The whole is greater than the sum of its parts

Using combinatorial optimization to create synergy

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AnacondaCON 2020

Planning a conference

Speakers

Attendees

Schedule

What is combinatorial optimization?

Process of searching for a maximum/minimum of an objective function whose domain is a discrete configuration space

– *A math textbook*

What is combinatorial optimization?

Process of searching for a maximum/minimum of **an objective function** whose domain is a discrete configuration space

– *A math textbook*

English translation:

A quantity to maximize or minimize (KPI)

E.g., revenue, time spent, productivity, costs, etc.

What is combinatorial optimization?

Process of searching for a maximum/minimum of an objective function whose domain is a **discrete configuration space**

– *A math textbook*

English translation:

A set of countable objects

E.g., products, driving routes, employees, processes, etc.

What is combinatorial optimization?

Process of **searching for a maximum/minimum** of an objective function whose domain is a discrete configuration space

– *A math textbook*

English translation:

Find the set of objects that maximizes/minimizes the KPI

Components of a CO problem

KPI to optimize

Objects that affect KPI

Agenda

- Introduce common CO problems in business
- How to solve these problems using Google OR Tools

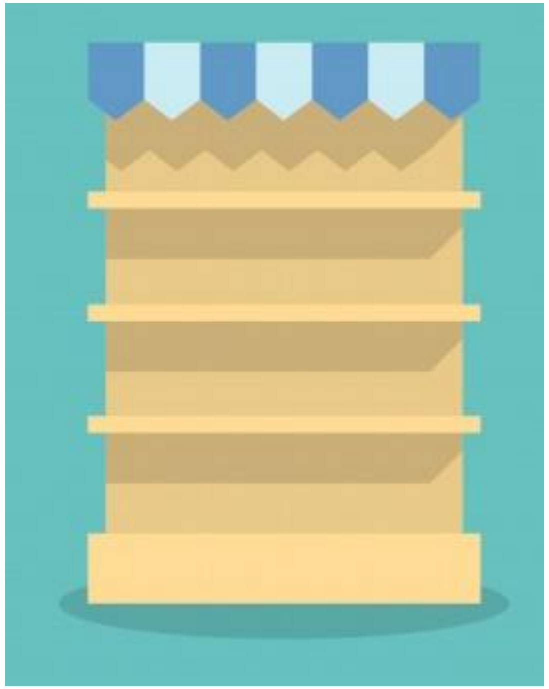
Packing Problems

How to stock a store

You have limited shelf space and can only stock so many products.

Each product has an associated profit margin.

Which items do you display to maximize profit?



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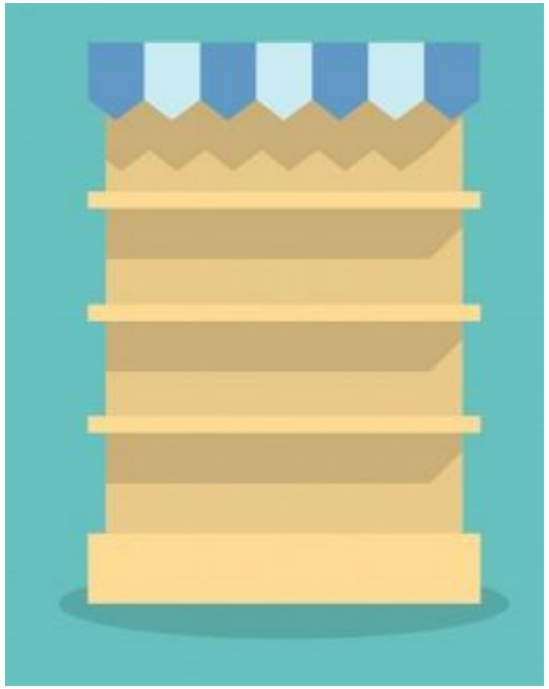

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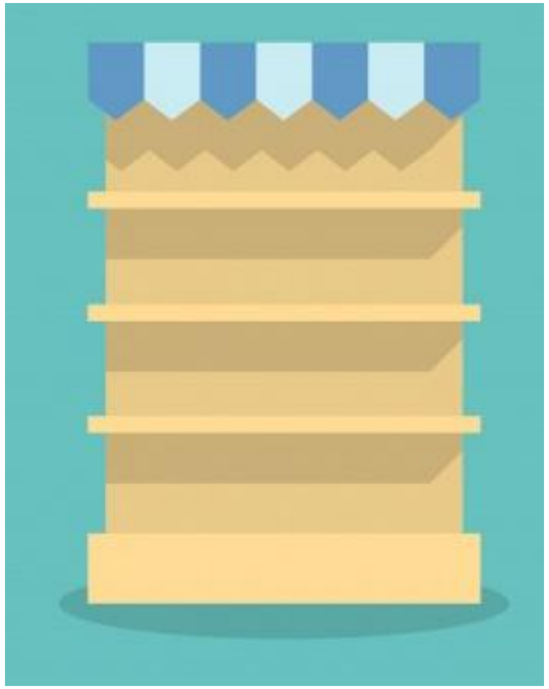


Knapsack problem

Given

1. a knapsack of limited capacity
2. N items of specific weights and user utility

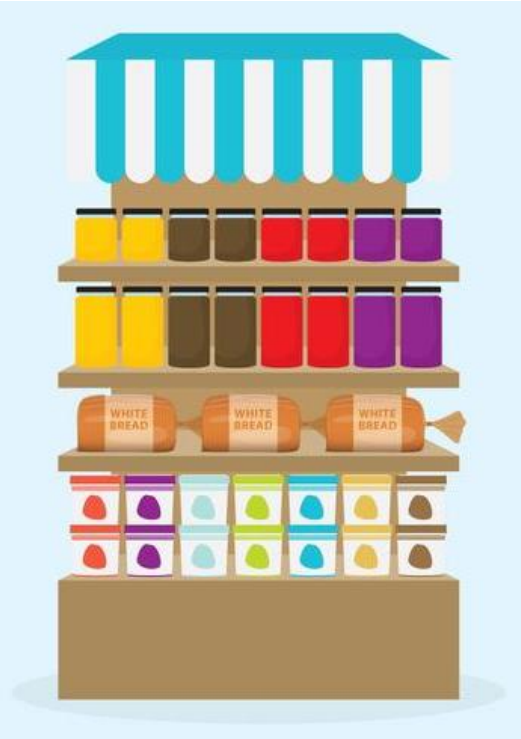
Determine the quantity of each item to pack to maximize overall utility

Knapsack problem: Grocery store

Given

1. shelf space
2. grocery items of varying size and varying profit margins

Determine the quantity of each item to stock to **maximize profit margin**



Knapsack problem: Digital library

Given

1. A book budget
2. Titles with associated costs and customer "enjoyment" (retention)

Determine which titles to include in the catalogue to **maximize user retention**

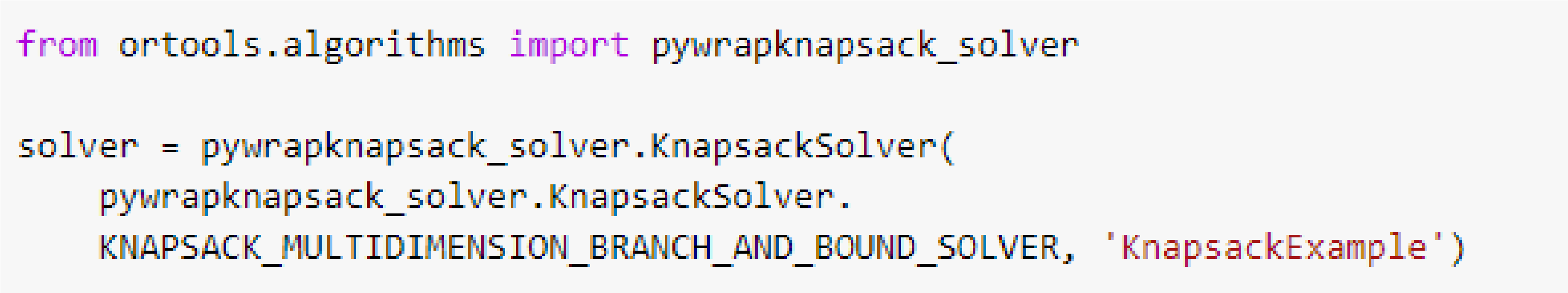
Creating an optimal library with OR Tools

Jupyter Notebook

https://bit.ly/36pZWkU

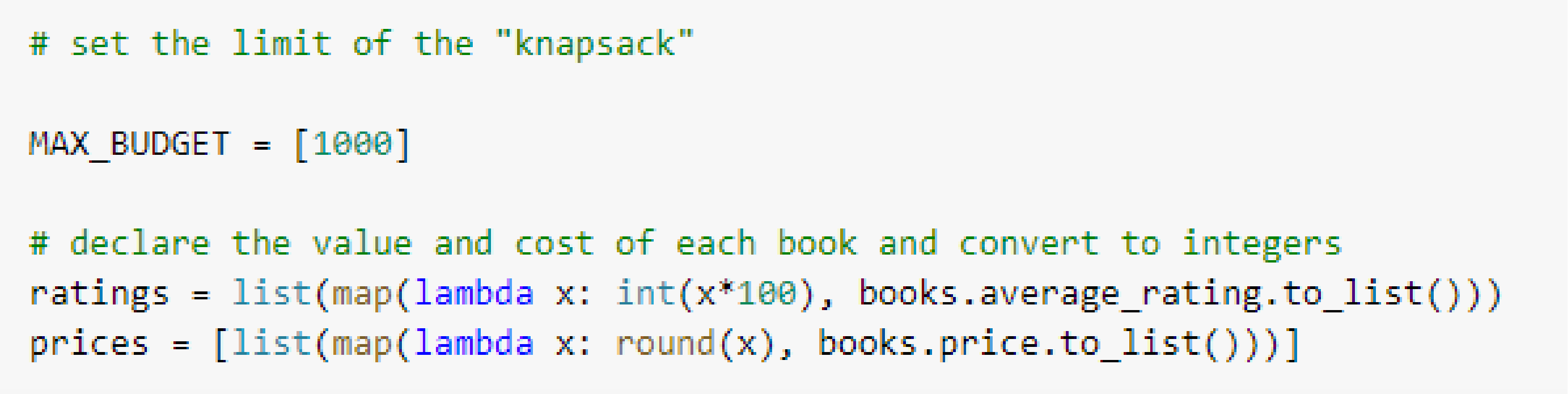
1. Initialize the solver
2. Specify the budget, costs and ratings
3. Run the solver

Step 1: Initialize the solver



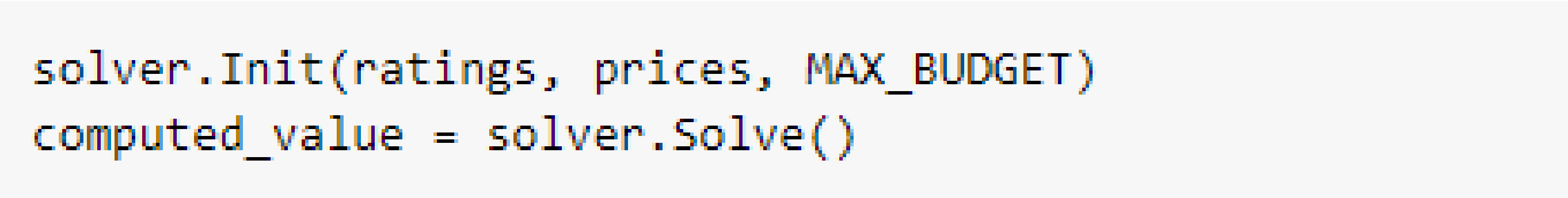
```
from ortools.algorithms import pywrapknapsack_solver

solver = pywrapknapsack_solver.KnapsackSolver(
    pywrapknapsack_solver.KnapsackSolver.
    KNAPSACK_MULTIDIMENSION_BRANCH_AND_BOUND_SOLVER, 'KnapsackExample')
```

Step 2: Specify the budget, costs and ratings



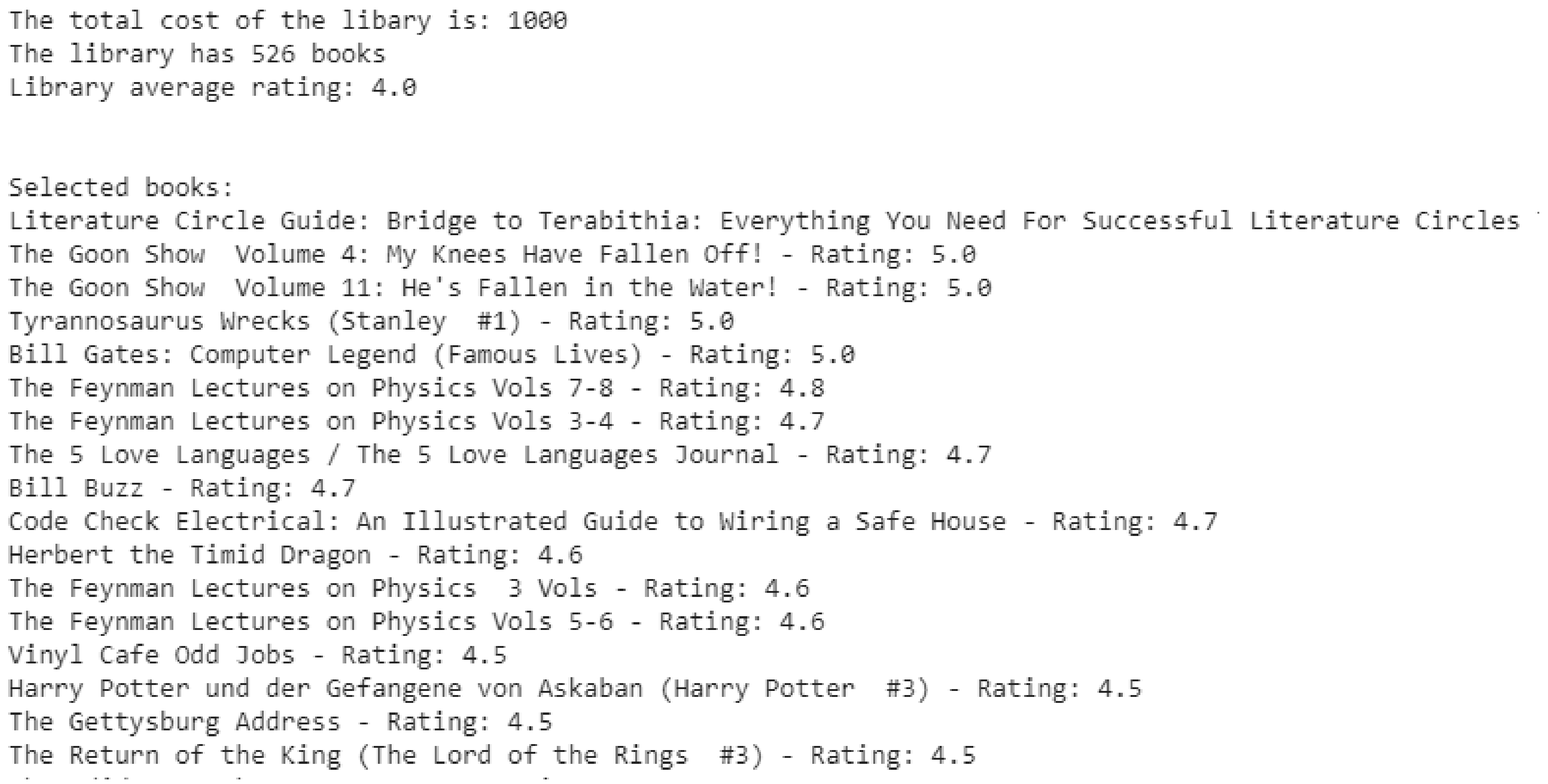
```
# set the limit of the "knapsack"

MAX_BUDGET = [1000]

# declare the value and cost of each book and convert to integers
ratings = list(map(lambda x: int(x*100), books.average_rating.to_list()))
prices = [list(map(lambda x: round(x), books.price.to_list()))]
```

Step 3: Run the solver



```
solver.Init(ratings, prices, MAX_BUDGET)
computed_value = solver.Solve()
```

The optimal library collection



```
The total cost of the libary is: 1000
The library has 526 books
Library average rating: 4.0


Selected books:
Literature Circle Guide: Bridge to Terabithia: Everything You Need For Successful Literature Circles
The Goon Show  Volume 4: My Knees Have Fallen Off! - Rating: 5.0
The Goon Show  Volume 11: He's Fallen in the Water! - Rating: 5.0
Tyrannosaurus Wrecks (Stanley  #1) - Rating: 5.0
Bill Gates: Computer Legend (Famous Lives) - Rating: 5.0
The Feynman Lectures on Physics Vols 7-8 - Rating: 4.8
The Feynman Lectures on Physics Vols 3-4 - Rating: 4.7
The 5 Love Languages / The 5 Love Languages Journal - Rating: 4.7
Bill Buzz - Rating: 4.7
Code Check Electrical: An Illustrated Guide to Wiring a Safe House - Rating: 4.7
Herbert the Timid Dragon - Rating: 4.6
The Feynman Lectures on Physics  3 Vols - Rating: 4.6
The Feynman Lectures on Physics Vols 5-6 - Rating: 4.6
Vinyl Cafe Odd Jobs - Rating: 4.5
Harry Potter und der Gefangene von Askaban (Harry Potter  #3) - Rating: 4.5
The Gettysburg Address - Rating: 4.5
The Return of the King (The Lord of the Rings  #3) - Rating: 4.5
```

Constraint Optimization

Constraint optimization

This is constraint optimization where the goal is to find a **feasible** solution under a **set of conditions.**

Optimization is a secondary goal

Constraint optimization: Planning a conference

Schedule the **speakers** so that:

A. All attendees are able to attend their top two "must attend" speakers

B. Accommodate speakers' availability

To **maximize participant satisfaction**

Constraint optimization: Forming teams

Financial advisors working in teams are known to be more productive than working alone.

How can we form teams of advisors so that overall **productivity is maximized**?

Constraint optimization: Forming teams

Conditions:

1. Are located < 10km of each other

2a. Each team has one senior member and one junior member, or

2b. At least one member is a specialist in area A and at least one member is a specialist in area B

3. Everyone must be on a team

4. Teams have a maximum size of 8 people

4 steps to creating synergistic teams

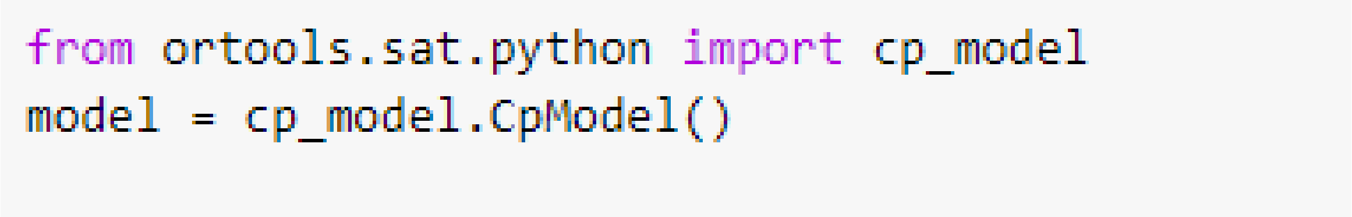
Jupyter Notebook

https://bit.ly/2A67GMJ

1. Initialize the solver
2. Declare decision variables
3. Add the constraints
4. Run the solver

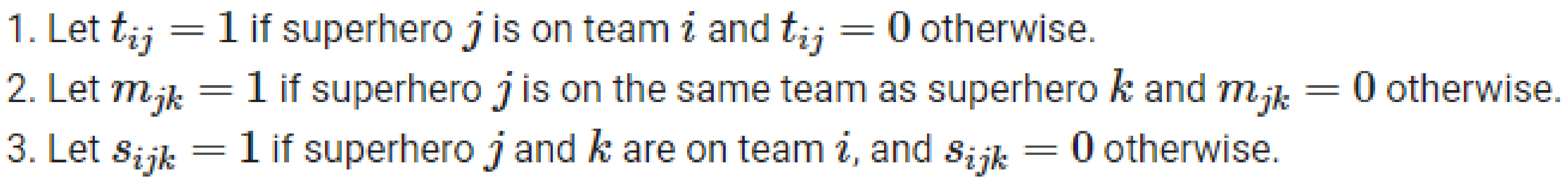
Teaming superheroes

Step 1: Initialize the solver



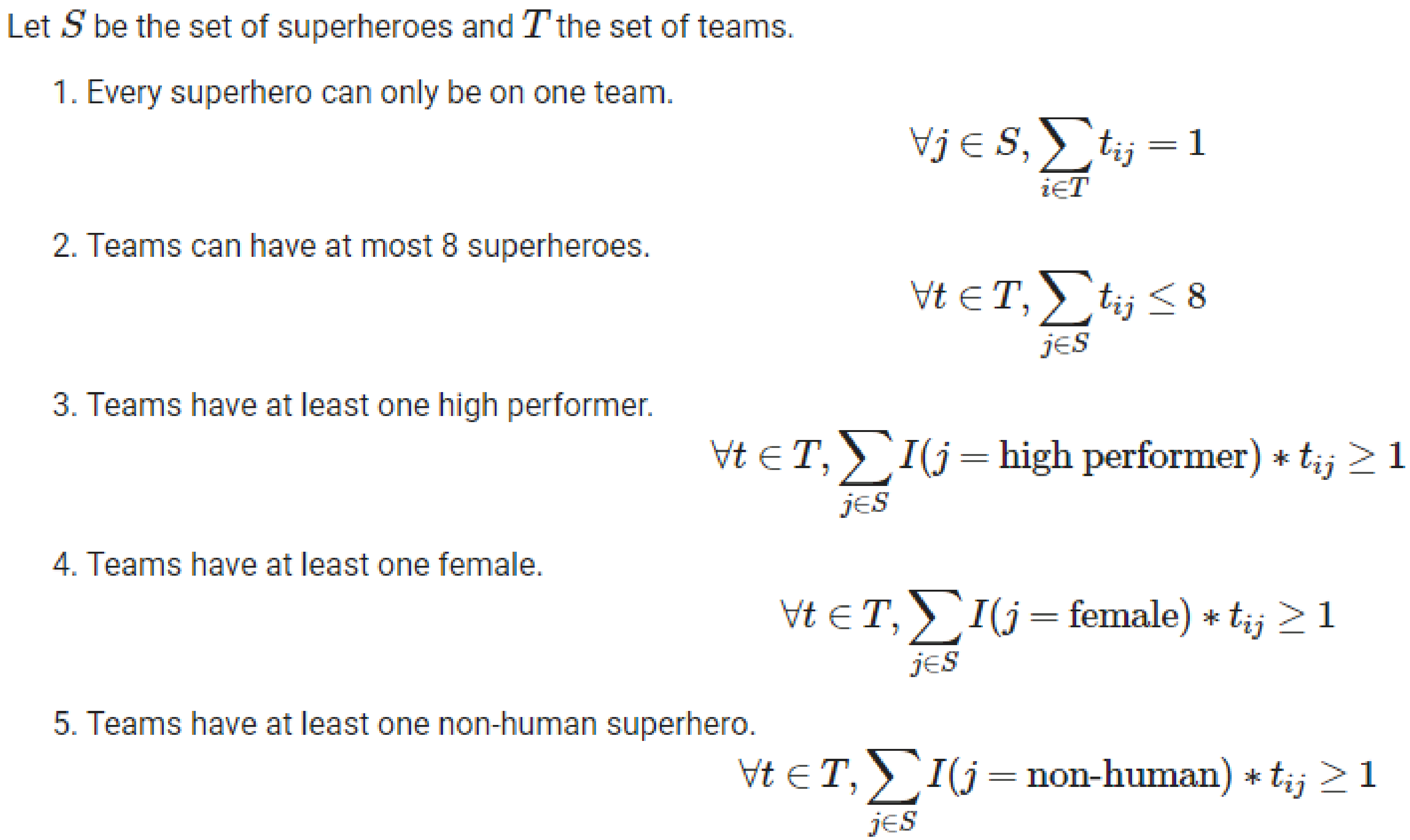
```
from ortools.sat.python import cp_model
model = cp_model.CpModel()
```

Step 2: Declare decision variables



1. Let $t_{ij} = 1$ if superhero j is on team i and $t_{ij} = 0$ otherwise.
2. Let $m_{jk} = 1$ if superhero j is on the same team as superhero k and $m_{jk} = 0$ otherwise.
3. Let $s_{ijk} = 1$ if superhero j and k are on team i, and $s_{ijk} = 0$ otherwise.

Step 3: Add the constraints



Let S be the set of superheroes and T the set of teams.

1. Every superhero can only be on one team.

$$\forall j \in S, \sum_{i \in T} t_{ij} = 1$$

2. Teams can have at most 8 superheroes.

$$\forall t \in T, \sum_{j \in S} t_{ij} \leq 8$$

3. Teams have at least one high performer.

$$\forall t \in T, \sum_{j \in S} I(j = \text{high performer}) * t_{ij} \geq 1$$

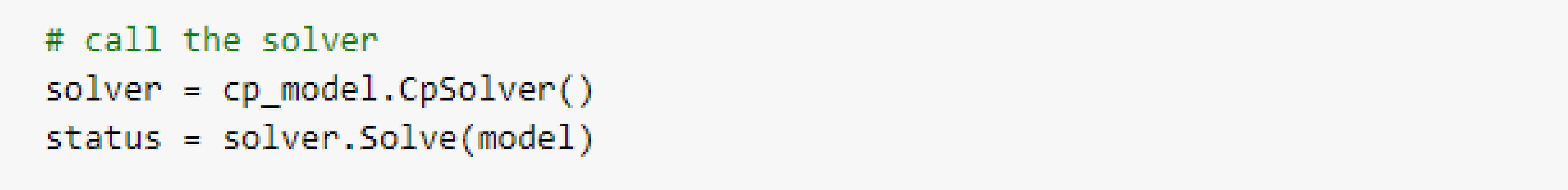
4. Teams have at least one female.

$$\forall t \in T, \sum_{j \in S} I(j = \text{female}) * t_{ij} \geq 1$$

5. Teams have at least one non-human superhero.

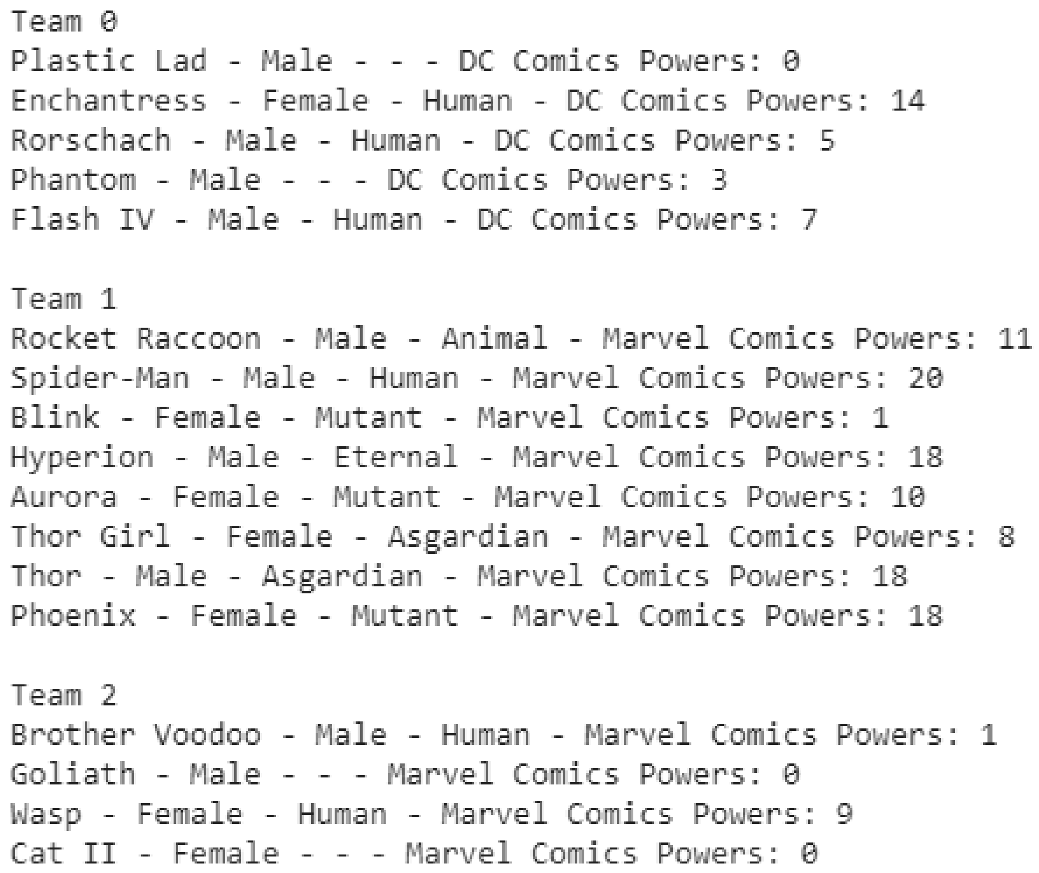
$$\forall t \in T, \sum_{j \in S} I(j = \text{non-human}) * t_{ij} \geq 1$$

Step 4: Run the solver



```
# call the solver
solver = cp_model.CpSolver()
status = solver.Solve(model)
```

Team assignments



```
Team 0
Plastic Lad - Male - - - DC Comics Powers: 0
Enchantress - Female - Human - DC Comics Powers: 14
Rorschach - Male - Human - DC Comics Powers: 5
Phantom - Male - - - DC Comics Powers: 3
Flash IV - Male - Human - DC Comics Powers: 7

Team 1
Rocket Raccoon - Male - Animal - Marvel Comics Powers: 11
Spider-Man - Male - Human - Marvel Comics Powers: 20
Blink - Female - Mutant - Marvel Comics Powers: 1
Hyperion - Male - Eternal - Marvel Comics Powers: 18
Aurora - Female - Mutant - Marvel Comics Powers: 10
Thor Girl - Female - Asgardian - Marvel Comics Powers: 8
Thor - Male - Asgardian - Marvel Comics Powers: 18
Phoenix - Female - Mutant - Marvel Comics Powers: 18

Team 2
Brother Voodoo - Male - Human - Marvel Comics Powers: 1
Goliath - Male - - - Marvel Comics Powers: 0
Wasp - Female - Human - Marvel Comics Powers: 9
Cat II - Female - - - Marvel Comics Powers: 0
```

Resources

Optimizing library Jupyter Notebook – https://bit.ly/36pZWkU

Creating synergistic teams Jupyter Notebook – https://bit.ly/2A67GMJ

Google OR-Tools – https://developers.google.com/optimization

Branch & Bound algorithm (Stanford) – https://stanford.io/2APH4QA

Thank you

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