Code Description for the MIP Challenge

The code is available at https://github.com/cristianomonteiro/RaizenChallenge. It was implemented in Python 3.9.7 using Jupyter notebook. The main libraries used were PuLP 2.6, Pandas 1.4.3 and the MIP solver was Coin-OR CBC 2.10.5. The following section summarizes the code structure.

1 Code Summary

The code is organized in the following phases:

1. Loading the data into a data frame;
2. Loading dictionaries of containers, boxes and cylinders objects;
3. Building and solving the optimization model;
4. Inserting an additional constraint to force the optimization model not to select again a previous optimal solution;
5. Re-solving the optimization model;
6. Repeating the last two phases until enough different optimal solutions are obtained;
7. Printing a solution selected by the user.

After each optimal solution is obtained, a function is run to check if all rules were properly applied. It was at first implemented to check whether the code has bugs, but I decided the keep it also in this final version. The following section presents the mathematical formulation.

2 Mathematical Formulation

The following tables defines the indices, variables and constants used in this formulation.

Table 1: Indices of the MIP Challenge

Index	Description
$i \in \mathbb{A}$	Container i
$j \in \mathbb{B}_i$	Box j from container i
$k \in \mathbb{C}_j \subseteq \mathbb{C}$	Cylinder k from box j
$k' \in \mathbb{C}' \subseteq \mathbb{C}$	Cylinder k selected in the previous optimal solution

Equation 1 defines the applied objective function. Since any feasible solution is good enough, all coefficients of the variables are defined as zero. Equations from 2 to 6 defines

Table 2: Variables of the MIP Challenge

Variable	Description
$c_i \in \{0, 1\}$	Indicates whether container i is chosen or not
$x_k \in \{0, 1\}$	Indicates whether cylinder k is selected or not
$x_{k'} \in \{0, 1\}$	Indicates the cylinder k' selected in the last optimization run

Table 3: Constants of the MIP Challenge

Constant	Description
v_k	Volume of the cylinder k
w_k	Weight of the cylinder k

the game's rules. The more complex constraint is the Equation 5 because it uses a Big-M method for assuring that if at least one cylinder is selected, then its container must also be chosen. The number of cylinders in the box was used as Big-M to avoid numbers too big.

$$\underset{c_i, x_k}{\arg\min}\ 0 \tag{1}$$

Subject to:

$$\sum_{i\ \in\ \mathbb{A}} c_i = 35 \tag{2}$$

$$\sum_{k\ \in\ \mathbb{C}} v_k x_k = 5163.69 \tag{3}$$

$$\sum_{k\ \in\ \mathbb{C}} w_k x_k = 18844 \tag{4}$$

$$|\mathbb{C}_j|\ c_i \geq \sum_{k\ \in\ \mathbb{C}_j} x_k \qquad \forall i, j \mid i \in \mathbb{A},\ j \in \mathbb{B}_i \tag{5}$$

$$\sum_{k\ \in\ \mathbb{C}_j} x_k \leq 1 \qquad \forall i, j \mid i \in \mathbb{A},\ j \in \mathbb{B}_i \tag{6}$$

Equation 7 is added when a different optimal solution is needed after solving the problem. This constraint forces the solver to find a solution without at least one of the cylinders chosen in the last optimal solution. If multiple different solutions are needed, then this constraint must be added multiple times, always based on the last optimal solution found. By doing so, every new optimal solution found will be unique.

$$\sum_{k'\ \in\ \mathbb{C}'} x_{k'} \leq |\mathbb{C}'| - 1 \tag{7}$$

The following section answers the questions asked in the challenge statement.

3 Answering the Questions

3.1 Which containers, boxes and cylinders will you choose?

I will choose the first optimal solution found by the solver (file in Solutions/1.txt). This winner option is presented below. When a container is repeated, its name is not written. By doing so, it easier to identify containers used more than once.

Table 4: Winner Option

Container	Box	Cylinder
AC	LB_1	16
AD	LB_2	3
AF	LB_1	15
AG	LB_1	11
AI	LB_1	7
AK	LB_1	8
AM	LB_1	7
	LB_2	2
AN	LB_1	24
	LB_2	3
AO	LB_1	8
AQ	LB_1	1
B	LB_1	1
D	LB_1	1
	LB_2	1
F	LB_1	1
G	LB_1	1
H	LB_1	1
	LB_2	2
I	LB_1	4
J	LB_1	4
L	LB_1	17
M	LB_1	12
	LB_2	2
N	LB_1	16
P	LB_1	3
Q	LB_1	4
S	LB_1	11
T	LB_2	4
U	LB_2	1
X	LB_1	8
Y	LB_1	4
Z	LB_1	4

A total of 33 cylinders from 28 different containers were chosen in this winner option.

3.2 Is there more than one winner option?

Yes. The folder Solutions has other one thousand possible winner options found. Probably, there are much more different winner options.