INF_OR_UNBD
if strcmp(result.status,'INF_OR_UNBD')
    params.DualReductions = 0;
    warning('Infeasible or unbounded, resolve without dual reductions to determine...');
    result = gurobi(model,params);
end

% Collect results
x = [];
output.message = result.status;
output.relativegap = [];
output.absolategap = [];
output.numnodes = result.nodecount;
output.constrviolation = [];

if isfield(result,'x')
    x = result.x;
    if nargout > 3
        slack = model.A*x-model.rhs;
        violA = slack(1:size(A,1));
        violAeq = norm(slack((size(A,1)+1):end),inf);
        viollb = model.lb(:)-x;
        violub = 0;
        if isfield(model,'ub')
            violub = x-model.ub(:);
        end
        output.constrviolation = max([0; violA; violAeq; viollb; violub]);
    end
endif
fval = [];

if isfield(result,'objval')
    fval = result.objval;
    if nargout > 3 && numel(intcon) > 0
        U = fval;
        L = result.objbound;
        output.relativegap = 100*(U-L)/(abs(U)+1);
        output.absolutegap = U-L;
    end
end

if strcmp(result.status,'OPTIMAL')
    exitflag = 1;
elseif strcmp(result.status,'INFEASIBLE') || strcmp(result.status,'CUTOFF')
    exitflag = -2;
elseif strcmp(result.status,'UNBOUNDED')
    exitflag = -3;
elseif isfield(result,'x')
    exitflag = 2;
else
    exitflag = 0;
end

% Local Functions =========================================================

function [f, intcon, A, b, Aeq, beq, lb, ub, x0, options] = probstruct2args(s)
% PROBSTRUCT2ARGS Get problem structure fields ([ ] is returned when missing)

f = getstructfield(s,'f');
intcon = getstructfield(s,'intcon');
A = getstructfield(s,'Aineq');
b = getstructfield(s,'bineq');
Aeq = getstructfield(s,'Aeq');
beq = getstructfield(s,'beq');
lb = getstructfield(s,'lb');
ub = getstructfield(s,'ub');
x0 = getstructfield(s,'x0');
options = getstructfield(s,'options');

function f = getstructfield(s, field)
% GETSTRUCTFIELD Get structure field ([ ] is returned when missing)

if isfield(s,field)
    f = getfield(s,field);
else
    f = [];
end

linprog.m

function [x,fval,exitflag,output,lambda] = linprog(f,A,b,Aeq,beq,lb,ub,x0,options)
% Copyright 2018, Gurobi Optimization, LLC
%
LINPROG A linear programming example using the Gurobi MATLAB interface

This example is based on the linprog interface defined in the MATLAB Optimization Toolbox. The Optimization Toolbox is a registered trademark of The Math Works, Inc.

x = LINPROG(f,A,b) solves the linear programming problem:

minimize \( f'x \)
subject to \( Ax \leq b \).

For large problems, you can pass \( A \) as a sparse matrix and \( b \) as a sparse vector.

x = LINPROG(f,A,b,Aeq,beq) solves the problem:

minimize \( f'x \)
subject to \( Ax \leq b \),
\( Aeqx = beq \).

For large problems, you can pass \( Aeq \) as a sparse matrix and \( beq \) as a sparse vector. You can set \( A=[] \) and \( b=[] \) if no inequalities exist.

x = LINPROG(f,A,b,Aeq,beq,lb,ub) solves the problem:

minimize \( f'x \)
subject to \( Ax \leq b \),
\( Aeqx = beq \),
\( lb \leq x \leq ub \).

You can set \( lb(j) = -\infty \), if \( x(j) \) has no lower bound, and \( ub(j) = \infty \), if \( x(j) \) has no upper bound. You can set \( Aeq=[] \) and \( beq=[] \) if no equalities exist.

x = LINPROG(f,A,b,Aeq,beq,lb,ub,OPTIONS) solves the problem above given the specified OPTIONS. Only a subset of possible options have any effect:

OPTIONS.Display 'off' or 'none' disable output,
OPTIONS.MaxTime time limit in seconds.

You can set \( lb=[] \) or \( ub=[] \) if no bounds exist.

x = LINPROG(PROBLEM) solves PROBLEM, which is a structure that must have solver name 'linprog' in PROBLEM.solver. You can also specify any of the input arguments above using fields PROBLEM.f, PROBLEM.A, ...

[x,fval] = LINPROG(f,A,b) returns the objective value at the solution. That is, \( f'x \).

[x,fval,exitflag] = LINPROG(f,A,b) returns an exitflag containing the status of the optimization. The values for exitflag and the corresponding status codes are:

1 converged to a solution (OPTIMAL),
0 maximum number of iterations reached (ITERATION_LIMIT),
% -2 no feasible point found (INFEASIBLE, NUMERIC, ...),
% -3 problem is unbounded (UNBOUNDED).
%
% [x,fval,exitflag,OUTPUT] = LINPROG(f,A,b) returns information about
% the optimization. OUTPUT is a structure with the following fields:
% OUTPUT.message Gurobi status code
% OUTPUT.constrviolation maximum violation for constraints and bounds
%
% [x,fval,exitflag,OUTPUT,LAMBDA] = LINPROG(f,A,b) returns the
% Lagrangian multipliers at the solution. LAMBDA is a structure with
% the following fields:
% LAMBDA.lower multipliers corresponding to x >= lb
% LAMBDA.upper multipliers corresponding to x <= ub
% LAMBDA.ineqlin multipliers corresponding to A*x <= b
% LAMBDA.eqlin multipliers corresponding to Aeq*x == beq
%
% Initialize missing arguments
if nargin == 1
    if isfield(f,'solver') && strcmpi(f.solver,'linprog')
        [f,A,b,Aeq,beq,lb,ub,x0,options] = probstruct2args(f);
    else
        error('PROBLEM should be a structure with valid fields');
    end
elseif nargin < 3 || nargin > 9
    error('LINPROG: the number of input arguments is wrong');
elseif nargin < 9
    options = struct();
    if nargin == 8
        if isfield(x0,'struct') || isa(x0,'optim.options.SolverOptions')
            options = x0; % x0 was omitted and options were passed instead
            x0 = [];
        end
    else
        x0 = [];
        if nargin < 7
            ub = [];
            if nargin < 6
                lb = [];
                if nargin < 5
                    beq = [];
                    if nargin < 4
                        Aeq = [];
                    end
                end
            end
        end
    end
    end
end

% Warn user if x0 argument is ignored
if ~isempty(x0)
    warning('LINPROG will ignore non-empty starting point X0');
end
% Build Gurobi model
model.obj = f;
model.A = [sparse(A); sparse(Aeq)]; % A must be sparse
model.sense = [repmat('<',size(A,1),1); repmat('=',size(Aeq,1),1)];
model.rhs = full([lb(:); beq(:)]); % rhs must be dense
if ~isempty(lb)
    model.lb = lb;
else
    model.lb = -inf(size(model.A,2),1); % default lb for MATLAB is -inf
end
if ~isempty(ub)
    model.ub = ub;
end

% Extract relevant Gurobi parameters from (subset of) options
params = struct();
if isfield(options,'Display') || isa(options,'optim.options.SolverOptions')
    if any(strcmp(options.Display,{'off','none'}))
        params.OutputFlag = 0;
    end
end
if isfield(options,'MaxTime') || isa(options,'optim.options.SolverOptions')
    params.TimeLimit = options.MaxTime;
end

% Solve model with Gurobi
result = gurobi(model,params);

% Resolve model if status is INF_OR_UNBD
if strcmp(result.status,'INF_OR_UNBD')
    params.DualReductions = 0;
    warning('Infeasible or unbounded, resolve without dual reductions to determine...');
    result = gurobi(model,params);
end

% Collect results
x = [];
output.message = result.status;
output.constrviolation = [];
if isfield(result,'x')
    x = result.x;
    if nargout > 3
        slack = model.A*x-model.rhs;
        violA = slack(1:size(A,1));
        violAeq = norm(slack((size(A,1)+1):end),inf);
        viollb = model.lb(:)-x;
        violub = 0;
        if isfield(model,'ub')
            violub = x-model.ub(:);
        end
        output.constrviolation = max([0; violA; violAeq; viollb; violub]);
    end
end
end

fval = []; if isfield(result,'objval')   fval = result.objval; end

if strcmp(result.status,'OPTIMAL')   exitflag = 1; % converged to a solution elseif strcmp(result.status,'UNBOUNDED')   exitflag = -3; % problem is unbounded elseif strcmp(result.status,'ITERATION_LIMIT')   exitflag = 0; % maximum number of iterations reached else   exitflag = -2; % no feasible point found end

lambda.lower = []; lambda.upper = []; lambda.ineqlin = []; lambda.eqlin = [];

if nargout > 4   if isfield(result,'rc')   lambda.lower = max(0,result.rc); lambda.upper = -min(0,result.rc); end   if isfield(result,'pi')   if isempty(A)   lambda.ineqlin = -result.pi(1:size(A,1)); end   if isempty(Aeq)   lambda.eqlin = -result.pi((size(A,1)+1):end); end   end
end

% Local Functions =========================================================

function [f,A,b,Aeq,beq,lb,ub,x0,options] = probstruct2args(s)
PROBSTRUCT2ARGS Get problem structure fields ([] is returned when missing)

f = getstructfield(s,'f'); A = getstructfield(s,'Aineq'); b = getstructfield(s,'bineq'); Aeq = getstructfield(s,'Aeq'); beq = getstructfield(s,'beq'); lb = getstructfield(s,'lb'); ub = getstructfield(s,'ub'); x0 = getstructfield(s,'x0'); options = getstructfield(s,'options');

function f = getstructfield(s,field)
GETSTRUCTFIELD Get structure field ([] is returned when missing)
if isfield(s, field)
    f = getfield(s, field);
else
    f = [];
end

lp.m

function lp()
    % Copyright 2018, Gurobi Optimization, LLC
    %
    % This example formulates and solv3 the following simple LP model:
    % maximize
    %     x + 2 y + 3 z
    % subject to
    %     x + y <= 1
    %     y + z <= 1
    %
    model.A = sparse([1 1 0; 0 1 1]);
    model.obj = [1 2 3];
    model.modelsense = 'Max';
    model.rhs = [1 1];
    model.sense = [ '<' '<' ];
    result = gurobi(model);
    disp(result.objval);
    disp(result.x);

    % Alternative representation of A - as sparse triplet matrix
    i = [1; 1; 2; 2];
    j = [1; 2; 2; 3];
    x = [1; 1; 1; 1];
    model.A = sparse(i, j, x, 2, 3);

    % Set some parameters
    params.method = 2;
    params.timelimit = 100;
    result = gurobi(model, params);
    disp(result.objval);
    disp(result.x)
end

lp2.m

function lp2()
    % Copyright 2018, Gurobi Optimization, LLC
    %
    % Formulate a simple linear program, solve it, and then solve it
    % again using the optimal basis.
    model.A = sparse([1 3 4; 8 2 3]);
    model.obj = [1 2 3];
model.rhs = [4 7];
model.sense = [>' '>];

% First solve requires a few simplex iterations
result = gurobi(model)

% Second solve - start from an optimal basis, so no iterations
model.vbasis = result.vbasis;
model.cbasis = result.cbasis;
result = gurobi(model)
end

lpmethod.m

function lpmethod(filename)
% Copyright 2018, Gurobi Optimization, LLC
%
% Solve a model with different values of the Method parameter;
% show which value gives the shortest solve time.

% Read model
fprintf('Reading model %s\n', filename);
model = gurobi_read(filename);

bestTime = inf;
bestMethod = -1;
for i = 0:4
    params.method = i;
    res = gurobi(model, params);
    if strcmp(res.status, 'OPTIMAL')
        bestMethod = i;
        bestTime = res.runtime;
        params.TimeLimit = bestTime;
    end
end

% Report which method was fastest
if bestMethod == -1
    fprintf('Unable to solve this model\n');
else
    fprintf('Solved in %g seconds with Method %d\n', bestTime, bestMethod);
end

lpmod.m

function lpmod(filename)
% Copyright 2018, Gurobi Optimization, LLC
%
% This example reads an LP model from a file and solves it.
% If the model can be solved, then it finds the smallest positive variable,
% sets its upper bound to zero, and resolves the model two ways:
% first with an advanced start, then without an advanced start
% (i.e. 'from scratch').
% Read model
fprintf('Reading model %s\n', filename);

model = gurobi_read(filename);

if (isfield(model, 'multiobj') && ~isempty(model.multiobj)) || ...
   (isfield(model, 'sos') && ~isempty(model.sos)) || ...
   (isfield(model, 'pwlobj') && ~isempty(model.pwlobj)) || ...
   (isfield(model, 'quadcon') && ~isempty(model.quadcon)) || ...
   (isfield(model, 'genconstr') && ~isempty(model.genconstr)) || ...
   isfield(model, 'Q')
   fprintf('The model is not a linear program, quit\n');
   return;
end

ivars = find(model.vtype ~= 'C');
ints = length(ivars);

if ints > 0
   fprintf('problem is a MIP, quit\n');
   return;
end

result = gurobi(model);
if ~strcmp(result.status, 'OPTIMAL')
   fprintf('This model cannot be solved because its optimization status is %s\n', result.status);
   return;
end

cols = size(model.A,2);

% create lb if they do not exists, and set them to default values
if ~isfield(model, 'lb') || isempty(model.lb)
   model.lb = zeros(cols, 1);
end

% Find the smallest variable value
minVal = inf;
minVar = -1;
for j = 1:cols
   if result.x(j) > 0.0001 && result.x(j) < minVal && model.lb(j) == 0.0
      minVal = result.x(j);
      minVar = j;
   end
end

fprintf('\n*** Setting %s from %d to zero ***\n', model.varnames{minVar}, minVar);
model.ub(minVar) = 0;
model.vbasis = result.vbasis;
model.cbasis = result.cbasis;

% Solve from this starting point
result = gurobi(model);

% Save iteration & time info
warmCount = result.itercount;
warmTime = result.runtime;

% Remove warm start basis and resolve
model = rmfield(model, 'vbasis');
model = rmfield(model, 'cbasis');
result = gurobi(model);
coldCount = result.itercount;
coldTime = result.runtime;

fprintf('
');
fprintf('*** Warm start: %g iterations, %g seconds
', warmCount, warmTime);
fprintf('*** Cold start: %g iterations, %g seconds
', coldCount, coldTime);

mip1.m

function mip1()
% Copyright 2018, Gurobi Optimization, LLC
% This example formulates and solves the following simple MIP model:
% maximize
% x + y + 2 z
% subject to
% x + 2 y + 3 z <= 4
% x + y >= 1
% x, y, z binary

names = {'x'; 'y'; 'z'};
model.A = sparse([[1 2 3]; [1 1 0]]);
model.obj = [1 1 2];
model.rhs = [4; 1];
model.sense = '<>';
model.vtype = 'B';
model.modelsense = 'max';
model.varnames = names;
gurobi_write(model, 'mip1.lp');
params.outputflag = 0;
result = gurobi(model, params);
disp(result);
for v=1:length(names)
    fprintf('%s %d
', names{v}, result.x(v));
end
fprintf('Obj: %e
', result.objval);
end

mip2.m

function mip2(filename)
% Copyright 2018, Gurobi Optimization, LLC
%
% This example reads a MIP model from a file, solves it and prints
% the objective values from all feasible solutions generated while
% solving the MIP. Then it creates the associated fixed model and
% solves that model.

% Read model
fprintf('Reading model %s\n', filename);
model = gurobi_read(filename);

cols = size(model.A, 2);
ivars = find(model.vtype ~= 'C');
ints = length(ivars);

if ints <= 0
    fprintf('All variables of the model are continuous, nothing to do\n');
    return;
end

% Optimize
params.poolsolutions = 20;
result = gurobi(model, params);

% Capture solution information
if ~strcmp(result.status, 'OPTIMAL')
    fprintf('This model cannot be solved because its optimization status is %s\n', ...
            result.status);
    return;
end

% Iterate over the solutions
if isfield(result, 'pool') && ~isempty(result.pool)
    solcount = length(result.pool);
    for k = 1:solcount
        fprintf('Solution %d has objective %g\n', k, result.pool(k).objval);
    end
else
    fprintf('Solution 1 has objective %g\n', result.objval);
end

% Convert to fixed model
for j = 1:cols
    if model.vtype(j) ~= 'C'
        t = floor(result.x(j) + 0.5);
        model.lb(j) = t;
        model.ub(j) = t;
    end
end

% Solve the fixed model
result2 = gurobi(model, params);
if ~strcmp(result.status, 'OPTIMAL')
    fprintf('Error: fixed model is not optimal\n');
end
return;
end
if abs(result.objval - result2.objval) > 1e-6 * (1 + abs(result.objval))
    fprintf('Error: Objective values differ\n');
end

% Print values of non-zero variables
for j = 1:cols
    if abs(result2.x(j)) > 1e-6
        fprintf('%s %g\n', model.varnames{j}, result2.x(j));
    end
end

multiobj.m

function multiobj()

% Copyright 2018, Gurobi Optimization, LLC
%
% Want to cover three different sets but subject to a common budget of
% elements allowed to be used. However, the sets have different priorities to
% be covered; and we tackle this by using multi-objective optimization.

% define primitive data
groundSetSize = 20;
nSubSets = 4;
Budget = 12;
Set = [
    1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0;
    0 0 0 0 0 1 1 1 1 0 0 0 0 0 1 1 1 1;
    0 0 0 1 1 0 1 1 0 0 0 0 1 1 0 1 1 0;
    0 0 0 1 1 0 0 0 1 1 1 0 0 1 1 1 0 0
];
SetObjPriority = [3; 2; 2; 1];
SetObjWeight = [1.0; 0.25; 1.25; 1.0];

% Initialize model
model.modelsense = 'max';
model.modelname = 'multiobj';

% Set variables and constraints
model.vtype = repmat('B', groundSetSize, 1);
model.lb = zeros(groundSetSize, 1);
model.ub = ones(groundSetSize, 1);
model.A = sparse(1, groundSetSize);
model.rhs = Budget;
model.sense = '<';
model.constrnames = {'Budget'};
for j = 1:groundSetSize
    model.varnames{j} = sprintf('El%d', j);
    model.A(1, j) = 1;
end

% Set multi-objectives
for m = 1:nSubSets
% Save model
gurobi_write(model,'multiobj_m.lp')

% Set parameters
params.PoolSolutions = 100;

% Optimize
result = gurobi(model, params);

% Capture solution information
if ~strcmp(result.status, 'OPTIMAL')
    fprintf('Optimization finished with status %d, quit now
', result.status);
    return;
end

% Print best solution
fprintf('Selected elements in best solution:
');
for j = 1:groundSetSize
    if result.x(j) >= 0.9
        fprintf('%s ', model.varnames{j});
    end
end
fprintf('
');

% Print all solution objectives and best furth solution
if isfield(result, 'pool') && ~isempty(result.pool)
solcount = length(result.pool);
fprintf('Number of solutions found: %d
', solcount);
for m = 1:nSubSets
    fprintf('Objective values for first %d solutions:
', solcount);
    for k = 1:solcount
        fprintf('%3g', result.pool(k).objval(m));
    end
    fprintf('
');
end
ffprintf('
');
else
    fprintf('Number of solutions found: 1
');
    fprintf('Solution 1 has objective values:
');
    for k = 1:nSubSets
        fprintf('%g', result.objval(k));
    end
end
fprintf('
');
function opttoolbox_lp()
% Copyright 2018, Gurobi Optimization, LLC
% This example uses Matlab 2017b problem based modeling feature, which
% requires Optimization Toolbox, to formulate and solve the following
% simple LP model, the same model as for lp.m
% maximize
% x + 2 y + 3 z
% subject to
% x + y <= 1
% y + z <= 1
%
% To use Gurobi with this example, linprog.m must be in the current
% directory or added to Matlab path
x = optimvar('x', 'LowerBound',0);
y = optimvar('y', 'LowerBound',0);
z = optimvar('z', 'LowerBound',0);
prob = optimproblem('ObjectiveSense','maximize');
prob.Objective = x + 2 * y + 3 * z;
prob.Constraints.cons1 = x + y <= 1;
prob.Constraints.cons2 = y + z <= 1;
options = optimoptions('linprog');
try
    sol = solve(prob, options)
catch gurobiError
    fprintf('Error reported\n');
end
end

function opttoolbox_mip1()
% Copyright 2018, Gurobi Optimization, LLC
% This example uses Matlab 2017b problem based modeling feature, which
% requires Optimization Toolbox, to formulate and solve the following
% simple MIP model, the same model as for mip1.m
% maximize
% x + y + 2 z
% subject to
% x + 2 y + 3 z <= 4
% x + y >= 1
% x, y, z binary
%
% To use Gurobi with this example, intlinprog.m must be in the current
% directory or added to Matlab path

x = optimvar('x', 'Type','integer','LowerBound',0,'UpperBound',1);
y = optimvar('y', 'Type','integer','LowerBound',0,'UpperBound',1);
z = optimvar('z', 'Type','integer','LowerBound',0,'UpperBound',1);

prob = optimproblem('ObjectiveSense','maximize');
prob.Objective = x + y + 2 * z;
prob.Constraints.cons1 = x + 2 * y + 3 * z <= 4;
prob.Constraints.cons2 = x + y >= 1;

options = optimoptions('intlinprog');

try
    sol = solve(prob, options)
catch gurobiError
    fprintf('Error reported
');
end

% function params(filename)
% % Copyright 2018, Gurobi Optimization, LLC
% % % Use parameters that are associated with a model.
% % % A MIP is solved for a few seconds with different sets of parameters.
% % The one with the smallest MIP gap is selected, and the optimization
% % is resumed until the optimal solution is found.
% % Read model
% fprintf('Reading model %s\n', filename);
% model = gurobi_read(filename);
% ivars = find(model.vtype ~= 'C');
% if length(ivars) <= 0
%     fprintf('All variables of the model are continuous, nothing to do\n');
%     return;
% end
% % Set a 2 second time limit
% params.TimeLimit = 2;
% % Now solve the model with different values of MIPFocus
% params.MIPFocus = 0;
% result = gurobi(model, params);
% bestgap = result.mipgap;
% bestparams = params;
% for i = 1:3
%     params.MIPFocus = i;
%     result = gurobi(model, params);
%     if result.mipgap < bestgap
%         bestgap = result.mipgap;
%         bestparams = params;
%     end
% end
% % Restore the original MIPFocus
% params.MIPFocus = 0;
% % Call gurobi again with bestparams
% result = gurobi(model, bestparams);
%
if result.mipgap < bestgap
    bestparams = params;
    bestgap = result.mipgap;
end
end

% Finally, reset the time limit and Re-solve model to optimality
bestparams.TimeLimit = Inf;
result = gurobi(model, bestparams);
fprintf('Solution status: %s, objective value %g\n',
    result.status, result.objval);
end

% This example considers the following separable, convex problem:
% minimize f(x) - y + g(z)
% subject to x + 2 y + 3 z <= 4
% x + y >= 1
% x, y, z <= 1
% where f(u) = exp(-u) and g(u) = 2 u^2 - 4 u, for all real u. It
% formulates and solves a simpler LP model by approximating f and
% g with piecewise-linear functions. Then it transforms the model
% into a MIP by negating the approximation for f, which corresponds
% to a non-convex piecewise-linear function, and solves it again.

names = {'x'; 'y'; 'z'};
model.A = sparse([1 2 3; 1 1 0]);
model.obj = [0; -1; 0];
model.rhs = [4; 1];
model.sense = '<>';
model.vtype = 'C';
model.lb = [0; 0; 0];
model.ub = [1; 1; 1];
model.varnames = names;

% Compute f and g on 101 points in [0,1]
u = linspace(0.0, 1.0, 101);
f = exp(-u);  
g = 2*u.^2 - 4*u;

% Set piecewise linear objective f(x)
model.pwlobj(1).var = 1;
model.pwlobj(1).x = u;
model.pwlobj(1).y = f;

% Set piecewise linear objective g(z)
model.pwlobj(2).var = 3;
model.pwlobj(2).x = u;
model.pwlobj(2).y = g;
% Optimize model as LP
result = gurobi(model);

disp(result);

for v=1:length(names)
    fprintf('%s %d
', names{v}, result.x(v));
end

fprintf('Obj: %e
', result.objval);

% Negate piecewise-linear objective function for x
f = -f;
model.pwlobj(1).y = f;
gurobi_write(model, 'pwl.lp')

% Optimize model as a MIP
result = gurobi(model);

disp(result);

for v=1:length(names)
    fprintf('%s %d
', names{v}, result.x(v));
end

fprintf('Obj: %e
', result.objval);
end

poolsearch.m

function poolsearch()

% Copyright 2018, Gurobi Optimization, LLC
%
% We find alternative epsilon-optimal solutions to a given knapsack
% problem by using PoolSearchMode
%
% define primitive data
groundSetSize = 10;
objCoef = [32; 32; 15; 15; 6; 6; 1; 1; 1; 1];
knapsackCoef = [16, 16, 8, 8, 4, 4, 2, 2, 1, 1];
Budget = 33;

% Initialize model
model.modelsense = 'max';
model.modelname = 'poolsearch';

% Set variables
model.obj = objCoef;
model.vtype = repmat('B', groundSetSize, 1);
model.lb = zeros(groundSetSize, 1);
model.ub = ones(groundSetSize, 1);
for j = 1:groundSetSize
    model.varnames{j} = sprintf('El%d', j);
% Build constraint matrix
model.A = sparse(knapsackCoef);
model.rhs = Budget;
model.sense = '<';
model.constrnames = {'Budget'};

% Set poolsearch parameters
params.PoolSolutions = 1024;
params.PoolGap = 0.10;
params.PoolSearchMode = 2;

% Save problem
gurobi_write(model, 'poolsearch_m.lp');

% Optimize
result = gurobi(model, params);

% Capture solution information
if ~strcmp(result.status, 'OPTIMAL')
    fprintf('Optimization finished with status %s, quit now
', result.status);
    return;
end

% Print best solution
fprintf('Selected elements in best solution:
');
for j = 1:groundSetSize
    if result.x(j) >= 0.9
        fprintf('%s ', model.varnames{j});
    end
end
fprintf('
');

% Print all solution objectives and best furth solution
if isfield(result, 'pool') && ~isempty(result.pool)
solcount = length(result.pool);
fprintf('Number of solutions found: %d
', solcount);
fprintf('Objective values for all %d solutions:
', solcount);
for k = 1:solcount
    fprintf('%g ', result.pool(k).objval);
end
fprintf('
');
if solcount >= 4
    fprintf('Selected elements in fourth best solution:
');
    for k = 1:groundSetSize
        if result.pool(4).xn(k) >= 0.9
            fprintf('%s ', model.varnames{k});
        end
    end
    fprintf('
');
else
    fprintf('Number of solutions found: 1
');
    fprintf('Solution 1 has objective: %g \n', result.objval);
end

function qcp()
% Copyright 2018, Gurobi Optimization, LLC
% This example formulates and solves the following simple QCP model:
% maximize
% x
% subject to
% x + y + z = 1
% x^2 + y^2 <= z^2 (second-order cone)
% x^2 <= yz (rotated second-order cone)

names = {'x', 'y', 'z'};
model.varnames = names;

% Set objective: x
model.obj = [1 0 0];
model.modelsense = 'max';

% Add constraint: x + y + z = 1
model.A = sparse([1 1 1]);
model.rhs = 1;
model.sense = '=';

% Add second-order cone: x^2 + y^2 <= z^2
model.quadcon(1).Qc = sparse([1 0 0; 0 1 0; 0 0 -1]);
model.quadcon(1).q = zeros(3,1);
model.quadcon(1).rhs = 0.0;
model.quadcon(1).name = 'std_cone';

% Add rotated cone: x^2 <= yz
model.quadcon(2).Qc = sparse([1 0 0; 0 0 1; 0 0 0]);
model.quadcon(2).q = zeros(3,1);
model.quadcon(2).rhs = 0;
model.quadcon(2).name = 'rot_cone';

gurobi_write(model, 'qcp.lp');

result = gurobi(model);

for j = 1:3
    fprintf('%s %e
', names{j}, result.x(j))
end

fprintf('Obj: %e
', result.objval);
end
function qp()
% Copyright 2018, Gurobi Optimization, LLC
% This example formulates and solves the following simple QP model:
% minimize
% x^2 + x*y + y^2 + y*z + z^2 + 2 x
% subject to
% x + 2 y + 3 z >= 4
% x + y >= 1
% It solves it once as a continuous model, and once as an integer model.

names = {'x', 'y', 'z'};
model.vnames = names;
model.Q = sparse([1 0.5 0; 0.5 1 0.5; 0 0.5 1]);
model.A = sparse([1 2 3; 1 1 0]);
model.obj = [2 0 0];
model.rhs = [4 1];
model.sense = '>';
gurobi_write(model, 'qp.lp');

results = gurobi(model);

for v = 1 : length(names)
    fprintf('%s %e
', names{v}, results.x(v));
end

fprintf('Obj : %e
', results.objval);

model.vtype = 'B';
results = gurobi(model);

for v = 1 : length(names)
    fprintf('%s %e
', names{v}, results.x(v));
end

fprintf('Obj : %e
', results.objval);

end

sensitivity.m

function sensitivity(filename)
% Copyright 2018, Gurobi Optimization, LLC
% A simple sensitivity analysis example which reads a MIP model
% from a file and solves it. Then each binary variable is set
% to 1-X, where X is its value in the optimal solution, and
% the impact on the objective function value is reported.
% Read model
fprintf('Reading model %s\n', filename);
model = gurobi_read(filename);
cols = size(model.A, 2);

ivars = find(model.vtype == 'C');
if length(ivars) <= 0
    fprintf('All variables of the model are continuous, nothing to do\n');
    return;
end

% Optimize
result = gurobi(model);

% Capture solution information
if result.status ~= 'OPTIMAL'
    fprintf('Model status is %d, quit now\n', result.status);
end

origx = result.x;
origobjval = result.objval;

params.OutputFlag = 0;

% Iterate through unfixed binary variables in the model
for j = 1:cols
    if model.vtype(j) == 'B' && model.vtype(j) == 'I'
        continue;
    end
    if model.vtype(j) == 'I'
        if model.lb(j) ~= 0.0 || model.ub(j) ~= 1.0
            continue;
        end
    else
        if model.lb(j) > 0.0 || model.ub(j) < 1.0
            continue;
        end
    end
end

% Update MIP start for all variables
model.start = origx;

% Set variable to 1-X, where X is its value in optimal solution
if any(origx < 0.5)
    model.start(j) = 1;
    model.lb(j) = 1;
else
    model.start(j) = 0;
    model.ub(j) = 1;
end

% Optimize
result = gurobi(model, params);

% Display result
if strcmp(result.status, 'OPTIMAL')
    gap = inf;
else
gap = result.objval - origobjval;
end
fprintf('Objective sensitivity for variable %s is %g\n', ... 
model.varnames{j}, gap);

% Restore original bounds
model.lb(j) = 0;
model.ub(j) = 1;
end

sos.m

function sos()
    % Copyright 2018, Gurobi Optimization, LLC
    %
    % This example creates a very simple Special Ordered Set (SOS)
    % model. The model consists of 3 continuous variables, no linear
    % constraints, and a pair of SOS constraints of type 1.

    model.ub = [1 1 2];
    model.obj = [2 1 1];
    model.modelsense = 'Max';
    model.A = sparse(1,3);
    model.rhs = 0;
    model.sense = '=';

    % Add first SOS: x1 = 0 or x2 = 0
    model.sos(1).type = 1;
    model.sos(1).index = [1 2];
    model.sos(1).weight = [1 2];

    % Add second SOS: x1 = 0 or x3 = 0
    model.sos(2).type = 1;
    model.sos(2).index = [1 3];
    model.sos(2).weight = [1 2];

    % Write model to file
    gurobi_write(model, 'sos.lp');

    result = gurobi(model);

    for i=1:3
        fprintf('x%d %e\n', i, result.x(i))
    end

    fprintf('Obj: %e\n', result.objval);
end

sudoku.m

function sudoku(filename)
    % Copyright 2018, Gurobi Optimization, LLC */
    %
    % Sudoku example.
    %

The Sudoku board is a 9x9 grid, which is further divided into a 3x3 grid of 3x3 grids. Each cell in the grid must take a value from 0 to 9. No two grid cells in the same row, column, or 3x3 subgrid may take the same value.

In the MIP formulation, binary variables $x[i,j,v]$ indicate whether cell $<i,j>$ takes value '$v$'. The constraints are as follows:

1. Each cell must take exactly one value ($\sum_v x[i,j,v] = 1$)
2. Each value is used exactly once per row ($\sum_i x[i,j,v] = 1$)
3. Each value is used exactly once per column ($\sum_j x[i,j,v] = 1$)
4. Each value is used exactly once per 3x3 subgrid ($\sum_{grid} x[i,j,v] = 1$)

Input datasets for this example can be found in examples/data/sudoku*.

```matlab
SUBDIM = 3;
DIM = SUBDIM*SUBDIM;

fileID = fopen(filename);
if fileID == -1
    fprintf('Could not read file %s, quit\n', filename);
    return;
end
board = repmat(-1, DIM, DIM);
for i = 1: DIM
    s = fgets(fileID, 100);
    if length(s) <= DIM
        fprintf('Error: not enough board positions specified, quit\n');
        return;
    end
    for j = 1: DIM
        if s(j) ~= '.'
            board(i, j) = str2double(s(j));
            if board(i,j) < 1 || board(i,j) > DIM
                fprintf('Error: Unexpected character in Input line %d, quit\n', i);
                return;
            end
        end
    end
end

% Map X(i,j,k) into an index variable in the model
nVars = DIM * DIM * DIM;

% Build model
model.vtype = repmat('B', nVars, 1);
model.lb = zeros(nVars, 1);
model.ub = ones(nVars, 1);
for i = 1: DIM
    for j = 1: DIM
        for v = 1: DIM
            var = (i-1)*DIM*DIM + (j-1)*DIM + v;
            model.varnames{var} = sprintf('x[%d,%d,%d]', i, j, v);
        end
    end
end
```

446
end
end
end

% Create constraints:
Row = 1;

% Each cell gets a value */
for i = 1:DIM
  for j = 1:DIM
    for v = 1:DIM
      if board(i,j) == v
        model.lb((i-1)*DIM*DIM + (j-1)*DIM + v) = 1;
      end
      model.A(Row, (i-1)*DIM*DIM + (j-1)*DIM + v) = 1;
    end
    Row = Row + 1;
  end
end

% Each value must appear once in each row
for v = 1:DIM
  for j = 1:DIM
    for i = 1:DIM
      model.A(Row, (i-1)*DIM*DIM + (j-1)*DIM + v) = 1;
    end
    Row = Row + 1;
  end
end

% Each value must appear once in each column
for v = 1:DIM
  for i = 1:DIM
    for j = 1:DIM
      model.A(Row, (i-1)*DIM*DIM + (j-1)*DIM + v) = 1;
    end
    Row = Row + 1;
  end
end

% Each value must appear once in each subgrid
for v = 1:DIM
  for ig = 0: SUBDIM-1
    for jg = 0: SUBDIM-1
      for i = ig*SUBDIM+1:(ig+1)*SUBDIM
        for j = jg*SUBDIM+1:(jg+1)*SUBDIM
          model.A(Row, (i-1)*DIM*DIM + (j-1)*DIM + v) = 1;
        end
      end
      Row = Row + 1;
    end
  end

447
% Save model
gurobi_write(model, 'sudoku_m.lp');

% Optimize model
params.logfile = 'sudoku_m.log';
result = gurobi(model, params);

if strcmp(result.status, 'OPTIMAL')
    fprintf('Solution:\n');
    for i = 1:DIM
        for j = 1:DIM
            for v = 1:DIM
                var = (i-1)*DIM*DIM + (j-1)*DIM + v;
                if result.x(var) > 0.99
                    fprintf('%d', v);
                end
            end
        end
        fprintf('\n');
    end
else
    fprintf('Problem was infeasible\n')
end

workforce1.m

function workforce1()

% Copyright 2018, Gurobi Optimization, LLC
% Assign workers to shifts; each worker may or may not be available on a
% particular day. If the problem cannot be solved, use IIS to find a set of
% conflicting constraints. Note that there may be additional conflicts
% besides what is reported via IIS.

% define data
nShifts = 14;
nWorkers = 7;
nVars = nShifts * nWorkers;
Shifts = {'Mon1'; 'Tue2'; 'Wed3'; 'Thu4'; 'Fri5'; 'Sat6'; 'Sun7';
    'Mon8'; 'Tue9'; 'Wed10'; 'Thu11'; 'Fri12'; 'Sat13'; 'Sun14'};
Workers = {'Amy'; 'Bob'; 'Cathy'; 'Dan'; 'Ed'; 'Fred'; 'Gu'};
pay = [10; 12; 10; 8; 8; 9; 11];
shiftRequirements = [3; 2; 4; 4; 5; 6; 5; 2; 2; 3; 4; 6; 7; 5];
availability = [ 0 1 1 0 1 0 1 0 1 1 1 1 1 1; 1 1 0 0 1 1 0 1 0 0 1 0 1 0; 0 0 1 1 1 0 1 1 1 1 1 1 1 1; 0 1 1 0 1 1 0 1 1 1 1 1 1 1;]
% Build model
model.modelname = 'workforce1';
model.modelsense = 'min';

% Initialize assignment decision variables:
% x[w][s] == 1 if worker w is assigned
% to shift s. Since an assignment model always produces integer
% solutions, we use continuous variables and solve as an LP.
model.ub = ones(nWorkers, 1);
model.obj = zeros(nVars, 1);

for w = 1:nWorkers
   for s = 1:nShifts
      model.varnames{s+(w-1)*nShifts} = sprintf('%s.%s', Workers{w}, Shifts{s});
      model.obj(s+(w-1)*nShifts) = pay(w);
      if availability(w, s) == 0
         model.ub(s+(w-1)*nShifts) = 0;
      end
   end
end

% Set-up shift-requirements constraints
model.sense = repmat('=', nShifts, 1);
model.rhs = shiftRequirements;
model.constrnames = Shifts;
model.A = sparse(nShifts, nVars);
for s = 1:nShifts
   for w = 1:nWorkers
      model.A(s, s+(w-1)*nShifts) = 1;
   end
end

% Save model
gurobi_write(model,'workforce1_m.lp');

% Optimize
params.logfile = 'workforce1_m.log';
result = gurobi(model, params);

% Display results
if strcmp(result.status, 'OPTIMAL')
   fprintf('The optimal objective is %g
', result.objval);
   fprintf('Schedule:
');
   for s = 1:nShifts
      fprintf('	%s:', Shifts{s});
      for w = 1:nWorkers
         if result.x(s+(w-1)*nShifts) > 0.9
            fprintf('%s ', Workers{w});
         end
      end
      fprintf('
');
   end
end
fprintf('
');
else
    if strcmp(result.status, 'INFEASIBLE')
        fprintf('Problem is infeasible.... computing IIS\n');
        iis = gurobi_iis(model, params);
        if iis.minimal
            fprintf('IIS is minimal\n');
        else
            fprintf('IIS is not minimal\n');
        end
    end
    if any(iis.Arows)
        fprintf('Rows in IIS: \n');
        disp(strjoin(model.constrnames(iis.Arows)));
    end
    if any(iis.lb)
        fprintf('LB in IIS: \n');
        disp(strjoin(model.varnames(iis.lb)));
    end
    if any(iis.ub)
        fprintf('UB in IIS: \n');
        disp(strjoin(model.varnames(iis.ub)));
    end
else
    % Just to handle user interruptions or other problems
    fprintf('Unexpected status %s\n', result.status);
end

workforce2.m

function workforce2()

    % Copyright 2018, Gurobi Optimization, LLC
    %
    % Assign workers to shifts; each worker may or may not be available on a
    % particular day. If the problem cannot be solved, use IIS iteratively to
    % find all conflicting constraints.
    %
    % define data
    nShifts = 14;
    nWorkers = 7;
    nVars = nShifts * nWorkers;
    Shifts = {'Mon1'; 'Tue2'; 'Wed3'; 'Thu4'; 'Fri5'; 'Sat6'; 'Sun7';
    'Mon8'; 'Tue9'; 'Wed10'; 'Thu11'; 'Fri12'; 'Sat13'; 'Sun14'};
    Workers = {'Amy'; 'Bob'; 'Cathy'; 'Dan'; 'Ed'; 'Fred'; 'Gu'};
    pay = [10; 12; 10; 8; 8; 9; 11];
    shiftRequirements = [3; 2; 4; 4; 5; 6; 5; 2; 2; 3; 4; 6; 7; 5];
    availability = [0 1 1 0 1 0 1 1 1 1 1 1];
% Build model
model.modelname = 'workforce2';
model.modelsense = 'min';

% Initialize assignment decision variables:
% x[w][s] == 1 if worker w is assigned
to shift s. Since an assignment model always produces integer
solutions, we use continuous variables and solve as an LP.
model.ub = ones(nVars, 1);
model.obj = zeros(nVars, 1);
for w = 1:nWorkers
  for s = 1:nShifts
    model.varnames{s+(w-1)*nShifts} = sprintf('%s.%s', Workers{w}, Shifts{s});
    model.obj(s+(w-1)*nShifts) = pay(w);
    if availability(w, s) == 0
      model.ub(s+(w-1)*nShifts) = 0;
    end
  end
end

% Set-up shift-requirements constraints
model.sense = repmat('=', nShifts, 1);
model.rhs = shiftRequirements;
model.constrnames = Shifts;
model.A = sparse(nShifts, nVars);
for s = 1:nShifts
  for w = 1:nWorkers
    model.A(s, s+(w-1)*nShifts) = 1;
  end
end

% Save model
gurobi_write(model, 'workforce2_m.lp');

% Optimize
paramslogfile = 'workforce2_m.log';
result = gurobi(model, params);

% If infeasible, remove IIS rows until it becomes feasible
numremoved = 0;
if strcmp(result.status, 'INFEASIBLE')
  numremoved = 0;
  while strcmp(result.status, 'INFEASIBLE')
    iis = gurobi_iis(model, params);
    keep = find(~iis.Arows);
    fprintf('Removing rows: ');
  end
end
disp(model.constrnames{iiis.Arows})
model.A = model.A(keep, :);
model.sense = model.sense(keep, :);
model.rhs = model.rhs(keep, :);
model.constrnames = model.constrnames(keep,:);
umremoved = numremoved + 1;
result = gurobi(model, params);
end
end

% Display results
if strcmp(result.status, 'OPTIMAL')
    if numremoved > 0
        fprintf('It becomes feasible after %d rounds of IIS row removing\n', numremoved);
    end
    printsolution(result, Shifts, Workers)
else
    % Just to handle user interruptions or other problems
    fprintf('Unexpected status %s
',result.status)
end
end

function printsolution(result, Shifts, Workers)
% Helper function to display results
nShifts = length(Shifts);
nWorkers = length(Workers);

fprintf('The optimal objective is %g
', result.objval);
fprintf('Schedule:\n');
for s = 1:nShifts
    fprintf('	%s:', Shifts{s});
    for w = 1:nWorkers
        if result.x(s+(w-1)*nShifts) > 0.9
            fprintf('%s ', Workers{w});
        end
    end
    fprintf('
');
end
end

workforce3.m

function workforce3()
% Copyright 2018, Gurobi Optimization, LLC
% Assign workers to shifts; each worker may or may not be available on a
% particular day. If the problem cannot be solved, relax the model
% to determine which constraints cannot be satisfied, and how much
% they need to be relaxed.
% define data
nShifts = 14;
nWorkers = 7;
nVars = nShifts * nWorkers;
Shifts = {'Mon1'; 'Tue2'; 'Wed3'; 'Thu4'; 'Fri5'; 'Sat6'; 'Sun7';
     'Mon8'; 'Tue9'; 'Wed10'; 'Thu11'; 'Fri12'; 'Sat13'; 'Sun14'};
Workers = {'Amy'; 'Bob'; 'Cathy'; 'Dan'; 'Ed'; 'Fred'; 'Gu'};

pay = [10; 12; 10; 8; 8; 9; 11];
shiftRequirements = [3; 2; 4; 4; 5; 6; 5; 2; 2; 3; 4; 6; 7; 5];
availability = [
    0 1 0 1 0 1 1 1 1 1 1 1 1 1; 
    1 0 0 1 1 0 1 0 1 0 1 1 1 1; 
    0 0 1 1 1 0 1 1 1 1 1 1 1 1; 
    1 1 0 1 0 1 1 1 1 1 1 1 1 1; 
    1 1 1 1 1 0 1 1 1 1 0 1 1 1; 
    1 1 1 0 0 1 1 1 0 0 1 1 1 1; 
    0 1 0 1 1 1 1 1 1 1 1 1 1 1
];

% Build model
model.modelname = 'workforce3';
model.modelsense = 'min';

% Initialize assignment decision variables:
% x[w][s] == 1 if worker w is assigned
% to shift s. Since an assignment model always produces integer
% solutions, we use continuous variables and solve as an LP.
model.ub = ones(nVars, 1);
model.obj = zeros(nVars, 1);

for w = 1:nWorkers
    for s = 1:nShifts
        model.varnames{s+(w-1)*nShifts} = sprintf('%s.%s', Workers{w}, Shifts{s});
        model.obj{s+(w-1)*nShifts} = pay(w);
        if availability(w, s) == 0
            model.ub{s+(w-1)*nShifts} = 0;
        end
    end
end

% Set-up shift-requirements constraints
model.sense = repmat('=', nShifts, 1);
model.rhs = shiftRequirements;
model.constrnames = Shifts;
model.A = sparse(nShifts, nVars);

for s = 1:nShifts
    for w = 1:nWorkers
        model.A(s, s+(w-1)*nShifts) = 1;
    end
end

% Save model
gurobi_write(model, 'workforce3_m.lp');

% Optimize
paramslogfile = 'workforce3_m.log';
result = gurobi(model, params);

% Display results
if strcmp(result.status, 'OPTIMAL')
    % The code may enter here if you change some of the data... otherwise
    % this will never be executed.
    printsolution(result, Shifts, Workers)
else
    if strcmp(result.status, 'INFEASIBLE')
        penalties.lb = inf(nVars, 1);
        penalties.ub = inf(nVars, 1);
        penalties.rhs = ones(nShifts, 1);
        feasrelax = gurobi_feasrelax(model, 0, false, penalties, params);
        result = gurobi(feasrelax.model, params);
        if strcmp(result.status, 'OPTIMAL')
            printsolution(result, Shifts, Workers);
            fprintf('Slack value:
');
            for j = nVars+1:length(result.x)
                if result.x(j) > 0.1
                    fprintf('	%s, %g
', feasrelax.model.varnames{j}, result.x(j));
                end
            end
        else
            fprintf('Unexpected status %s
', result.status);
        end
    else
        fprintf('Unexpected status %s
', result.status);
    end
else
    % Just to handle user interruptions or other problems
    fprintf('Unexpected status %s
', result.status);
end
end

function printsolution(result, Shifts, Workers)
% Helper function to display results
nShifts = length(Shifts);
nWorkers = length(Workers);
fprintf('The optimal objective is %g
', result.objval);
fprintf('Schedule:
');
for s = 1:nShifts
    fprintf('%s:
', Shifts(s));
    for w = 1:nWorkers
        if result.x(s+(w-1)*nShifts) > 0.9
            fprintf('%s ', Workers{w});
        end
    end
    fprintf('
');
end
end

function workforce4()
% Copyright 2018, Gurobi Optimization, LLC
%
% Assign workers to shifts; each worker may or may not be available on a particular day. We use Pareto optimization to solve the model:
% first, we minimize the linear sum of the slacks. Then, we constrain the sum of the slacks, and we minimize a quadratic objective that tries to balance the workload among the workers.

% define data
nShifts = 14;
nWorkers = 7;
nVars = (nShifts + 1) * (nWorkers + 1) + nWorkers + 1;
avgShiftIdx = (nShifts+1)*(nWorkers+1);
totalSlackIdx = nVars;

Shifts = {'Mon1'; 'Tue2'; 'Wed3'; 'Thu4'; 'Fri5'; 'Sat6'; 'Sun7'; 'Mon8'; 'Tue9'; 'Wed10'; 'Thu11'; 'Fri12'; 'Sat13'; 'Sun14'};
Workers = {'Amy'; 'Bob'; 'Cathy'; 'Dan'; 'Ed'; 'Fred'; 'Gu'};

shiftRequirements = [3; 2; 4; 4; 5; 6; 5; 2; 2; 3; 4; 6; 7; 5];

availability = [0 1 1 0 1 0 1 1 1 1 1 1 1 1 1; 1 1 0 0 1 1 0 1 0 1 1 0 1 0 0; 0 0 1 1 1 0 1 1 1 1 1 1 1 1 1; 0 1 1 0 1 1 0 1 1 1 1 1 1 1 1; 1 1 1 1 1 0 1 1 0 1 0 1 1 1 1; 1 1 1 0 0 1 0 1 1 0 0 1 1 1 1; 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1];

% Build model
model.name = 'workforce4';
model.sense = 'min';

% Initialize assignment decision variables:
% x[w][s] == 1 if worker w is assigned to shift s. Since an assignment model always produces integer solutions, we use continuous variables and solve as an LP.
model.vtype = repmat('C', nVars, 1);
model.lb = zeros(nVars, 1);
model.ub = ones(nVars, 1);
model.obj = zeros(nVars, 1);

for w = 1:nWorkers
    for s = 1:nShifts
        model.varnames{s+(w-1)*nShifts} = sprintf('%s.%s', Workers{w}, Shifts{s});
        if availability(w, s) == 0
            model.ub(s+(w-1)*nShifts) = 0;
        end
    end
end

% Initialize shift slack variables
for s = 1:nShifts
    model.varnames{s+nShifts*nWorkers} = sprintf('ShiftSlack_%s', Shifts{s});
    model.ub(s+nShifts*nWorkers) = inf;
end
% Initialize worker slack and diff variables
for w = 1:nWorkers
    model.varnames{w + nShifts * (nWorkers+1)} = sprintf('TotalShifts_%s', Workers{w});
    model.ub(w + nShifts * (nWorkers+1)) = inf;
    model.varnames(w + avgShiftIdx) = sprintf('DiffShifts_%s', Workers{w});
    model.ub(w + avgShiftIdx) = inf;
    model.lb(w + avgShiftIdx) = -inf;
end

% Initialize average shift variable
model.ub((nShifts+1)*(nWorkers+1)) = inf;
model.varnames((nShifts+1)*(nWorkers+1)) = 'AvgShift';

% Initialize total slack variable
model.ub(totalSlackIdx) = inf;
model.varnames{totalSlackIdx} = 'TotalSlack';
model.obj{totalSlackIdx} = 1;

% Set-up shift-requirements constraints with shift slack
model.sense = repmat('=', nShifts+1+nWorkers, 1);
model.rhs = [shiftRequirements; zeros(1+nWorkers, 1)];
model.constrnames = Shifts;
model.A = sparse(nShifts+1+nWorkers, nVars);
for s = 1:nShifts
    for w = 1:nWorkers
        model.A(s, s+(w-1)*nShifts) = 1;
    end
    model.A(s, s + nShifts * nWorkers) = 1;
end

% Set TotalSlack equal to the sum of each shift slack
for s = 1:nShifts
    model.A(nShifts+1, s+nShifts*nWorkers) = -1;
end
model.A(nShifts+1, totalSlackIdx) = 1;
model.constrnames{nShifts+1} = 'TotalSlack';

% Set total number of shifts for each worker
for w = 1:nWorkers
    for s = 1:nShifts
        model.A(w + nShifts+1, s+(w-1)*nShifts) = -1;
    end
    model.A(w + nShifts+1, w + nShifts * (nWorkers+1)) = 1;
    model.constrnames{nShifts+1+w} = sprintf('totShifts_%s', Workers{w});
end

% Save model
gurobi_write(model,'workforce4a_m.lp');

% Optimize
params.logfile = 'workforce4_m.log';
result = solveandprint(model, params, Shifts, Workers);
if ~strcmp(result.status, 'OPTIMAL')
    fprintf('Quit now\n');
    return;
end
end

% Constraint the slack by setting its upper and lower bounds
totalSlack = result.x(totalSlackIdx);
model.lb(totalSlackIdx) = totalSlack;
model.ub(totalSlackIdx) = totalSlack;

Rows = nShifts+nWorkers;
for w = 1:nWorkers
    model.A(Rows+w, w + nShifts * (nWorkers+1)) = 1;
    model.A(Rows+w, w + avgShiftIdx) = -1;
    model.A(Rows+nWorkers, w + nShifts * (nWorkers+1)) = 1;
    model.rhs(Rows+w) = 0;
    model.sense(Rows+w) = '=';
    model.constrnames{Rows+w} = sprintf('DiffShifts_%s_AVgShift', Workers{w});
end
model.A(Rows+nWorkers, avgShiftIdx) = -nWorkers;
model.rhs(Rows+nWorkers) = 0;
model.sense(Rows+nWorkers) = '=';
model.constrnames{Rows+nWorkers} = 'AvgShift';

% Objective: minimize the sum of the square of the difference from the
% average number of shifts worked
model.obj = zeros(nVars, 1);
model.Q = sparse(nVars, nVars);
for w = 1:nWorkers
    model.Q(avgShiftIdx + w, avgShiftIdx + w) = 1;
end

% model is no longer an assignment problem, enforce binary constraints
% on shift decision variables.
model.vtype(1:(nWorkers * nShifts), 1) = 'B';
model.vtype((nWorkers * nShifts + 1):nVars, 1) = 'C';

% Save modified model
gurobi_write(model,'workforce4b_m.lp');

% Optimize
result = solveandprint(model, params, Shifts, Workers);
if ~strcmp(result.status, 'OPTIMAL')
    fprintf('Not optimal
');
end
end

function result = solveandprint(model, params, Shifts, Workers)
% Helper function to solve and display results
nShifts = length(Shifts);
NWorkers = length(Workers);
result = gurobi(model, params);
if strcmp(result.status, 'OPTIMAL')
    fprintf('The optimal objective is %g
', result.objval);
    fprintf('Schedule:
');
    for s = 1:nShifts
        fprintf('%s
', Shifts{s});
        for w = 1:nWorkers
            if result.x(w + s * (nWorkers+1)) == 1
                fprintf('Worker %s
', Workers{w});
            end
        end
    end
end

fprintf('	\%s:', Shifts{s});
for w = 1:nWorkers
  if result.x(s+(w-1)*nShifts) > 0.9
    fprintf('\%s ', Workers{w});
  end
end
fprintf('
');
end
fprintf('Workload:
');
for w = 1:nWorkers
  fprintf('	\%s: %g
', Workers{w}, result.x(w + nShifts * (nWorkers+1)));
end
else
  fprintf('Optimization finished with status \%s\n', result.status);
end
end

workforce5.m

function workforce5()
  
  % Copyright 2018, Gurobi Optimization, LLC
  %
  % Assign workers to shifts; each worker may or may not be available on a
  % particular day. We use multi-objective optimization to solve the model.
  % The highest-priority objective minimizes the sum of the slacks
  % (i.e., the total number of uncovered shifts). The secondary objective
  % minimizes the difference between the maximum and minimum number of
  % shifts worked among all workers. The second optimization is allowed
  % to degrade the first objective by up to the smaller value of 10% and 2

  % define data
  nShifts = 14;
  nWorkers = 8;
  nVars = (nShifts + 1) * (nWorkers + 1) + 2;
  minShiftIdx = (nShifts +1)*(nWorkers+1);
  maxShiftIdx = minShiftIdx+1;
  totalSlackIdx = nVars;

  Shifts = { 'Mon1'; 'Tue2'; 'Wed3'; 'Thu4'; 'Fri5'; 'Sat6'; 'Sun7';
            'Mon8'; 'Tue9'; 'Wed10'; 'Thu11'; 'Fri12'; 'Sat13'; 'Sun14' };
  Workers = { 'Amy'; 'Bob'; 'Cathy'; 'Dan'; 'Ed'; 'Fred'; 'Gu'; 'Tobi' };

  shiftRequirements = [ 3; 2; 4; 4; 5; 6; 5; 2; 2; 3; 4; 6; 7; 5 ];

  availability = [
    0 1 1 0 1 0 1 0 1 1 1 1 1 1 1 1 1 0 1 0 1 0 1 0 0 0 1 1 0 1 0 1 0 1 0 0 0 1 1 0 1 0 1 0 1 0 0 1 1 0 1 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1 0 1 0 1 0 1 0 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
  ];
% Build model
model.modelname = 'workforce5';
model.modelsense = 'min';

% Initialize assignment decision variables:
% x[w][s] == 1 if worker w is assigned
% to shift s. Since an assignment model always produces integer
% solutions, we use continuous variables and solve as an LP.
model.vtype = repmat ('C', nVars , 1);
model.lb = zeros(nVars, 1);
model.ub = ones(nVars, 1);

for w = 1:nWorkers
    for s = 1:nShifts
        model.vtype(s+(w -1)* nShifts ) = 'B';
        model.varnames {s+(w -1)* nShifts } = sprintf ('%s.%s', Workers {w}, Shifts {s});
        if availability(w, s) == 0
            model.ub(s+(w -1)* nShifts ) = 0;
        end
    end
end

% Initialize shift slack variables
for s = 1:nShifts
    model.varnames {s+nShifts*nWorkers} = sprintf ('ShiftSlack_%s', Shifts {s});
    model.ub(s+nShifts*nWorkers) = inf;
end

% Initialize worker slack and diff variables
for w = 1:nWorkers
    model.varnames {w + nShifts * (nWorkers+1)} = sprintf ('TotalShifts_%s', Workers {w});
    model.ub(w + nShifts * (nWorkers+1)) = inf;
end

% Initialize min/max shift variables
model.ub(minShiftIdx) = inf;
model.varnames{minShiftIdx} = 'MinShift';
model.ub(maxShiftIdx) = inf;
model.varnames{maxShiftIdx} = 'MaxShift';

% Initialize total slack variable
model.ub(totalSlackIdx) = inf;
model.varnames{totalSlackIdx} = 'TotalSlack';

% Set-up shift-requirements constraints with shift slack
model.sense = repmat ('=', nShifts+1+nWorkers, 1);
model.rhs = [shiftRequirements; zeros(1+nWorkers, 1)];
model.constrnames = Shifts;
model.A = sparse(nShifts+1+nWorkers, nVars);
for s = 1:nShifts
    for w = 1:nWorkers
        model.A(s, s+(w -1)* nShifts) = 1;
    end
    model.A(s, s + nShifts*nWorkers) = 1;
end
% Set TotalSlack equal to the sum of each shift slack
for s = 1:nShifts
    model.A(nShifts+1, s+nShifts*nWorkers) = -1;
end
model.A(nShifts+1, totalSlackIdx) = 1;
model.constrnames{nShifts+1} = 'TotalSlack';

% Set total number of shifts for each worker
for w = 1:nWorkers
    for s = 1:nShifts
        model.A(w + nShifts+1, s+(w-1)*nShifts) = -1;
    end
    model.A(w + nShifts+1, w + nShifts * (nWorkers+1)) = 1;
    model.constrnames{nShifts+1+w} = sprintf('totShifts_%s', Workers{w});
end

% Set minShift / maxShift general constraints
model.genconmin.resvar = minShiftIdx;
model.genconmin.name = 'MinShift';
model.genconmax.resvar = maxShiftIdx;
model.genconmax.name = 'MaxShift';
for w = 1:nWorkers
    model.genconmin.vars(w) = w + nShifts * (nWorkers+1);
    model.genconmax.vars(w) = w + nShifts * (nWorkers+1);
end

% Set multiobjective
model.multiobj(1).objn = zeros(nVars, 1);
model.multiobj(1).objn(totalSlackIdx) = 1;
model.multiobj(1).priority = 2;
model.multiobj(1).weight = 1;
model.multiobj(1).abstol = 2;
model.multiobj(1).reptol = 0.1;
model.multiobj(1).name = 'TotalSlack';
model.multiobj(1).con = 0.0;
model.multiobj(2).objn = zeros(nVars, 1);
model.multiobj(2).objn(minShiftIdx) = -1;
model.multiobj(2).objn(maxShiftIdx) = 1;
model.multiobj(2).priority = 1;
model.multiobj(2).weight = 1;
model.multiobj(2).abstol = 0;
model.multiobj(2).reptol = 0;
model.multiobj(2).name = 'Fairness';
model.multiobj(2).con = 0.0;

% Save initial model
gurobi_write(model,'workforce5_m.lp');

% Optimize
params.logfile = 'workforce5_m.log';
result = solveandprint(model, params, Shifts, Workers);
if ~strcmp(result.status, 'OPTIMAL')
    fprintf('Not optimal\n');
end
function result = solveandprint(model, params, Shifts, Workers)
% Helper function to solve and display results

nShifts = length(Shifts);
nWorkers = length(Workers);
result = gurobi(model, params);
if strcmp(result.status, 'OPTIMAL')
    fprintf('The optimal objective is %g\n', result.objval);
    fprintf('Schedule:\n');
    for s = 1:nShifts
        fprintf('%s:', Shifts{s});
        for w = 1:nWorkers
            if result.x(s+(w-1)*nShifts) > 0.9
                fprintf('%s ', Workers{w});
            end
        end
    fprintf(' Workload:\n');
    for w = 1:nWorkers
        fprintf('%s: %g
', Workers{w}, result.x(w + nShifts * (nWorkers+1)));
    end
else
    fprintf('Optimization finished with status %s\n', result.status);
end
end

3.8 R Examples

This section includes source code for all of the Gurobi R examples. The same source code can be found in the examples/R directory of the Gurobi distribution.

diet.R

# Copyright 2018, Gurobi Optimization, LLC
#
# Solve the classic diet model, showing how to add constraints
# to an existing model.

library(Matrix)
library(gurobi)

# display results
printSolution <- function(model, res, nCategories, nFoods) {
    if (res$status == 'OPTIMAL') {
        cat('\nCost : ',res$objval,'\nBuy :
')
        for (j in nCategories + 1:nFoods)
            if (res$x[j] > 1e-4) {
                cat(format(model$varnames[j], justify='left',width=10),':',
                    format(res$x[j], justify='right',width=10,nsmall=2),'
')
            }
        cat('\nNutrition:
')
        for (j in 1:nCategories)
            cat(''}
}
cat(format(model$varnames[j], justify='left', width=10), ':',
  format(res$x[j], justify='right', width=10, nsmall=2), '
')
}
}

# define primitive data
Categories <- c('calories', 'protein', 'fat', 'sodium')
nCategories <- length(Categories)
minNutrition <- c(1800, 91, 0, 0)
maxNutrition <- c(2200, Inf, 65, 1779)

Foods <- c('hamburger', 'chicken', 'hot dog', 'fries', 'macaroni',
  'pizza', 'salad', 'milk', 'ice cream')
nFoods <- length(Foods)

# Build model
model <- list()

model$A <- spMatrix(nCategories, nCategories + nFoods,
  i = mapply(rep, 1:4, 1 + nFoods),
  j = c(1, (nCategories+1):(nCategories+nFoods),
    2, (nCategories+1):(nCategories+nFoods),
    3, (nCategories+1):(nCategories+nFoods),
    4, (nCategories+1):(nCategories+nFoods)),
  x = c(-1.0, nutritionValues[1 + nCategories*0:(nFoods-1)]),
    -1.0, nutritionValues[2 + nCategories*0:(nFoods-1)]),
    -1.0, nutritionValues[3 + nCategories*0:(nFoods-1)]),
    -1.0, nutritionValues[4 + nCategories*0:(nFoods-1)]))

model$obj <- c(rep(0, nCategories), cost)
model$lb <- c(minNutrition, rep(0, nFoods))
model$ub <- c(maxNutrition, rep(Inf, nFoods))
model$varnames <- c(Categories, Foods)
model rhs <- rep(0, nCategories)
model$sense <- rep('=', nCategories)
model$constrnames <- Categories
model$modelname <- 'diet'
model$modelsense <- 'min'

# Optimize
res <- gurobi(model)
printSolution(model, res, nCategories, nFoods)

# Adding constraint: at most 6 servings of dairy
# this is the matrix part of the constraint
B <- spMatrix(1, nCategories + nFoods,
i = rep(1, 2),
j = (nCategories + c(8, 9)),
x = rep(1, 2))

# append B to A
model$A <- rbind(model$A, B)
# extend row-related vectors
model$constrnames <- c(model$constrnames, 'limit_dairy')
model$rhs <- c(model$rhs, 6)
model$sense <- c(model$sense, '<')

# Optimize
res <- gurobi(model)
printSolution(model, res, nCategories, nFoods)

# Clear space
rm(res, model)

facility.R

# Copyright 2018, Gurobi Optimization, LLC
#
# Solve the classic diet model, showing how to add constraints
# to an existing model.

library(Matrix)
library(gurobi)

# define primitive data
nPlants <- 5
nWarehouses <- 4
# Warehouse demand in thousands of units
Demand <- c(15, 18, 14, 20)
# Plant capacity in thousands of units
Capacity <- c(20, 22, 17, 19, 18)
# Fixed costs for each plant
FixedCosts <- c(12000, 15000, 17000, 13000, 16000)
# Transportation costs per thousand units
TransCosts <- c(4000, 2000, 3000, 2500, 4500,
                2500, 2600, 3400, 3000, 4000,
                1200, 1800, 2600, 4100, 3000,
                2200, 2600, 3100, 3700, 3200)

flowidx <- function(w, p) { nPlants * (w-1) + p}

# Build model
model <- list()
model$modelsense <- 'min'

# initialize data for variables
model$lb <- 0
model$ub <- c(rep(1, nPlants), rep(Inf, nPlants * nWarehouses))
model$type <- c(rep('B', nPlants), rep('C', nPlants * nWarehouses))
model$obj <- c(FixedCosts, TransCosts)
model$varnames <- c(paste0(rep('Open', nPlants), 1:nPlants),
                     sprintf('Trans%d,%d', 1:nPlants, 1:nPlants))
\[
\begin{align*}
&c(\text{mapply}(\text{rep},1:\text{nWarehouses},\text{nPlants})), \\
&1:\text{nPlants})
\end{align*}
\]

# build production constraint matrix

A1 <- spMatrix(\text{nPlants}, \text{nPlants}, \text{i} = c(1:\text{nPlants}), \text{j} = (1:\text{nPlants}), \text{x} = -\text{Capacity})

A2 <- spMatrix(\text{nPlants}, \text{nPlants} * \text{nWarehouses},
\text{i} = c(\text{mapply}(\text{rep},1:\text{nPlants}, \text{nWarehouses})),
\text{j} = \text{mapply} (\text{flowidx},1: \text{nWarehouses},c(\text{mapply}(\text{rep},1:\text{nPlants}, \text{nWarehouses}))),
\text{x} = \text{rep}(1, \text{nWarehouses} * \text{nPlants}))

A3 <- spMatrix(\text{nWarehouses}, \text{nPlants})

A4 <- spMatrix(\text{nWarehouses}, \text{nPlants} * \text{nWarehouses},
\text{i} = c(\text{mapply}(\text{rep},1:\text{nWarehouses}, \text{nPlants})),
\text{j} = \text{mapply} (\text{flowidx},c(\text{mapply}(\text{rep},1:\text{nWarehouses}, \text{nPlants})),1: \text{nPlants}),
\text{x} = \text{rep}(1, \text{nPlants} * \text{nWarehouses}))

\text{model}$A$ <- \text{rbind}(\text{cbind}(A1, A2),\text{cbind}(A3, A4))

\text{model}$\text{rhs}$ <- \text{c}(\text{rep}(0, \text{nPlants}), \text{Demand})

\text{model}$\text{sense}$ <- \text{c}(\text{rep}('<=', \text{nPlants}), \text{rep}('=', \text{nWarehouses}))

\text{model}$\text{constrnames}$ <- \text{c}(\text{sprintf}('\text{Capacity%d}',1: \text{nPlants}),
\text{sprintf}('\text{Demand%d}',1: \text{nWarehouses}))

# Save model
gurobi_write(\text{model},'\text{facilityR.lp}')

# Guess at the starting point: close the plant with the highest fixed
# costs; open all others first open all plants
\text{model}$\text{start}$ <- \text{c}(\text{rep}(1, \text{nPlants}), \text{rep}(\text{NA}, \text{nPlants} * \text{nWarehouses}))

# find most expensive plant, and close it in mipstart
cat(\text{`Initial guess:\n'})
worstidx <- which.max(\text{FixedCosts})
\text{model}$\text{start}[\text{worstidx}]$ <- 0
cat(\text{`Closing plant',worstidx,'\n'})

# set parameters
\text{params} <- \text{list}()
\text{params}$\text{method}$ <- 2

# Optimize
\text{res} <- gurobi(\text{model}, \text{params})

# Print solution
if (\text{res}$\text{status}$ == 'OPTIMAL') {
  cat(\text{`\nTotal Costs:',res}$\text{objval}','\nsolution:\n'})
  cat(\text{`Facilities:', \text{model}$\text{varnames}[\text{which}(\text{res}$x[1: \text{nPlants}] > 1e-5)], '\n'})
  active <- \text{nPlants} + \text{which}(\text{res}$x[(\text{nPlants} +1):(\text{nPlants} * (\text{nWarehouses} +1))] > 1e-5)
  cat(\text{`Flows: '})
  \text{cat}(\text{sprintf}(\text{'%s=%g'}, \text{model}$\text{varnames}[\text{active}], \text{res}$x[\text{active}]), '\n')
  \text{rm}(\text{active})
} else {
  cat(\text{`No solution\n'})
}

# Clear space
\text{rm}(\text{res}, \text{model}, \text{params}, \text{A1}, \text{A2}, \text{A3}, \text{A4})
feasopt.R

# Copyright 2018, Gurobi Optimization, LLC
#
# This example reads a MIP model from a file, adds artificial
# variables to each constraint, and then minimizes the sum of the
# artificial variables. A solution with objective zero corresponds
# to a feasible solution to the input model.
# We can also use FeasRelax feature to do it. In this example, we
# use minrelax=1, i.e. optimizing the returned model finds a solution
# that minimizes the original objective, but only from among those
# solutions that minimize the sum of the artificial variables.

library(Matrix)
library(gurobi)

args <- commandArgs(trailingOnly = TRUE)
if (length(args) < 1) {
  stop('Usage: Rscript feasopt.R filename
')
}

# Set-up environment
env <- list()
env$logfile <- 'feasopt.log'

# Read model
cat('Reading model', args[1], '...')
model <- gurobi_read(args[1], env)
cat('... done
')

# Create penalties
penalties <- list()
penalties$lb <- Inf
penalties$ub <- Inf
penalties rhs <- rep(1, length(model rhs))

result <- gurobi_feasrelax(model, 0, TRUE, penalties, env = env)

# Display results
if (result$feasojb > 1e-6) {
  cat('Model', args[1], 'is infeasible within variable bounds\n')
} else {
  cat('Model', args[1], 'is feasible\n')
}

# Clear space
rm(env, model, penalties, result)

fixanddive.R

# Copyright 2018, Gurobi Optimization, LLC
#
# Implement a simple MIP heuristic. Relax the model,
# sort variables based on fractionality, and fix the 25% of
# the fractional variables that are closest to integer variables.
# Repeat until either the relaxation is integer feasible or
# linearly infeasible.
library(Matrix)
library(gurobi)

args <- commandArgs(trailingOnly = TRUE)
if (length(args) < 1) {
  stop('Usage: Rscript fixanddive.R filename\n')
}

# Read model
cat('Reading model', args[1], '...')
model <- gurobi_read(args[1])
cat('... done\n')

# Detect set of non-continuous variables
numvars <- ncol(model$A)
intvars <- which(model$vtype != 'C')
numintvars <- length(intvars)
if (numintvars < 1) {
  stop('All model\'s variables are continuous, nothing to do\n')
}

# create lb and ub if they do not exist, and set them to default values
if (!('lb' %in% model)) {
  model$lb <- numeric(numvars)
}
if (!('ub' %in% model)) {
  model$ub <- Inf + numeric(numvars)
}

# set all variables to continuous
ovtype <- model$vtype
model$vtype[1:numvars] <- 'C'

# parameters
params <- list()
params$OutputFlag <- 0
result <- gurobi(model, params)

# Perform multiple iterations. In each iteration, identify the first quartile of integer variables that are closest to an integer value swap in the relaxation, fix them to the nearest integer, and repeat.
for (iter in 1:1000) {
  # See if status is optimal
  if (result$status != 'OPTIMAL') {
    cat('Model status is', result$status, '\n')
    stop('Can not keep fixing variables\n')
  }
  # collect fractionalitiy of integer variables
  fractional <- abs(result$x - floor(result$x+0.5))
  fractional <- replace(fractional, fractional < 1e-5, 1)
  fractional <- replace(fractional, ovtype == 'C', 1)
  fractional <- replace(fractional, ovtype == 'S', 1)
  nfractional <- length(which(fractional < 0.51))
cat('Iteration:', iter, 'Obj:', result$objval, 
    'Fractional:', nfractional, '\n')
if (nfractional == 0) {
    cat('Found feasible solution - objective', result$objval, '\n')
    break
}

# order the set of fractional index
select <- order(fractional, na.last = TRUE, decreasing = FALSE)

# fix 25% of variables
nfix <- as.integer(ceiling(nfractional / 4))
# cat('Will fix', nfix, 'variables, out of', numvars, '\n')
if (nfix < 10)
    cat('Fixing ')
else
    cat('Fixing ', nfix, 'variables, fractionality threshold:', fractional[select[nfix]], '\n')
for (k in 1:nfix) {
    j <- select[k]
    val <- floor(result$x[j] + 0.5)
    model$lb[j] <- val
    model$ub[j] <- val
    if (nfix < 10)
        cat(model$varname[j], 'x*=', result$x[j], 'to', val, ' ')
}
if (nfix < 10)
    cat('\n')

# reoptimize
result <- gurobi(model, params)

# Clear space
rm(model, params, result)

# Copyright 2018, Gurobi Optimization, LLC
#
# In this example we show the use of general constraints for modeling
# some common expressions. We use as an example a SAT-problem where we
# want to see if it is possible to satisfy at least four (or all) clauses
# of the logical for
#
# We do this by introducing two variables for each literal (itself and its
# negated value), a variable for each clause, and then two
# variables for indicating if we can satisfy four, and another to identify
# the minimum of the clauses (so if it one, we can satisfy all clauses)
# and put these two variables in the objective.
# i.e. the Objective function will be
# maximize Obj0 + Obj1
# Obj0 = MIN(Clause1, ..., Clause8)
# Obj1 = 1 -> Clause1 + ... + Clause8 >= 4
#
# thus, the objective value will be two if and only if we can satisfy all
# clauses; one if and only if at least four clauses can be satisfied, and
# zero otherwise.
#
library(Matrix)
library(gurobi)

# Set-up environment
env <- list()
env$logfile <- 'genconstr.log'

# define primitive data
nLiterals <- 4
nClauses <- 8
nObj <- 2
nVars <- 2 * nLiterals + nClauses + nObj
Literal <- function(n) {n}
NotLit <- function(n) {n + nLiterals}
Clause <- function(n) {2 * nLiterals + n}
Obj <- function(n) {2 * nLiterals + nClauses + n}

Clauses <- list(c(Literal(1), NotLit(2), Literal(3)),
                 c(Literal(2), NotLit(3), Literal(4)),
                 c(Literal(3), NotLit(4), Literal(1)),
                 c(Literal(4), NotLit(1), Literal(2)),
                 c(NotLit(1), NotLit(2), Literal(3)),
                 c(NotLit(2), NotLit(3), Literal(4)),
                 c(NotLit(3), NotLit(4), Literal(1)),
                 c(NotLit(4), NotLit(1), Literal(2)))

# Create model
model <- list()
model$modelname <- 'genconstr'
model$modelsense <- 'max'

# Create objective function, variable names, and variable types
model$ctype <- rep('B', nVars)
model$ub <- rep(1, nVars)
model$varnames <- c(sprintf('X%d', seq(1, nLiterals)),
                      sprintf('notX%d', seq(1, nLiterals)),
                      sprintf('Clause%d', seq(1, nClauses)),
                      sprintf('Obj%d', seq(1, nObj)))
model$obj <- c(rep(0, 2 * nLiterals + nClauses), rep(1, nObj))

# Create linear constraints linking literals and not literals
model$A <- spMatrix(nLiterals, nVars,
                    i = c(seq(1, nLiterals),
                         seq(1, nLiterals)),
                    j = c(seq(1, nLiterals),
                         seq(1, nLiterals)),
                    v = rep(1, 2 * nLiterals + nClauses))
j = c(seq(1,nLiterals),
     seq(1+nLiterals,2*nLiterals)),
x = rep(1,2*nLiterals))
model$constrnames <- c(sprintf("CNSTR_X%d",seq(1,nLiterals)))
model$rhs <- rep(1, nLiterals)
model$sense <- rep(\'=\', nLiterals)

# Create OR general constraints linking clauses and literals
model$genconor <- lapply(1:nClauses,
                           function(i) list(resvar = Clause(i),
                                            vars = Clauses[[i]],
                                            name = sprintf("CNSTR_Claude%d",i)))

# Set-up Obj1 = Min(Clause[1:nClauses])
model$genconmin <- list(list(resvar = Obj(1),
                             vars = c(seq(Clause(1),Clause(nClauses))),
                             name = 'CNSTR_Obj1'))

# Set-up Obj2 to signal if any clause is satisfied, i.e.
# we use an indicator constraint of the form:
# (Obj2 = 1) -> sum(Clause[1:nClauses]) >= 4
model$genconind <- list(list(binvar = Obj(2),
                          binval = 1,
                          a = c(rep(0,2*nLiterals),
                               rep(1,nClauses),
                               rep(0,nObj)),
                          sense = '>\',
                          rhs = 4,
                          name = 'CNSTR_Obj2'))

# Save model
gurobi_write(model, 'genconstr.lp', env)

# Optimize
result <- gurobi(model, env = env)

# Check optimization status
if (result$status == 'OPTIMAL') {
  if (result$objval > 1.9) {
    cat("Logical expression is satisfiable\n")
  } else if(result$objval > 0.9) {
    cat("At least four clauses are satisfiable\n")
  } else {
    cat("At most three clauses may be satisfiable\n")
  }
} else {
  cat("Optimization failed\n")
}

# Clear space
rm(model,result,env,Clauses)

lp.R

# Copyright 2018, Gurobi Optimization, LLC
#
# This example formulates and solves the following simple LP model:
# maximize
# x + 2 y + 3 z
# subject to
# x + y <= 1
# y + z <= 1

library(Matrix)
library(gurobi)

model <- list()

model$A <- matrix(c(1,1,0,0,1,1), nrow=2, byrow=T)
model$obj <- c(1,2,3)
model$modelsense <- 'max'
model$rhs <- c(1,1)
model$sense <- c('<','<')

result <- gurobi(model)
print(result$objval)
print(result$x)

# Second option for A - as a sparseMatrix (using the Matrix package)...
model$A <- spMatrix(2, 3, c(1,1,2,2), c(1,2,2,3), c(1,1,1,1))
params <- list(Method=2, TimeLimit=100)
result <- gurobi(model, params)
print(result$objval)
print(result$x)

# Third option for A - as a sparse triplet matrix (using the slam package)...
model$A <- simple_triplet_matrix(c(1,1,2,2), c(1,2,2,3), c(1,1,1,1))
params <- list(Method=2, TimeLimit=100)
result <- gurobi(model, params)
print(result$objval)
print(result$x)

# Clear space
rm(result, params, model)

# Copyright 2018, Gurobi Optimization, LLC
# Formulate a simple linear program, solve it, and then solve it
# again using the optimal basis.
library(gurobi)
model <- list()

model$A <- matrix(c(1,3,4,8,2,3), nrow=2, byrow=T)
model$obj <- c(1,2,3)
model$rhs <- c(4,7)
model$sense <- c(‘>’, ‘>’)  

# First solve - requires a few simplex iterations
result <- gurobi(model)

model$vbasis <- result$vbasis
model$cbasis <- result$cbasis

# Second solve - start from optimal basis, so no iterations
result <- gurobi(model)

# Clear space
rm(model, result)

lpmethod.R

# Copyright 2018, Gurobi Optimization, LLC
#
# Solve a model with different values of the Method parameter;
# show which value gives the shortest solve time.

library(Matrix)
library(gurobi)

args <- commandArgs(trailingOnly = TRUE)
if (length(args) < 1) {
  stop('Usage: Rscript lpmethod.R filename\n')
}

# Read model
cat('Reading model', args[1], '...')
model <- gurobi_read(args[1])
cat('... done\n')

# Solve the model with different values of Method
params <- list()
bestTime <- Inf
bestMethod <- -1
for (i in 0:4) {
  params$method <- i
  res <- gurobi(model, params)
  if (res$status == 'OPTIMAL') {
    bestMethod <- i
    bestTime <- res$runtime
    params$TimeLimit <- bestTime
  }
}
# Report which method was fastest
if (bestMethod == -1) {
    cat('Unable to solve this model
')
} else {
    cat('Solved in ', bestTime, ' seconds with Method: ', bestMethod, '
')
}
rm(params, model)

lpmod.R

# Copyright 2018, Gurobi Optimization, LLC
#
# This example reads an LP model from a file and solves it.
# If the model can be solved, then it finds the smallest positive variable,
# sets its upper bound to zero, and reslutions the model two ways:
# first with an advanced start, then without an advanced start
# (i.e. 'from scratch').

library(Matrix)
library(gurobi)

args <- commandArgs(trailingOnly = TRUE)
if (length(args) < 1) {
    stop('Usage: Rscript lpmod.R filename
')
}

# Read model
cat('Reading model ', args[1], '... ')
model <- gurobi_read(args[1])
cat('... done
')

# Determine whether it is an LP
if ('multiobj' %in% names(model) ||
    'sos' %in% names(model) ||
    'pwlobj' %in% names(model) ||
    'cones' %in% names(model) ||
    'quadcon' %in% names(model) ||
    'genconstr' %in% names(model) ) {
    stop('The model is not a linear program
')
}

# Detect set of non-continuous variables
intvars <- which(model$vtype != 'C')
umintvars <- length(intvars)
if (numintvars > 0) {
    stop('problem is a MIP, nothing to do
')
}

# Optimize
result <- gurobi(model)
if (result$status != 'OPTIMAL') {
    cat('This model cannot be solved because its optimization status is',
        result$status, '
')
    stop('Stop now
')
}
# Recover number of variables in model
numvars <- ncol(model$A)

# Ensure bounds array is initialized
if (is.null(model$lb)) {
  model$lb <- rep(0, numvars)
}
if (is.null(model$ub)) {
  model$ub <- rep(Inf, numvars)
}

# Find smallest (non-zero) variable value with zero lower bound
x <- replace(result$x, result$x < 1e-4, Inf)

x <- replace(x, model$lb > 1e-6, Inf)

minVar <- which.min(x)

minVal <- x[minVar]

# Get variable name
varname <- ''
if (is.null(model$varnames)) {
  varname <- sprintf('C%d', minVar)
} else {
  varname <- model$varnames[minVar]
}

cat('

 *** Setting ', varname, ' from ', minVal, ' to zero ***

')

model$ub[minVar] <- 0

# Set advance start basis information
model$vbasis <- result$vbasis
model$cbasis <- result$cbasis

result2 <- gurobi(model)

warmCount <- result2$itercount
warmTime <- result2$runtime

# Reset - advance start information
model$vbasis <- NULL
model$cbasis <- NULL

result2 <- gurobi(model)

coldCount <- result2$itercount
coldTime <- result2$runtime

cat('

 *** Warm start: ', warmCount, ' iterations, ', warmTime, ' seconds

')

cat('

 *** Cold start: ', coldCount, ' iterations, ', coldTime, ' seconds

')

# Clear space
rm(model, result, result2)

mip.R

# Copyright 2018, Gurobi Optimization, LLC
#
# This example formulates and solves the following simple MIP model:
# maximize
# x + y + 2 z
# subject to
# x + 2 y + 3 z <= 4
# x + y >= 1
# x, y, z binary

library(gurobi)

model <- list()

model$A <- matrix(c(1,2,3,1,1,0), nrow=2, ncol=3, byrow=T)
model$obj <- c(1,1,2)
model$modelsense <- 'max'
model$rhs <- c(4,1)
model$sense <- c('<', '>
model$vtype <- 'B'

params <- list(OutputFlag=0)

result <- gurobi(model, params)

print('Solution: ')
print(result$objval)
print(result$x)

# Clear space
rm(model, result, params)

mip2.R

# Copyright 2018, Gurobi Optimization, LLC
# This example reads a MIP model from a file, solves it and
# prints the objective values from all feasible solutions
# generated while solving the MIP. Then it creates the fixed
# model and solves that model.

library(Matrix)
library(gurobi)

args <- commandArgs(trailingOnly = TRUE)
if (length(args) < 1) {
  stop('Usage: Rscript mip2.R filename\n')
}

# Read model
cat('Reading model', args[1], '...')
model <- gurobi_read(args[1])

# Detect set of non-continous variables
numvars <- dim(model$A)[2]
intvars <- which(model$vtype != 'C')
umintvars <- length(intvars)
if (numintvars < 1) {

stop('All model\'s variables are continuous, nothing to do\n')
}

# Optimize
params <- list()
params$poolsolutions <- 20
result <- gurobi(model, params)

# Capture solution information
if (result$status != 'OPTIMAL') {
  cat('Optimization finished with status', result$status, '\n')
  stop('Stop now\n')
}

# Iterate over the solutions
if ('pool' %in% names(result)) {
  solcount <- length(result$pool)
  for (k in 1:solcount) {
    cat('Solution', k, 'has objective:', result$pool[[k]]$objval, '\n')
  }
} else {
  solcount <- 1
  cat('Solution 1 has objective:', result$objval, '\n')
}

# Convert to fixed model
for (j in 1:numvars) {
  if (model$vtype[j] != 'C') {
    t <- floor(result$x[j]+0.5)
    model$lb[j] <- t
    model$ub[j] <- t
  }
}

# Solve the fixed model
result2 <- gurobi(model, params)
if (result2$status != 'OPTIMAL') {
  stop('Error: fixed model isn\'t optimal\n')
}

if (abs(result$objval - result2$objval) > 1e-6 * (1 + abs(result$objval))) {
  stop('Error: Objective values differ\n')
}

# Print values of non-zero variables
for (j in 1:numvars) {
  if (abs(result2$x[j]) < 1e-6) next
  varnames <- ''
  if ('varnames' %in% names(model)) {
    varnames <- model$varnames[j]
  } else {
    varnames <- sprintf('X%d', j)
  }
  cat(format(varnames, justify='left', width=10), ':',
       format(result2$x[j], justify='right', digits=2, width=10), '\n')
}
# Clear space
rm(model, params, result, result2)

multiobj.R

# Copyright 2018, Gurobi Optimization, LLC
#
# Want to cover three different sets but subject to a common budget of
# elements allowed to be used. However, the sets have different priorities to
# be covered; and we tackle this by using multi-objective optimization.

library(Matrix)
library(gurobi)

# define primitive data
groundSetSize <- 20
nSubSets <- 4
Budget <- 12
Set <- list(
  c( 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 ),
  c( 0, 0, 0, 0, 0, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1 ),
  c( 0, 0, 0, 1, 1, 0, 1, 1, 0, 0, 0, 0, 1, 1, 0, 1, 1, 0, 0 ),
  c( 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1, 0, 0, 0, 1, 1, 0, 0, 0 )
)
SetObjPriority <- c(3, 2, 2, 1)
SetObjWeight <- c(1.0, 0.25, 1.25, 1.0)

# Initialize model
model <- list()
model$modelsense <- 'max'
model$modelname <- 'multiobj'

# Set variables, all of them are binary, with 0,1 bounds.
model$vtype <- 'B'
model$lb <- 0
model$ub <- 1
model$varnames <- paste(rep('El ', groundSetSize), 1:groundSetSize, sep='')

# Build constraint matrix
model$A <- spMatrix(1, groundSetSize,
  i = rep(1, groundSetSize),
  j = 1:groundSetSize,
  x = rep(1, groundSetSize))
model$rhs <- c(Budget)
model$sense <- c('<')
model$constrnames <- c('Budget')

# Set multi-objectives
model$multiobj <- list()
for (m in 1:nSubSets) {
  model$multiobj[[m]] <- list()
  model$multiobj[[m]]$objn <- Set[[m]]
  model$multiobj[[m]]$priority <- SetObjPriority[m]
  model$multiobj[[m]]$weight <- SetObjWeight[m]
  model$multiobj[[m]]$abstol <- m
  model$multiobj[[m]]$reltol <- 0.01
model$multiobj[[m]]$name <- sprintf('Set%d', m)
model$multiobj[[m]]$con <- 0.0

# Save model
gurobi_write(model,'multiobj_R.lp')

# Set parameters
params <- list()
params$PoolSolutions <- 100

# Optimize
result <- gurobi(model, params)

# Capture solution information
if (result$status != 'OPTIMAL') {
  cat('Optimization finished with status', result$status, '\n')
  stop('Stop now\n')
}

# Print best solution
if ('pool' %in% names(result)) {
  solcount <- length(result$pool)
  cat('Number of solutions found:', solcount, '\n')
  if (solcount > 10) {
    solcount <- 10
  }
  cat('Objective values for first', solcount, 'solutions:\n')
  for (k in 1:solcount) {
    cat('Solution', k, 'has objective:', result$pool[[k]]$objval[1], '\n')
  }
} else {
  solcount <- 1
  cat('Number of solutions found:', solcount, '\n')
  cat('Solution 1 has objective:', result$objval, '\n')
}

# Clean up
rm(model, params, result)

params.R

# Copyright 2018, Gurobi Optimization, LLC
#
# Use parameters that are associated with a model.
#
# A MIP is solved for a few seconds with different sets of parameters.
# The one with the smallest MIP gap is selected, and the optimization
library(Matrix)
library(gurobi)

args <- commandArgs(trailingOnly = TRUE)
if (length(args) < 1) {
  stop('Usage: Rscript params.R filename\n')
}

# Read model
cat(' Reading model', args[1], '...')
model <- gurobi_read(args[1])
cat('... done\n')

# Detect set of non-continuous variables
intvars <- which(model$vtype != 'C')
numintvars <- length(intvars)
if (numintvars < 1) {
  stop('All model\'s variables are continuous, nothing to do\n')
}

# Set a 2 second time limit
params <- list()
params$TimeLimit <- 2
# Now solve the model with different values of MIPFocus
params$MIPFocus <- 0
result <- gurobi(model, params)
bestgap <- result$mipgap
bestparams <- params
for (i in 1:3) {
  params$MIPFocus <- i
  result <- gurobi(model, params)
  if (result$mipgap < bestgap) {
    bestparams <- params
    bestgap <- result$mipgap
  }
}

# Finally, reset the time limit and Re-solve model to optimality
bestparams$TimeLimit <- Inf
result <- gurobi(model, bestparams)
cat('Solved with MIPFocus:', bestparams$MIPFocus, '\n')

# Clear space
rm(model, params, result, bestparams)

# Copyright 2018, Gurobi Optimization, LLC
#
# This example considers the following separable, convex problem:
#
# minimize
# f(x) - y + g(z)
library(gurobi)

model <- list()

model$A <- matrix(c(1,2,3,1,1,0), nrow=2, byrow=T)
model$obj <- c(0,-1,0)
model$ub <- c(1,1,1)
model$rhs <- c(4,1)
model$sense <- c('<', '>')

# Uniformly spaced points in [0.0, 1.0]

u <- seq(from=0, to=1, by=0.01)

# First piecewise-linear function: f(x) = exp(-x)
pwl1 <- list()
pwl1$var <- 1
pwl1$x <- u
pwl1$y <- sapply(u, function(x) exp(-x))

# Second piecewise-linear function: g(z) = 2 z^2 - 4 z
pwl2 <- list()
pwl2$var <- 3
pwl2$x <- u
pwl2$y <- sapply(u, function(z) 2 * z * z - 4 * z)

model$pwlobj <- list(pwl1, pwl2)

result <- gurobi(model)

print(result$objval)
print(result$x)

# Negate piecewise-linear function on x, making it non-convex

model$pwlobj[[1]]$y <- sapply(u, function(x) -exp(-x))

result <- gurobi(model)
gurobi_write(model, "pwl.lp")

print(result$objval)
print(result$x)

# Clear space
rm(model, pwl1, pwl2, result)
```
# Copyright 2018, Gurobi Optimization, LLC
#
# We find alternative epsilon-optimal solutions to a given knapsack
# problem by using PoolSearchMode

library(Matrix)
library(gurobi)

# define primitive data
groundSetSize <- 10
objCoef <- c(32, 32, 15, 15, 6, 6, 1, 1, 1, 1)
knapsackCoef <- c(16, 16, 8, 8, 4, 4, 2, 2, 1, 1)
Budget <- 33

# Initialize model
model <- list()
model$modelsense <- 'max'
model$modelname <- 'poolsearch'

# Set variables
model$obj <- objCoef
model$vtype <- 'B'
model$lb <- 0
model$ub <- 1
model$varnames <- sprintf('El%d', seq(1, groundSetSize))

# Build constraint matrix
model$A <- spMatrix(1, groundSetSize,
  i = rep(1, groundSetSize),
  j = 1:groundSetSize,
  x = knapsackCoef)
model$rhs <- c(Budget)
model$sense <- c('<')
model$constrnames <- c('Budget')

# Set poolsearch parameters
params <- list()
params$PoolSolutions <- 1024
params$PoolGap <- 0.10
params$PoolSearchMode <- 2

# Save problem
gurobi_write(model, 'poolsearch_R.lp')

# Optimize
result <- gurobi(model, params)

# Capture solution information
if (result$status != 'OPTIMAL') {
  cat('Optimization finished with status', result$status, '
')
  stop('Stop now')
}

# Print best solution
```

480
#'Selected elements in best solution:
'
cat(model$varnames[which(result$x >= 0.9)], 'n')

# Print all solution objectives and best furth solution
if ('pool' %in% names(result)) {
  solcount <- length(result$pool)
  cat('Number of solutions found:', solcount, 'n')
  cat('Objective values for first', solcount, 'solutions:
')
  for (k in 1:solcount) {
    cat(result$pool[[k]]$objval, ', ', sep = '')
  }
  cat('
')
  if (solcount >= 4) {
    cat('Selected elements in fourth best solution:
')
    cat(model$varnames[which(result$pool[[4]]$xn >= 0.9)], 'n')
  } else {
    solcount <- 1
    cat('Number of solutions found:', solcount, 'n')
    cat('Solution 1 has objective:', result$objval, 'n')
  }
}

# Clean up
rm(model, params, result)

qcp.R

# Copyright 2018, Gurobi Optimization, LLC
#
# This example formulates and solves the following simple QCP model:
# maximize
# x
# subject to
# x + y + z = 1
# x^2 + y^2 <= z^2 (second-order cone)
# x^2 <= yz (rotated second-order cone)

library(gurobi)
library(Matrix)

model <- list()

model$A <- matrix(c(1,1,1), nrow=1, byrow=T)
model$modelsense <- 'max'
model$obj <- c(1,0,0)
model$rhs <- c(1)
model$sense <- c('=')

# First quadratic constraint: x^2 + y^2 - z^2 <= 0
qc1 <- list()
qc1$Qc <- spMatrix(3, 3, c(1, 2, 3), c(1, 2, 3), c(1.0, 1.0, -1.0))
qc1$rhs <- 0.0

# Second quadratic constraint: x^2 - yz <= 0
qc2 <- list()
qc2$Qc <- spMatrix(3, 3, c(1, 2), c(1, 3), c(1.0, -1.0))
qc2$rhs <- 0.0

model$quadcon <- list(qc1, qc2)

result <- gurobi(model)

print(result$objval)
print(result$x)

# Clear space
rm(model, result)

qp.R

# Copyright 2018, Gurobi Optimization, LLC
#
# This example formulates and solves the following simple QP model:
# minimize
#   x^2 + xy + y^2 + yz + z^2 + 2x
# subject to
#   x + 2y + 3z >= 4
#   x + y >= 1

library(gurobi)

model <- list()

model$A <- matrix(c(1,2,3,1,1,0), nrow=2, byrow=T)
model$Q <- matrix(c(1,0.5,0,0.5,1,0.5,0,0.5,1), nrow=3, byrow=T)
model$obj <- c(2,0,0)
model$rhs <- c(4,1)
model$sense <- c('>', '>

result <- gurobi(model)

print(result$objval)
print(result$x)

model$vtype <- c('I', 'I', 'I')

result <- gurobi(model)

print(result$objval)
print(result$x)

# Clear space
rm(model, result)

sensitivity.R

# Copyright 2018, Gurobi Optimization, LLC
#
# A simple sensitivity analysis example which reads a MIP model
# from a file and solves it. Then each binary variable is set
to 1-X, where X is its value in the optimal solution, and
# the impact on the objective function value is reported.
library(Matrix)
library(gurobi)

args <- commandArgs(trailingOnly = TRUE)
if (length(args) < 1) {
  stop('Usage: Rscript sensitivity.R filename\n')
}

# Read model
cat('Reading model', args[1], '...')
model <- gurobi_read(args[1])
cat('... done\n')

# Detect set of non-continuous variables
numvars <- ncol(model$A)
intvars <- which(model$vtype != 'C')
numintvars <- length(intvars)
if (numintvars < 1) {
  stop('All model\'s variables are continuous, nothing to do\n')
}

# Optimize
result <- gurobi(model)

# Capture solution information
if (result$status != 'OPTIMAL') {
  cat('Optimization finished with status', result$status, '\n')
  stop('Stop now\n')
}
origx <- result$x
origobjval <- result$objval

# create lb and ub if they do not exists, and set them to default values
if (!(\'lb\' %in% names(model))) {
  model$lb <- numeric(numvars)
}
if (!(\'ub\' %in% names(model))) {
  model$ub <- Inf + numeric(numvars)
}

# Disable output for subsequent solves
params <- list()
params$OutputFlag <- 0

# Iterate through unfixed binary variables in the model
for (j in 1:numvars) {
  if (model$vtype[j] != 'B' &&
      model$vtype[j] != 'I') next
  if (model$vtype[j] == 'I') {
    if (model$lb[j] == 0.0) next
    if (model$ub[j] == 1.0) next
  } else {
    if (model$lb[j] > 0.0) next
    if (model$ub[j] < 1.0) next
  }
# Update MIP start for all variables
model$start <- origx

# Set variable to 1-X, where X is its value in optimal solution
if (origx[j] < 0.5) {
    model$start[j] <- 1
    model$lb[j]   <- 1
} else {
    model$start[j] <- 0
    model$ub[j]   <- 0
}

# Optimize
result <- gurobi(model, params)

# Display result
varnames <- ''
if ('varnames' %in% names(model)) {
    varnames <- model$varnames[j]
} else {
    varnames <- sprintf('%s%d', model$vtype[j], j)
}
gap <- 0
if (result$status != 'OPTIMAL') {
    gap <- Inf
} else {
    gap <- result$objval - origobjval
}
cat('Objective sensitivity for variable', varnames, 'is', gap, 'n')

# Restore original bounds
model$lb[j] <- 0
model$ub[j] <- 1

# Clear space
rm(model, params, result, origx)

sos.R

# Copyright 2018, Gurobi Optimization, LLC
#
# This example formulates and solves the following simple SOS model:
# maximize
# 2 x + y + z
# subject to
# x1 = 0 or x2 = 0 (SOS1 constraint)
# x1 = 0 or x3 = 0 (SOS1 constraint)
# x1 <= 1, x2 <= 1, x3 <= 2

library(gurobi)

model <- list()
```r
model$A <- matrix(c(0,0,0), nrow=1, byrow=T)
model$obj <- c(2,1,1)
model$modelsense <- 'max'
model$ub <- c(1,1,2)
model$rhs <- c(0)
model$sense <- c( '=' )

# First SOS: x1 = 0 or x2 = 0
sos1 <- list()
sos1$type <- 1
sos1$index <- c(1, 2)
sos1$weight <- c(1, 2)

# Second SOS: x1 = 0 or x3 = 0
sos2 <- list()
sos2$type <- 1
sos2$index <- c(1, 3)
sos2$weight <- c(1, 2)

model$sos <- list(sos1, sos2)

result <- gurobi(model)

print(result$objval)
print(result$x)

# Clear space
rm(model, result)

sudoku.R

# Copyright 2018, Gurobi Optimization, LLC */
#
# Sudoku example.
#
# The Sudoku board is a 9x9 grid, which is further divided into a 3x3 grid
# of 3x3 grids. Each cell in the grid must take a value from 0 to 9.
# No two grid cells in the same row, column, or 3x3 subgrid may take the
# same value.
#
# In the MIP formulation, binary variables x[i,j,v] indicate whether
# cell <i,j> takes value 'v'. The constraints are as follows:
# 1. Each cell must take exactly one value (sum_y x[i,j,v] = 1)
# 2. Each value is used exactly once per row (sum_i x[i,j,v] = 1)
# 3. Each value is used exactly once per column (sum_j x[i,j,v] = 1)
# 4. Each value is used exactly once per 3x3 subgrid (sum_grid x[i,j,v] = 1)
#
# Input datasets for this example can be found in examples/data/sudoku*. 
#
library(Matrix)
library(gurobi)

args <- commandArgs(trailingOnly = TRUE)
if (length(args) < 1) {
  stop(’Usage: Rscript sudoku.R filename
’)```
# Read input file
conn <- file(args[1], open='r')
if(!isOpen(conn)) {
  cat('Could not read file',args[1],'
')
  stop('Stop now\n')
}
linn <- readLines(conn)
close(conn)

# Ensure that all lines have the same length as the number of lines, and
# that the character set is the correct one.
# Load fixed positions in board
Dim <- length(linn)
board <- matrix(0, Dim, Dim, byrow = TRUE)
if (Dim != 9) {
  cat('Input file',args[1],'has',Dim,'lines instead of 9\n')
  stop('Stop now\n')
}
for (i in 1:Dim) {
  line <- strsplit(linn[[i]],split='')[[1]]
  if (length(line) != Dim) {
    cat('Input line',i,'has',length(line),'characters, expected',Dim,'\n')
    stop('Stop now\n')
  }
  for (j in 1:Dim) {
    if (line[[j]] != '.') {
      k <- as.numeric(line[[j]])
      if (k < 1 || k > Dim) {
        cat('Unexpected character in Input line',i,'character',j,'\n')
        stop('Stop now\n')
      } else {
        board[i,j] = k
      }
    }
  }
}

# Map X[i,j,k] into an index variable in the model
nVars <- Dim * Dim * Dim
varIdx <- function(i,j,k) {i + (j-1) * Dim + (k-1) * Dim * Dim}

cat('Dataset grid:',Dim,'x',Dim,'\n')

# Set-up environment
env <- list()
env$logfile <- 'sudoku.log'

# Build model
model <- list()
model$modelname <- 'sudoku'
model$modelsense <- 'min'

# Create variable names, types, and bounds
model$vtype <- 'B'
model$lb <- rep(0, nVars)
model$ub <- rep(1, nVars)
model$varnames <- rep('', nVars)
for (i in 1:Dim) {
    for (j in 1:Dim) {
        for (k in 1:Dim) {
            if (board[i,j] == k) model$lb[varIdx(i,j,k)] = 1
            model$varnames[varIdx(i,j,k)] = paste0('X',i,j,k)
        }
    }
}

# Create (empty) constraints:
model$A <- spMatrix(0, nVars)
model$rhs <- c()
model$sense <- c()
model$constrnames <- c()

# Each cell gets a value:
for (i in 1:Dim) {
    for (j in 1:Dim) {
        B <- spMatrix(1, nVars,
                      i = rep(1,Dim),
                      j = varIdx(i,j,1:Dim),
                      x = rep(1,Dim))
        model$A <- rbind(model$A, B)
        model$rhs <- c(model$rhs, 1)
        model$sense <- c(model$sense, '=')
        model$constrnames <- c(model$constrnames, paste0('OneValInCell',i,j))
    }
}

# Each value must appear once in each column
for (i in 1:Dim) {
    for (k in 1:Dim) {
        B <- spMatrix(1, nVars,
                      i = rep(1,Dim),
                      j = varIdx(i,1:Dim,k),
                      x = rep(1,Dim))
        model$A <- rbind(model$A, B)
        model$rhs <- c(model$rhs, 1)
        model$sense <- c(model$sense, '=')
        model$constrnames <- c(model$constrnames, paste0('OnceValueInRow',i,k))
    }
}

# Each value must appear once in each row
for (j in 1:Dim) {
    for (k in 1:Dim) {
        B <- spMatrix(1, nVars,
                      i = rep(1,Dim),
                      j = varIdx(1:Dim,j,k),
                      x = rep(1,Dim))
        model$A <- rbind(model$A, B)
        model$rhs <- c(model$rhs, 1)
        model$sense <- c(model$sense, '=')
    }
}
# Each value must appear once in each subgrid
SubDim <- 3
for (k in 1:Dim) {
  for (g1 in 1:SubDim) {
    for (g2 in 1:SubDim) {
      B <- spMatrix(1, nVars, 
      i = rep(1,Dim), 
      j = c(varIdx(1+(g1-1)*SubDim,(g2-1)*SubDim + 1:SubDim, k), 
               varIdx(2+(g1-1)*SubDim,(g2-1)*SubDim + 1:SubDim, k), 
               varIdx(3+(g1-1)*SubDim,(g2-1)*SubDim + 1:SubDim, k)), 
      x = rep(1,Dim))
      model$A <- rbind(model$A, B)
      model$rhs <- c(model$rhs, 1)
      model$sense <- c(model$sense, '=')
      model$constrnames <- c(model$constrnames, 
               paste0('OnceValueInSubGrid',g1,g2,k))
    }
  }
}

# Save model
gurobi_write(model, 'sudoku.lp', env)

# Optimize model
result <- gurobi(model, env = env)

if (result$status == 'OPTIMAL') {
  cat('Solution:\n')
  cat('-----------------------------------\n')
  for (i in 1:Dim) {
    for (j in 1:Dim) {
      if (j %% SubDim == 1) cat('|  ')
    }
    cat('|
    if (i %% SubDim == 0) cat('-----------------------------------\n')
  }
  cat('|\n  if (i %% SubDim == 0) cat('-----------------------------------\n')
} else {
  cat('Problem was infeasible\n')
}

# Clear space
rm(result, model, board, linn, env)

workforce1.R

# Copyright 2018, Gurobi Optimization, LLC
# Assign workers to shifts; each worker may or may not be available on a
# particular day. If the problem cannot be solved, use IIS to find a set of
# conflicting constraints. Note that there may be additional conflicts
# besides what is reported via IIS.

library(Matrix)
library(gurobi)

# define data
nShifts <- 14
nWorkers <- 7
nVars <- nShifts * nWorkers
varIdx <- function(w,s) {s+(w-1)*nShifts}

Shifts <- c('Mon1', 'Tue2', 'Wed3', 'Thu4', 'Fri5', 'Sat6', 'Sun7',
            'Mon8', 'Tue9', 'Wed10', 'Thu11', 'Fri12', 'Sat13', 'Sun14')
Workers <- c('Amy', 'Bob', 'Cathy', 'Dan', 'Ed', 'Fred', 'Gu')
pay <- c(10, 12, 10, 8, 8, 9, 11)
shiftRequirements <- c(3, 2, 4, 4, 5, 2, 2, 3, 4, 6, 7, 5)
availability <- list(c(0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1),
                      c(1, 1, 0, 0, 1, 0, 1, 0, 1, 0, 1, 0),
                      c(0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1),
                      c(0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1),
                      c(1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1),
                      c(1, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 1),
                      c(1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1))

# Set-up environment
env <- list()
env$logfile <- 'workforce1.log'

# Build model
model <- list()
model$modelname <- 'workforce1'
model$modelsense <- 'min'

# Initialize assignment decision variables:
# x[w][s] == 1 if worker w is assigned
# to shift s. Since an assignment model always produces integer
# solutions, we use continuous variables and solve as an LP.
model$lb <- 0
model$ub <- rep(1, nVars)
model$obj <- rep(0, nVars)
model$varnames <- rep('',nVars)
for (w in 1:nWorkers) {
  for (s in 1:nShifts) {
    model$varnames[varIdx(w,s)] = paste0(Workers[w],'.',Shifts[s])
    model$obj[varIdx(w,s)] = pay[w]
    if (availability[[w]][s] == 0) model$ub[varIdx(w,s)] = 0
  }
}

# Set-up shift-requirements constraints
model$A <- spMatrix(nShifts,nVars,
                   i = c(mapply(rep,1:nShifts,nWorkers)),
                   j = mapply(varIdx,1:nWorkers,
                               mapply(rep,1:nShifts,nWorkers)),
                   x = rep(1,nShifts*nWorkers))
model$sense <- rep('=',nShifts)
model$rhs <- shiftRequirements
model$constrnames <- Shifts

# Save model
gurobi_write(model,'workforce1.lp', env)

# Optimize
result <- gurobi(model, env = env)

# Display results
if (result$status == 'OPTIMAL') {
  # The code may enter here if you change some of the data... otherwise
  # this will never be executed.
  cat('The optimal objective is',result$objval,'
')
  cat('Schedule:
')
  for (s in 1:nShifts) {
    cat('	', Shifts[s],':
')
    for (w in 1:nWorkers) {
      if (result$x[varIdx(w,s)] > 0.9) cat(Workers[w],' ')}
  }
  cat('
')
}
else if (result$status == 'INFEASIBLE') {
  # Find ONE IIS
  cat('Problem is infeasible.... computing IIS
')
  iis <- gurobi_iis(model, env = env)
  if (iis$minimal) cat('IIS is minimal
')
  else cat('IIS is not minimal
')
  cat('Rows in IIS: ', model$constrnames[iis$Arows])
  cat('
LB in IIS: ', model$varnames[iis$lb])
  cat('
UB in IIS: ', model$varnames[iis$ub])
  cat('
')
  rm(iis)
} else {
  # Just to handle user interruptions or other problems
  cat('Unexpected status',result$status,'
Ending now
')
}

#Clear space
rm(model, env, availability, Shifts, Workers, pay, shiftRequirements, result)

workforce2.R

# Copyright 2018, Gurobi Optimization, LLC
#
# Assign workers to shifts; each worker may or may not be available on a
# particular day. If the problem cannot be solved, use IIS iteratively to
# find all conflicting constraints.

library(Matrix)
library(gurobi)

# Function to display results
printsolution <- function(result) {
  if(result$status == 'OPTIMAL') {
    cat('The optimal objective is', result$objval, 'n')
    cat('Schedule:
')
    for (s in 1:nShifts) {
      cat('	', Shifts[s], ':
')
      for (w in 1:nWorkers) {
        if (result$x[varIdx(w,s)] > 0.9) cat(Workers[w], ' ')
      }
      cat('n')
    }
  }
}

# define data
nShifts <- 14
nWorkers <- 7
nVars <- nShifts * nWorkers
varIdx <- function(w,s) {s+(w-1)*nShifts}
Shifts <- c('Mon1', 'Tue2', 'Wed3', 'Thu4', 'Fri5', 'Sat6', 'Sun7',
            'Mon8', 'Tue9', 'Wed10', 'Thu11', 'Fri12', 'Sat13', 'Sun14')
Workers <- c('Amy', 'Bob', 'Cathy', 'Dan', 'Ed', 'Fred', 'Gu')
pay <- c(10, 12, 10, 8, 8, 9, 11)
shiftRequirements <- c(3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5)
availability <- list(c(0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1),
                     c(1, 1, 0, 1, 1, 0, 1, 0, 1, 0, 1, 0),
                     c(0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1),
                     c(1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1),
                     c(0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1),
                     c(1, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1))

# Set-up environment
env <- list()
env$logfile <- 'workforce2.log'

# Build model
model <- list()
model$modelname <- 'workforce2'
model$modelsense <- 'min'

# Initialize assignment decision variables:
# x[w][s] == 1 if worker w is assigned to shift s. Since an assignment model always produces integer solutions, we use continuous variables and solve as an LP.
model$lb <- 0
model$ub <- rep(1, nVars)
model$obj <- rep(0, nVars)
model$varnames <- rep('x', nVars)
for (w in 1:nWorkers) {
  for (s in 1:nShifts) {
    model$varnames[varIdx(w,s)] = paste0(Workers[w],'.',Shifts[s])
    model$obj[varIdx(w,s)] = pay[w]
    if (availability[[w]][s] == 0) model$ub[varIdx(w,s)] = 0
  }
}

# Set up shift-requirements constraints
model$A <- spMatrix(nShifts,nVars, 
  i = c(mapply(rep,1:nShifts,nWorkers)),
  j = mapply(varIdx,1:nWorkers,
              mapply(rep,1:nShifts,nWorkers)),
  x = rep(1,nShifts * nWorkers))
model$sense <- rep('=',nShifts)
model$rhs <- shiftRequirements
model$constrnames <- Shifts

# Save model
gurobi_write(model,'workforce2.lp', env)

# Optimize
result <- gurobi(model, env = env)

# Display results
if (result$status == 'OPTIMAL') {
  # The code may enter here if you change some of the data... otherwise
  # this will never be executed.
  printsolution(result);
} else if (result$status == 'INFEASIBLE') {
  # We will loop until we reduce a model that can be solved
  numremoved <- 0
  while(result$status == 'INFEASIBLE') {
    iis <- gurobi_iis(model, env = env)
    keep <- (!iis$Arows)
    cat('Removing rows', model$constrnames[iis$Arows],'
    model$A <- model$A[keep,,drop = FALSE]
    model$sense <- model$sense[keep]
    model$rhs <- model$rhs[keep]
    model$constrnames <- model$constrnames[keep]
    numremoved <- numremoved + 1
    gurobi_write(model, paste0('workforce2-',numremoved,'.lp'), env)
    result <- gurobi(model, env = env)
  }
  printsolution(result)
  rm(iis)
} else {
  # Just to handle user interruptions or other problems
  cat('Unexpected status',result$status,'

# Clear space
rm(model, env, availability, Shifts, Workers, pay, shiftRequirements, result)

workforce3.R
# Copyright 2018, Gurobi Optimization, LLC
#
# Assign workers to shifts; each worker may or may not be available on a
# particular day. If the problem cannot be solved, relax the model
# to determine which constraints cannot be satisfied, and how much
# they need to be relaxed.

library(Matrix)
library(gurobi)

# Function to display results
printSolution <- function(result) {
  if(result$status == 'OPTIMAL') {
    cat('The optimal objective is ', result$objval, '
')
    cat('Schedule:
')
    for (s in 1:nShifts) {
      cat('	', Shifts[s],':
')
      for (w in 1:nWorkers) {
        if (result$x[varIdx(w,s)] > 0.9)
          cat(Workers[w], ' ')
      }
      cat('
')
    }
  }
}

# define data
nShifts <- 14
nWorkers <- 7
nVars <- nShifts * nWorkers
varIdx <- function(w,s) {s+(w -1)*nShifts }
Shifts <- c('Mon1', 'Tue2', 'Wed3', 'Thu4', 'Fri5', 'Sat6', 'Sun7',
            'Mon8', 'Tue9', 'Wed10', 'Thu11', 'Fri12', 'Sat13', 'Sun14')
Workers <- c('Amy', 'Bob', 'Cathy', 'Dan', 'Ed', 'Fred', 'Gu')
pay <- c(10, 12, 10, 8, 8, 9, 11)
shiftRequirements <- c(3, 2, 4, 4, 5, 2, 2, 3, 4, 6, 7, 5)
availability <- list( c( 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1 ),
                       c( 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 1 ),
                       c( 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 ),
                       c( 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1 ),
                       c( 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1 ),
                       c( 1, 1, 1, 0, 0, 1, 0, 1, 1, 0, 0, 1 ),
                       c( 1, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 1 ) )

# Set-up environment
env <- list()
env$logfile <- 'workforce3.log'

# Build model
model <- list()
model$modelname <- 'workforce3'
model$modelsense <- 'min'
# Initialize assignment decision variables:
# \( x[w][s] == 1 \) if worker \( w \) is assigned
# to shift \( s \). Since an assignment model always produces integer
# solutions, we use continuous variables and solve as an LP.

```r
model$lb <- 0
model$ub <- rep(1, nVars)
model$obj <- rep(0, nVars)
model$varnames <- rep('', nVars)
for (w in 1:nWorkers) {
  for (s in 1:nShifts) {
    model$varnames[varIdx(w, s)] = paste0(Workers[w], '.', Shifts[s])
    model$obj[varIdx(w, s)] = pay[w]
    if (availability[[w]][s] == 0) model$ub[varIdx(w, s)] = 0
  }
}

# Set-up shift-requirements constraints
model$A <- spMatrix(nShifts, nVars,
    i = c(mapply(rep, 1:nShifts, nWorkers)),
    j = mapply(varIdx, 1:nWorkers, mapply(rep, 1:nShifts, nWorkers)),
    x = rep(1, nShifts * nWorkers))
model$sense <- rep('=', nShifts)
model$rhs <- shiftRequirements
model$constrnames <- Shifts

# Save model
gurobi_write(model, 'workforce3.lp', env)

# Optimize
result <- gurobi(model, env = env)

# Display results
if (result$status == 'OPTIMAL') {
  # The code may enter here if you change some of the data... otherwise
  # this will never be executed.
  printsolution(result);
} else if (result$status == 'INFEASIBLE') {
  # Use gurobi_feasrelax to find out which constraints should be relaxed
  # and by how much to make the problem feasible.
  penalties <- list()
  penalties$lb <- Inf
  penalties$ub <- Inf
  penalties$rhs <- rep(1, length(model$rhs))
  feasrelax <- gurobi_feasrelax(model, 0, FALSE, penalties, env = env)
  result <- gurobi(feasrelax$model, env = env)
  if (result$status == 'OPTIMAL') {
    printsolution(result)
    cat('Slack values:
')
    for (j in (nVars+1):length(result$x)) {
      if(result$x[j] > 0.1)
        cat('	', feasrelax$model$varnames[j], result$x[j], '
')
    }
  } else {
    cat('Unexpected status', result$status, '\nEnding now\n')
}
```
rm(penalties, feasrelax)
} else {
# Just to handle user interruptions or other problems
  cat('Unexpected status', result$status, '\nEnding now\n')
}

# Clear space
rm(model, env, availability, Shifts, Workers, pay, shiftRequirements, result)

workforce4.R

# Copyright 2018, Gurobi Optimization, LLC
#
# Assign workers to shifts; each worker may or may not be available on a
# particular day. We use Pareto optimization to solve the model:
# first, we minimize the linear sum of the slacks. Then, we constrain
# the sum of the slacks, and we minimize a quadratic objective that
# tries to balance the workload among the workers.

library(Matrix)
library(gurobi)

# define data
nShifts <- 14
nWorkers <- 7
nVars <- (nShifts + 1) * (nWorkers + 1) + nWorkers + 1
varIdx <- function(w,s) {s+(w-1)*nShifts}
shiftSlackIdx <- function(s) {s+nShifts*nWorkers}
totShiftIdx <- function(w) {w + nShifts * (nWorkers+1)}
avgShiftIdx <- ((nShifts+1)*(nWorkers+1))
diffShiftIdx <- function(w) {w + avgShiftIdx}
totalSlackIdx <- nVars

Shifts <- c('Mon1', 'Tue2', 'Wed3', 'Thu4', 'Fri5', 'Sat6', 'Sun7',
          'Mon8', 'Tue9', 'Wed10', 'Thu11', 'Fri12', 'Sat13', 'Sun14')
Workers <- c('Amy', 'Bob', 'Cathy', 'Dan', 'Ed', 'Fred', 'Gu')

shiftRequirements <- c(3, 2, 4, 4, 5, 6, 5, 2, 2, 3, 4, 6, 7, 5)

availability <- list(c( 0, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1 ),
                      c( 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 1, 0, 0 ),
                      c( 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1 ),
                      c( 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1 ),
                      c( 1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 1, 1, 1 ),
                      c( 1, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1 ),
                      c( 1, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1 ))

# Function to display results
solveandprint <- function(model, env) {
  result <- gurobi(model, env = env)
  if(result$status == 'OPTIMAL') {
    cat('The optimal objective is', result$objval, '\n')
    cat('Schedule:\n')
    for (s in 1:nShifts) {
      cat('  ', Shifts[s], ':')
    }
  }
}
for (w in 1:nWorkers) {
    if (result$x[varIdx(w,s)] > 0.9) cat(Workers[w],' ')
    cat('
')
} cat('Workload:
')
for (w in 1:nWorkers) {
    cat('	', Workers[w],':', result$x[totShiftIdx(w)],'
')
} else {
    cat('Optimization finished with status',result$status)
}
result

# Set-up environment
env <- list()
env$logfile <- 'workforce4.log'

# Build model
model <- list()
model$modelname <- 'workforce4'
model$modelsense <- 'min'

# Initialize assignment decision variables:
# x[w][s] == 1 if worker w is assigned to shift s.
# This is no longer a pure assignment model, so we must
# use binary variables.
model$vtype <- rep('C', nVars)
model$lb <- rep(0, nVars)
model$ub <- rep(1, nVars)
model$obj <- rep(0, nVars)
model$varnames <- rep('',nVars)
for (w in 1:nWorkers) {
    for (s in 1:nShifts) {
        model$vtype[varIdx(w,s)] = 'B'
        model$varnames[varIdx(w,s)] = paste0(Workers[w],'.',Shifts[s])
        if (availability[[w]][s] == 0) model$ub[varIdx(w,s)] = 0
    }
}

# Initialize shift slack variables
for (s in 1:nShifts) {
    model$varnames[shiftSlackIdx(s)] = paste0('ShiftSlack',Shifts[s])
    model$ub[shiftSlackIdx(s)] = Inf
}

# Initialize worker slack and diff variables
for (w in 1:nWorkers) {
    model$varnames[totShiftIdx(w)] = paste0('TotalShifts',Workers[w])
    model$ub[totShiftIdx(w)] = Inf
    model$varnames[diffShiftIdx(w)] = paste0('DiffShifts',Workers[w])
    model$ub[diffShiftIdx(w)] = Inf
    model$lb[diffShiftIdx(w)] = -Inf
}
# Initialize average shift variable
model$ub[avgShiftIdx] = Inf
model$varnames[avgShiftIdx] = 'AvgShift'

# Initialize total slack variable
model$ub[totalSlackIdx] = Inf
model$varnames[totalSlackIdx] = 'TotalSlack'
model$obj[totalSlackIdx] = 1

# Set up shift requirements constraints
model$A <- spMatrix(nShifts, nVars,
i = c(mapply(rep, 1:nShifts, nWorkers)),
c(1:nShifts)),
j = c(mapply(varIdx, 1:nWorkers,
  mapply(rep, 1:nShifts, nWorkers)),
  shiftSlackIdx(1:nShifts)),
x = rep(1, nShifts * (nWorkers + 1)))
model$sense <- rep('=', nShifts)
model$rhs <- shiftRequirements
model$constrnames <- Shifts

# Set TotalSlack equal to the sum of each shift slack
B <- spMatrix(1, nVars,
i = rep(1, nShifts + 1),
j = c(shiftSlackIdx(1:nShifts), totalSlackIdx),
x = c(rep(1, nShifts), -1))
model$A <- rbind(model$A, B)
model$rhs <- c(model$rhs, 0)
model$sense <- c(model$sense, '=')
model$constrnames <- c(model$constrnames, 'TotalSlack')

# Set total number of shifts for each worker
B <- spMatrix(nWorkers, nVars,
i = c(mapply(rep, 1:nWorkers, nShifts),
  1:nWorkers),
j = c(mapply(varIdx, c(mapply(rep, 1:nWorkers, nShifts)), 1:nShifts),
  totShiftIdx(1:nWorkers)),
x = c(rep(1, nShifts * nWorkers), rep(-1, nWorkers)))
model$A <- rbind(model$A, B)
model$rhs <- c(model$rhs, rep(0, nWorkers))
model$sense <- c(model$sense, rep('=', nWorkers))
model$constrnames <- c(model$constrnames, sprintf('TotalShifts%s', Workers[1:nWorkers]))

# Save initial model
gurobi_write(model, 'workforce4.lp', env)

# Optimize
result <- solveandprint(model, env)
if (result$status != 'OPTIMAL') stop('Stop now\n')

# Constraint the slack by setting its upper and lower bounds
totalSlack <- result$x[totalSlackIdx]
model$lb[totalSlackIdx] = totalSlack
model$ub[totalSlackIdx] = totalSlack

# Link average number of shifts worked and difference with average

497
B <- spMatrix(nWorkers + 1, nVars,
  i = c(1:nWorkers,
        1:nWorkers,
        1:nWorkers,
        rep(nWorkers + 1, nWorkers + 1)),
  j = c(totShiftIdx(1:nWorkers),
        diffShiftIdx(1:nWorkers),
        rep(avgShiftIdx, nWorkers),
        totShiftIdx(1:nWorkers), avgShiftIdx),
  x = c(rep(1, nWorkers),
        rep(-1, nWorkers),
        rep(-1, nWorkers),
        rep(1, nWorkers), - nWorkers))

model$A <- rbind(model$A, B)
model$rhs <- c(model$rhs, rep(0, nWorkers + 1))
model$sense <- c(model$sense, rep(‘=’, nWorkers + 1))
model$constrnames <- c(model$constrnames,
                       sprintf(‘DiffShifts%s’, Workers[1:nWorkers]),
                       ‘AvgShift’)

# Objective: minimize the sum of the square of the difference from the
# average number of shifts worked
model$obj <- 0
model$Q <- spMatrix(nVars, nVars,
  i = c(diffShiftIdx(1:nWorkers)),
  j = c(diffShiftIdx(1:nWorkers)),
  x = rep(1, nWorkers))

# Save modified model
gurobi_write(model, ‘workforce4b.lp’, env)

# Optimize
result <- solveandprint(model, env)
if (result$status != ‘OPTIMAL’) stop(‘Stop now
’)

# Clear space
rm(model, env, availability, Shifts, Workers, shiftRequirements, result)

workforce5.R

# Copyright 2018, Gurobi Optimization, LLC
#
# Assign workers to shifts; each worker may or may not be available on a
# particular day. We use multi-objective optimization to solve the model.
# The highest-priority objective minimizes the sum of the slacks
# (i.e., the total number of uncovered shifts). The secondary objective
# minimizes the difference between the maximum and minimum number of
# shifts worked among all workers. The second optimization is allowed
# to degrade the first objective by up to the smaller value of 10% and 2

library(‘Matrix’)  
library(‘gurobi’)  

# define data
nShifts <- 14
nWorkers <- 8
nVars <- (nShifts + 1) * (nWorkers + 1) + 2
varIdx <- function(w, s) {s*(w-1)*nShifts}
shiftSlackIdx <- function(s) {s*nShifts*nWorkers}
totShiftIdx <- function(w) {w + nShifts * (nWorkers+1)}
minShiftIdx <- ((nShifts+1)*(nWorkers+1))
maxShiftIdx <- (minShiftIdx+1)
totalSlackIdx <- nVars

Shifts <- c('Mon1', 'Tue2', 'Wed3', 'Thu4', 'Fri5', 'Sat6', 'Sun7',
            'Mon8', 'Tue9', 'Wed10', 'Thu11', 'Fri12', 'Sat13', 'Sun14')
Workers <- c('Amy', 'Bob', 'Cathy', 'Dan', 'Ed', 'Fred', 'Gu', 'Tobi')

shiftRequirements <- c(3, 2, 4, 4, 5, 2, 3, 4, 6, 7, 5)
availability <- list(c(0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1),
                     c(1, 1, 0, 0, 1, 0, 1, 1, 1, 0, 0),
                     c(0, 0, 1, 1, 0, 1, 1, 1, 1, 0, 1),
                     c(0, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1),
                     c(1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1),
                     c(0, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1),
                     c(1, 1, 1, 0, 0, 1, 0, 1, 1, 0, 1),
                     c(0, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1),
                     c(1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1))

# Function to display results
solveandprint <- function(model, env) {
  result <- gurobi(model, env = env)
  if(result$status == 'OPTIMAL') {
    cat('The optimal objective is', result$objval, 'n')
    cat('Schedule:n')
    for (s in 1:nShifts) {
      cat('	', Shifts[s], ':')
      for (w in 1:nWorkers) {
        if (result$x[varIdx(w, s)] > 0.9) cat(Workers[w], ' ')
      }
    }
    cat('n')
    cat('Workload:n')
    for (w in 1:nWorkers) {
      cat('	', Workers[w], ':', result$x[totShiftIdx(w)], 'n')
    }
  } else {
    cat('Optimization finished with status', result$status)
  }
  result
}

# Set-up environment
env <- list()
env$logfile <- 'workforce5.log'

# Build model
model <- list()
model$modelname <- 'workforce5'
model$modelsense <- 'min'
# Initialize assignment decision variables:
# x[w][s] == 1 if worker w is assigned to shift s.
# This is no longer a pure assignment model, so we must
# use binary variables.
model$vtype <- rep('C', nVars)
model$lb <- rep(0, nVars)
model$ub <- rep(1, nVars)
model$varnames <- rep('', nVars)
for (w in 1:nWorkers) {
  for (s in 1:nShifts) {
    model$vtype[varIdx(w, s)] = 'B'
    model$varnames[varIdx(w, s)] = paste0(Workers[w], '.', Shifts[s])
    if (availability[[w]][s] == 0) model$ub[varIdx(w, s)] = 0
  }
}

# Initialize shift slack variables
for (s in 1:nShifts) {
  model$varnames[shiftSlackIdx(s)] = paste0('ShiftSlack', Shifts[s])
  model$ub[shiftSlackIdx(s)] = Inf
}

# Initialize worker slack and diff variables
for (w in 1:nWorkers) {
  model$varnames[totShiftIdx(w)] = paste0('TotalShifts', Workers[w])
  model$ub[totShiftIdx(w)] = Inf
}

# Initialize min/max shift variables
model$ub[minShiftIdx] = Inf
model$varnames[minShiftIdx] = 'MinShift'
model$ub[maxShiftIdx] = Inf
model$varnames[maxShiftIdx] = 'MaxShift'

# Initialize total slack variable
model$ub[totalSlackIdx] = Inf
model$varnames[totalSlackIdx] = 'TotalSlack'

# Set-up shift-requirements constraints
model$A <- spMatrix(nShifts, nVars,
  i = c(mapply(rep, 1:nShifts, nWorkers)),
  c(1:nShifts)),
  j = c(mapply(varIdx, 1:nWorkers, mapply(rep, 1:nShifts, nWorkers)),
    shiftSlackIdx(1:nShifts)),
  x = rep(1, nShifts * (nWorkers + 1)))
model$sense <- rep('=', nShifts)
model$rhs <- shiftRequirements
model$constrnames <- Shifts

# Set TotalSlack equal to the sum of each shift slack
B <- spMatrix(1, nVars,
  i = rep(1, nShifts + 1),
  j = c(shiftSlackIdx(1:nShifts), totalSlackIdx),
  x = c(rep(1, nShifts), -1))
model$A <- rbind(model$A, B)
# Set total number of shifts for each worker
B <- spMatrix(nWorkers, nVars, 
  i = c(mapply(rep,1:nWorkers,nShifts), 1:nWorkers), 
  j = c(mapply(varIdx,c(mapply(rep,1:nWorkers,nShifts)),1:nShifts), totShiftIdx(1:nWorkers)), 
  x = c(rep(1,nShifts*nWorkers),rep(-1,nWorkers)))
model$A <- rbind(model$A, B)
model$rhs <- c(model$rhs,rep(0,nWorkers))
model$sense <- c(model$sense,rep('=',nWorkers))
model$constrnames <- c(model$constrnames, sprintf(' TotalShifts %s', Workers[1:nWorkers]))

# Set minShift / maxShift general constraints
model$genconmin <- list(list(resvar = minShiftIdx, 
  vars = c(totShiftIdx(1:nWorkers)), 
  name = 'MinShift'))
model$genconmax <- list(list(resvar = maxShiftIdx, 
  vars = c(totShiftIdx(1:nWorkers)), 
  name = 'MaxShift'))

# Set multiobjective
model$multiobj <- list(1:2)
model$multiobj[[1]] <- list() 
model$multiobj[[1]]$objn <- c(rep(0,nVars))
model$multiobj[[1]]$objn[totalSlackIdx] = 1
model$multiobj[[1]]$priority <- 2
model$multiobj[[1]]$weight <- 1
model$multiobj[[1]]$abstol <- 2
model$multiobj[[1]]$reltol <- 0.1
model$multiobj[[1]]$name <- 'TotalSlack'
model$multiobj[[1]]$con <- 0.0
model$multiobj[[2]] <- list() 
model$multiobj[[2]]$objn <- c(rep(0,nVars))
model$multiobj[[2]]$objn[minShiftIdx] = -1
model$multiobj[[2]]$objn[maxShiftIdx] = 1
model$multiobj[[2]]$priority <- 1
model$multiobj[[2]]$weight <- 1
model$multiobj[[2]]$abstol <- 0
model$multiobj[[2]]$reltol <- 0
model$multiobj[[2]]$name <- 'Fairness'
model$multiobj[[2]]$con <- 0.0

# Save initial model
gurobi_write(model,'workforce5.lp', env)

# Optimize
result <- solveandprint(model, env)
if (result$status != 'OPTIMAL') stop('Stop now!
')

# Clear space
rm(model, env, availability, Shifts, Workers, shiftRequirements, result)