Machine Learning via Optimisation Approach

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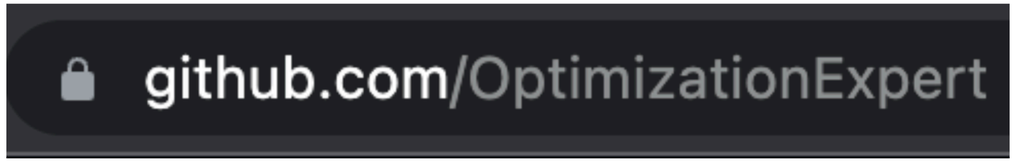
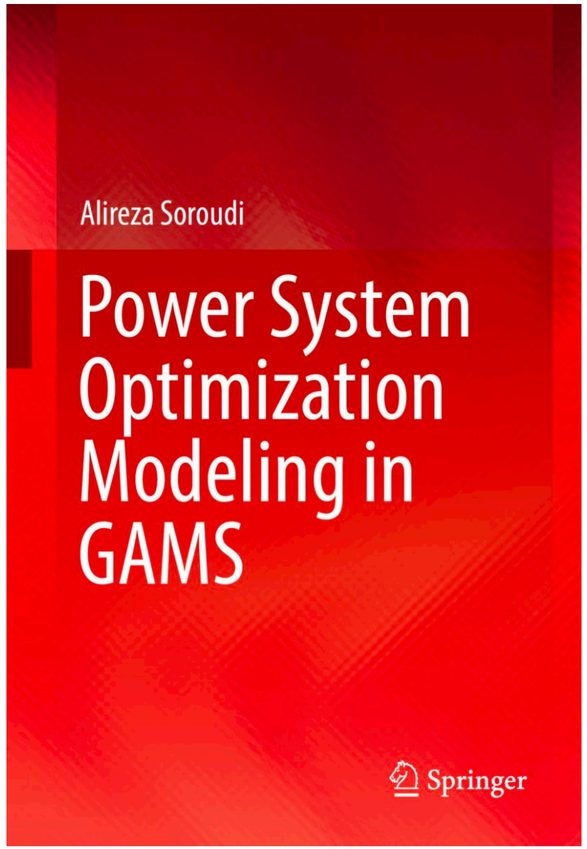
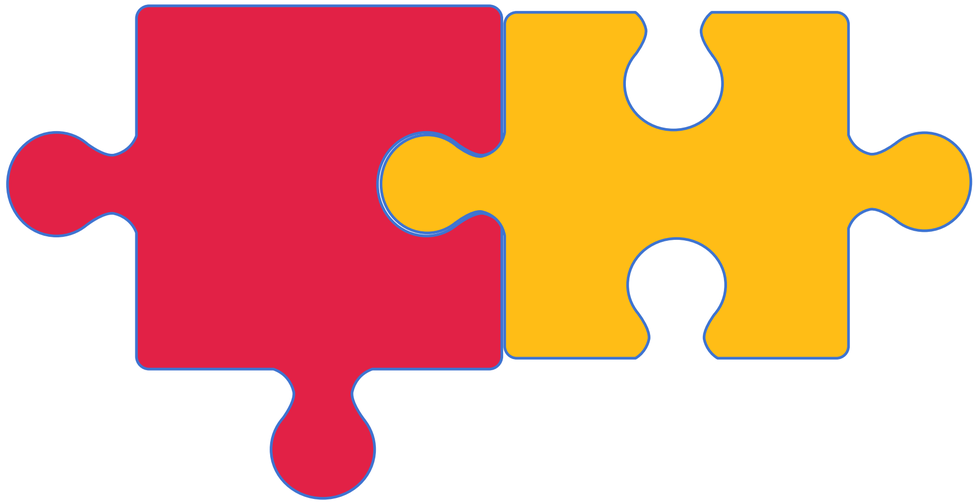


How it started



How it’s going

Machine Learning - Operations Research



Course plan

- Understand the concept of machine learning method
- Mathematical formulation of ML problem
- Solving the ML problem

Course plan

Session 1

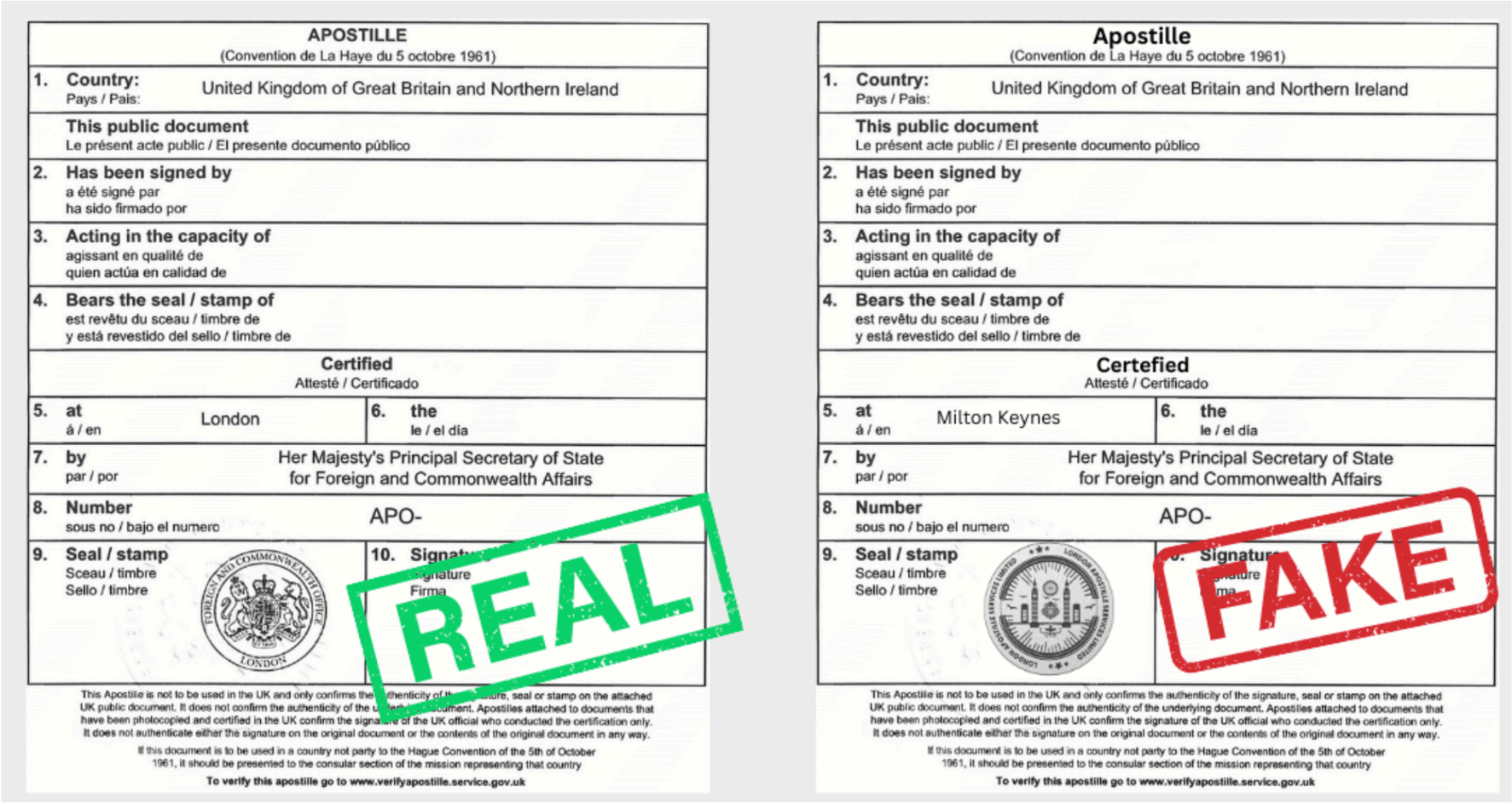
- Introduction
- Pyomo
- Some python tips
- GoogleColab
- Q&A

What is Machine Learning ?

- Learn from experience
- Identify the invisible patterns

What is Machine Learning ?

Application



What is Machine Learning ?

Application

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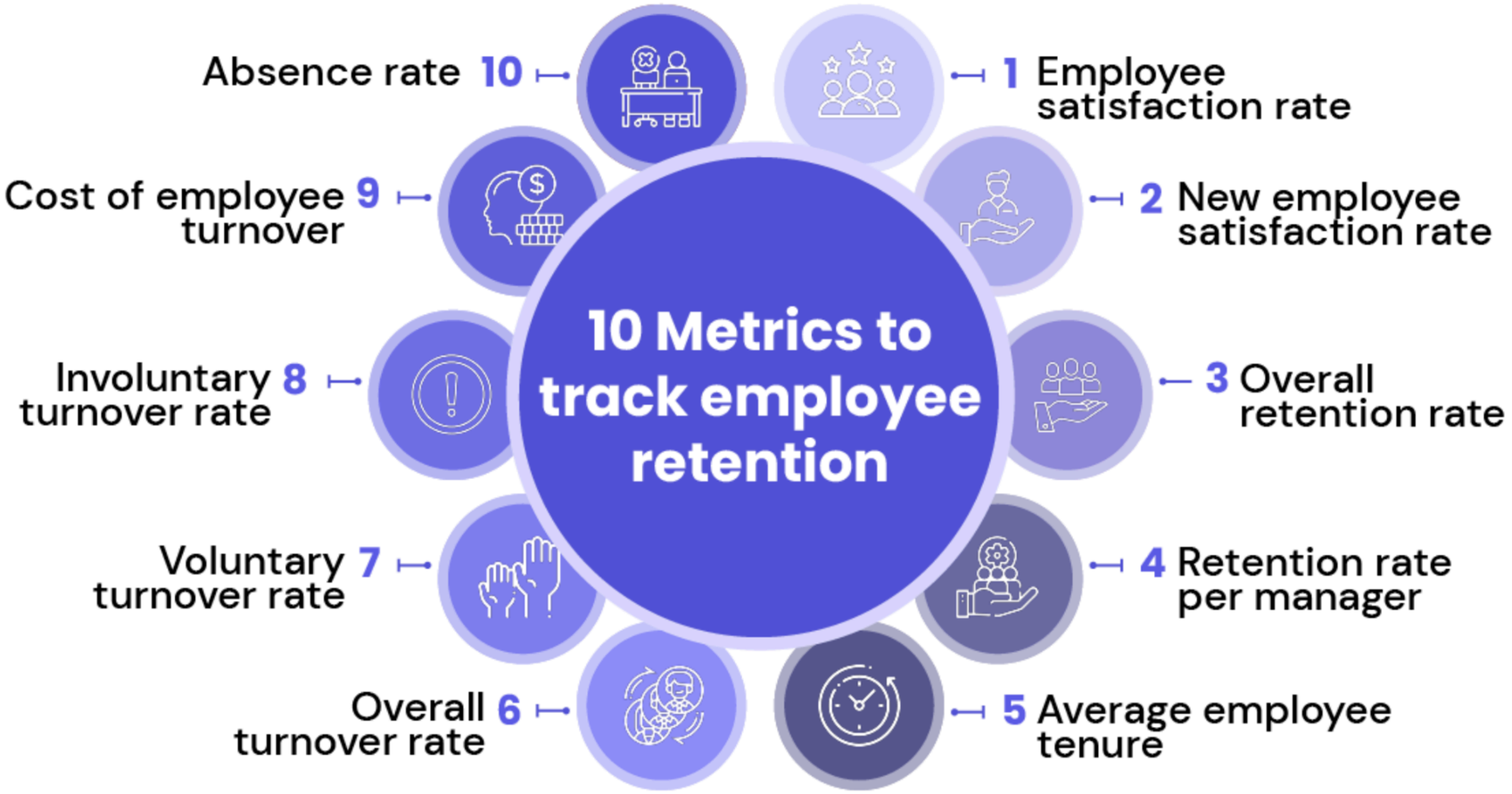
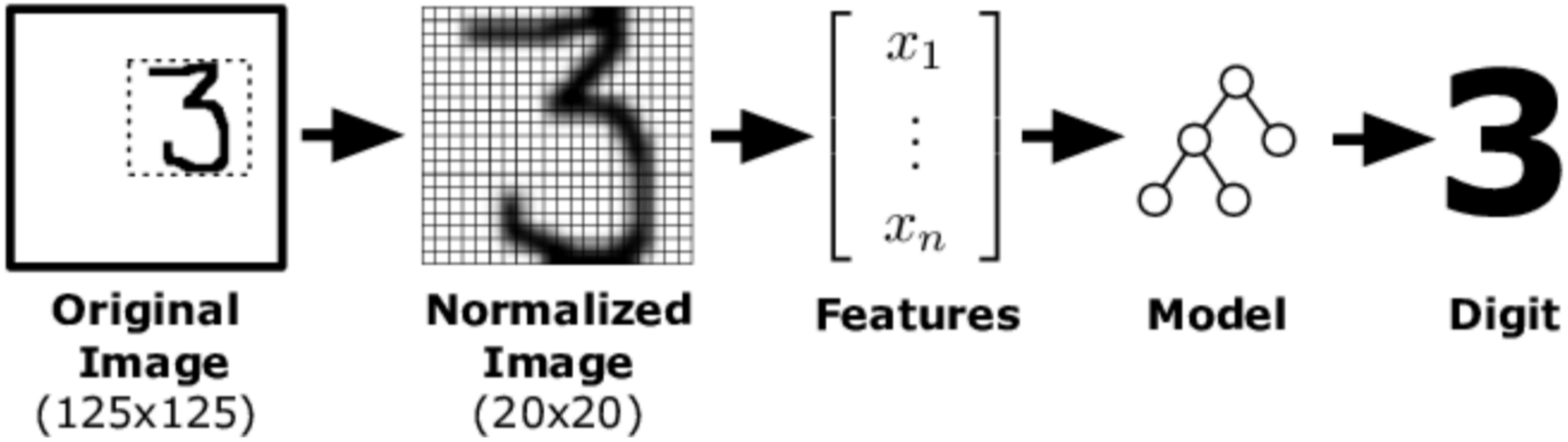


What is Machine Learning ?

Application

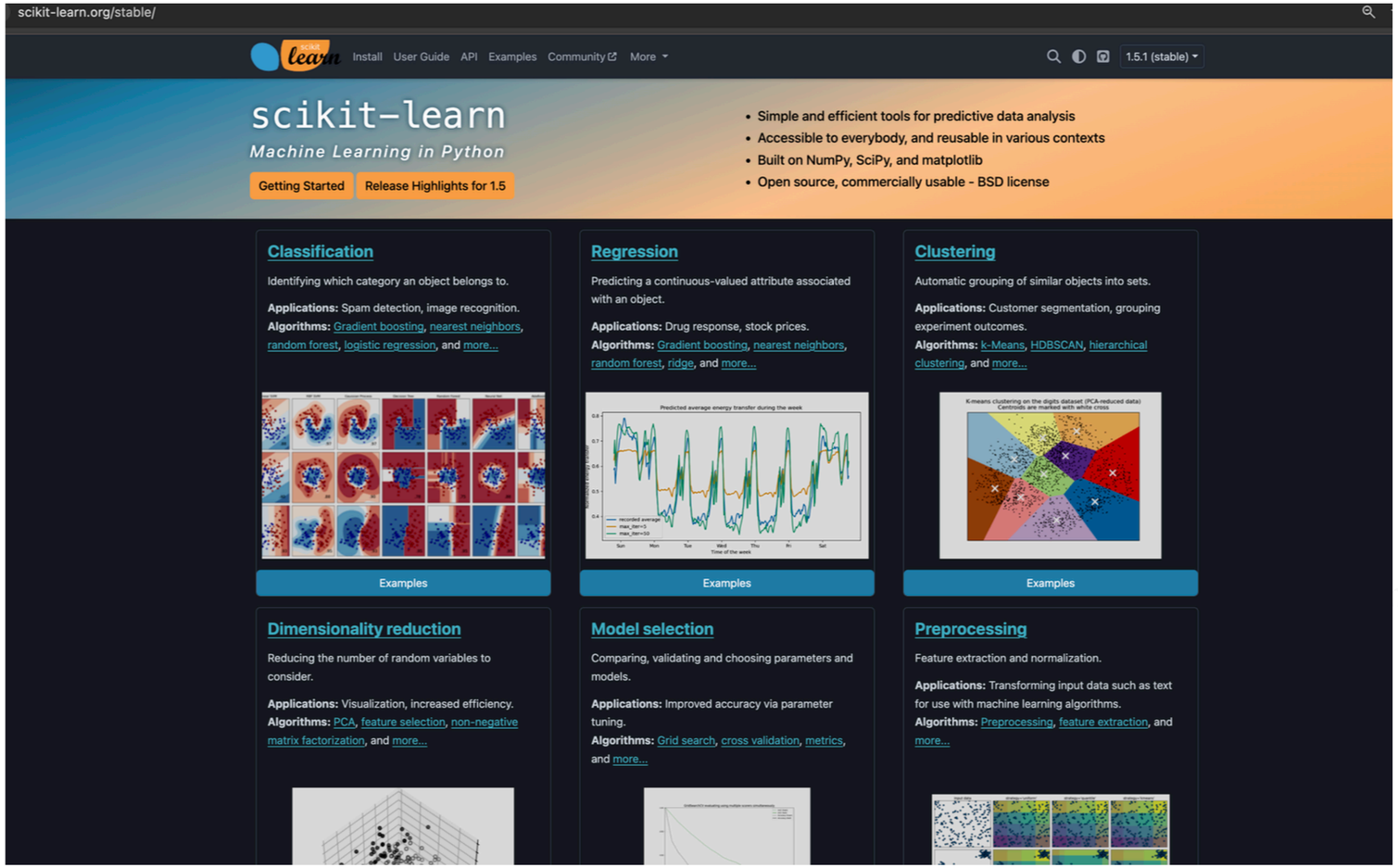
What is Machine Learning ?

Application



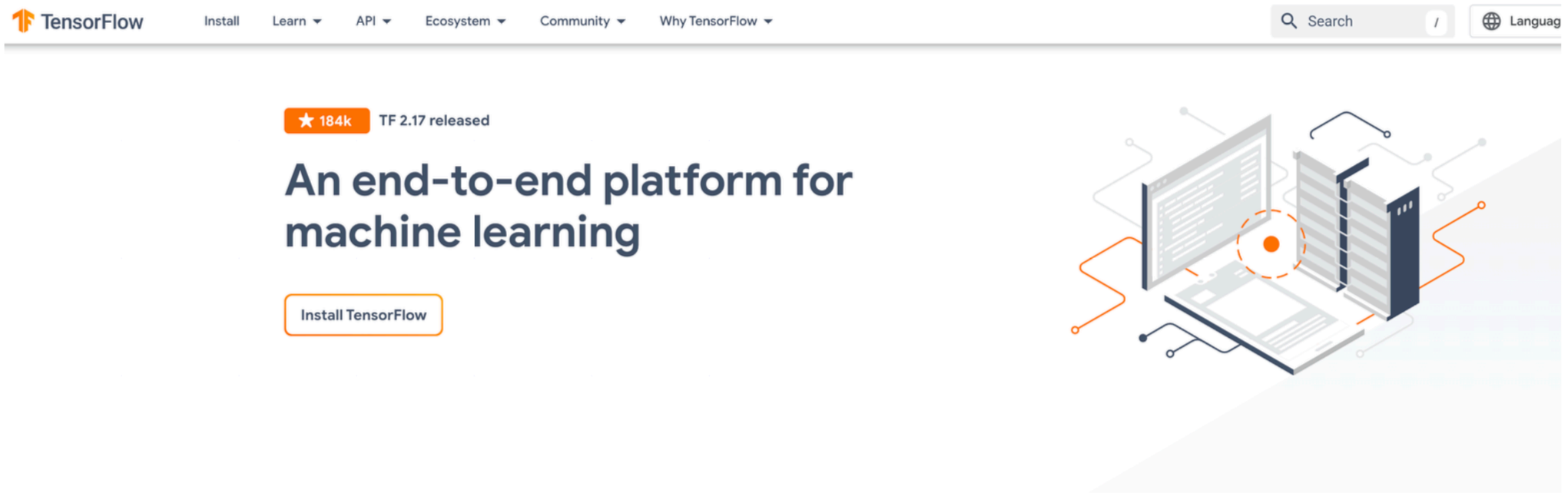
Machine Learning Packages

Scikit-learn



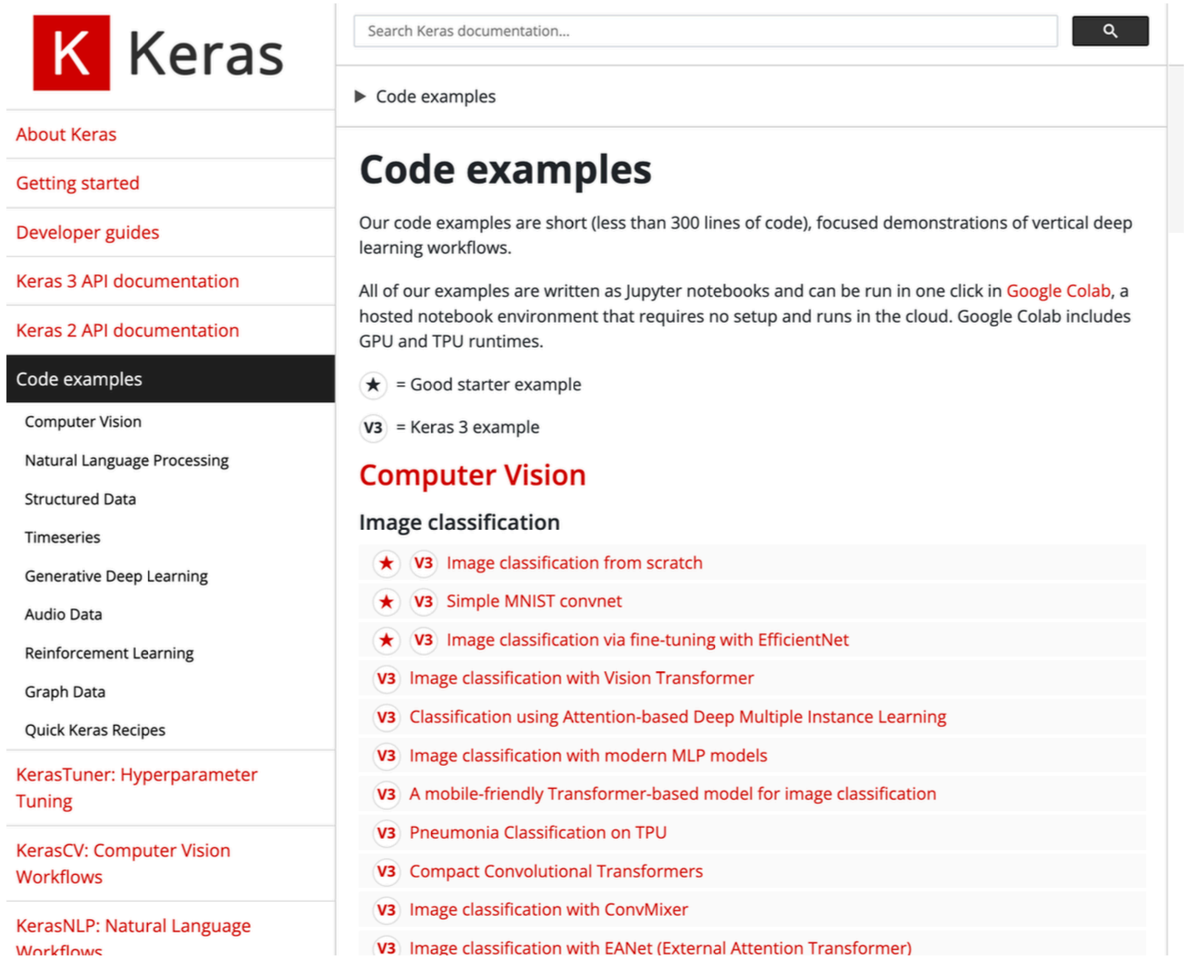
Machine Learning Packages

Tensorflow



Machine Learning Packages

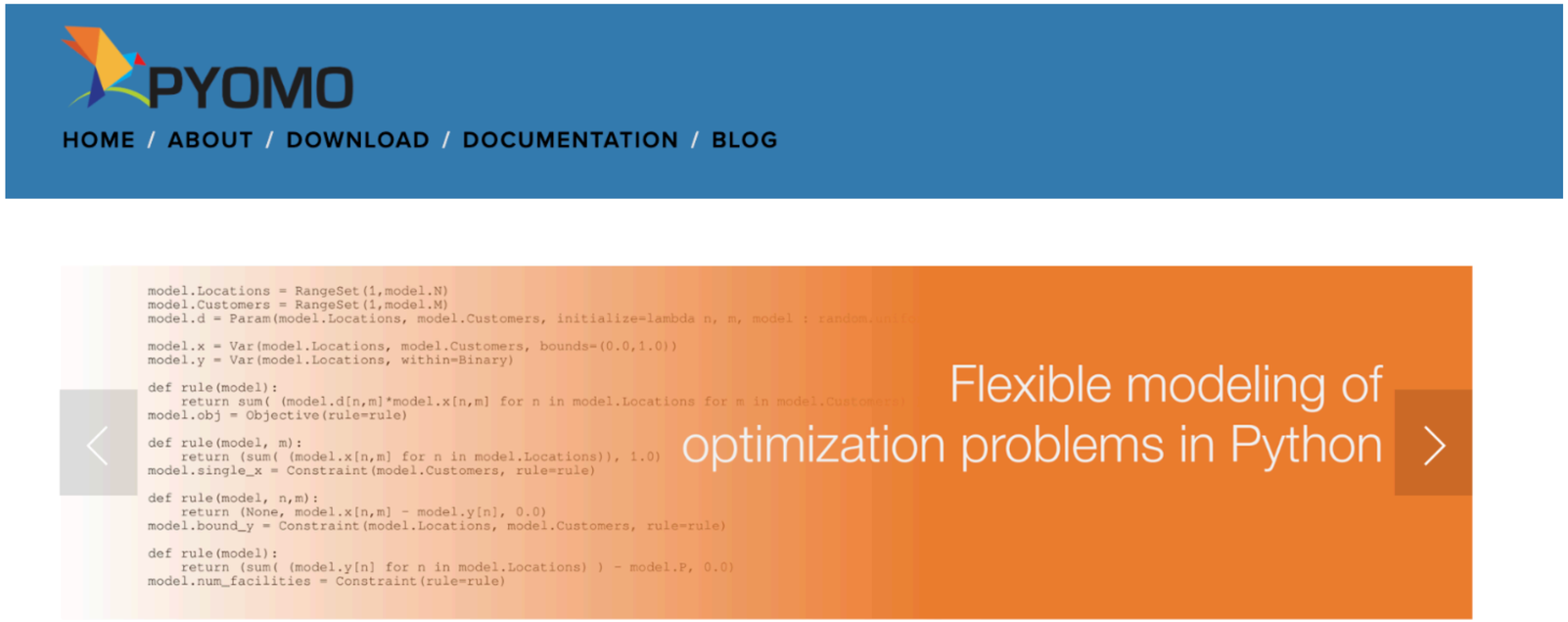
Keras



Optimisation Tools

Optimisation Package

Pyomo



Different Machine Learning Methods

Supervised Learning (classification)

- KNN, ANN
- Regression
- SVM

Set of labeled examples to learn from: training data
Develop model from training data
Use model to make predictions about new data Unsupervised machine learning

- **Unsupervised Learning**
  - Clustering

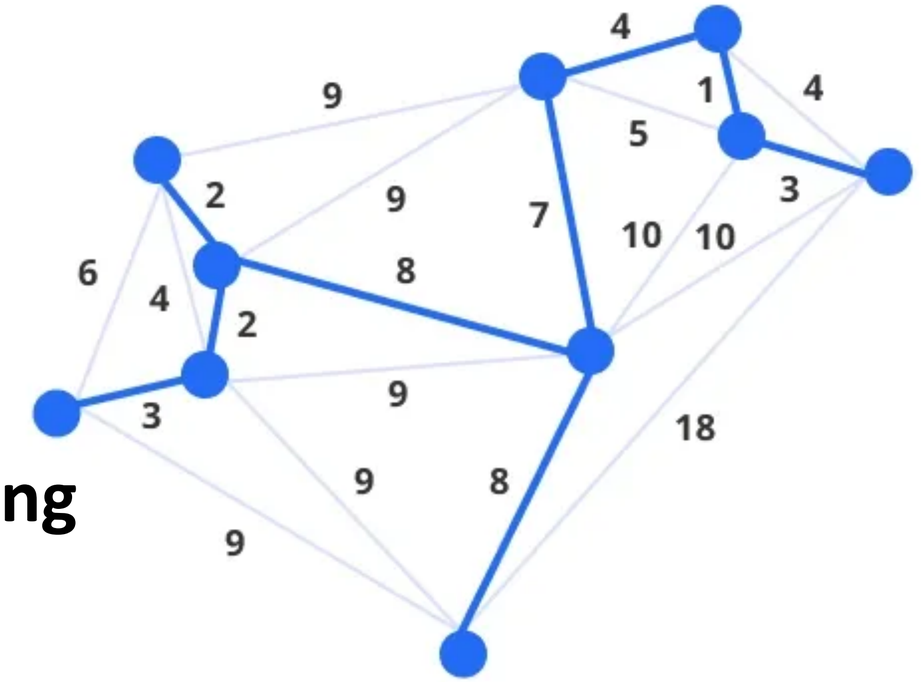
Unlabelled data, look for patterns or structure

- **PCA**

What makes this course unique ?

Optimisation in Python

- Introduction to optimisation
- Optimisation problem modelling
- Open source/commercial optimisation tools
- Application of optimisation tools in Engineering
- Useful resources for learning optimisation
- Academia/Industry pathway for optimisation experts

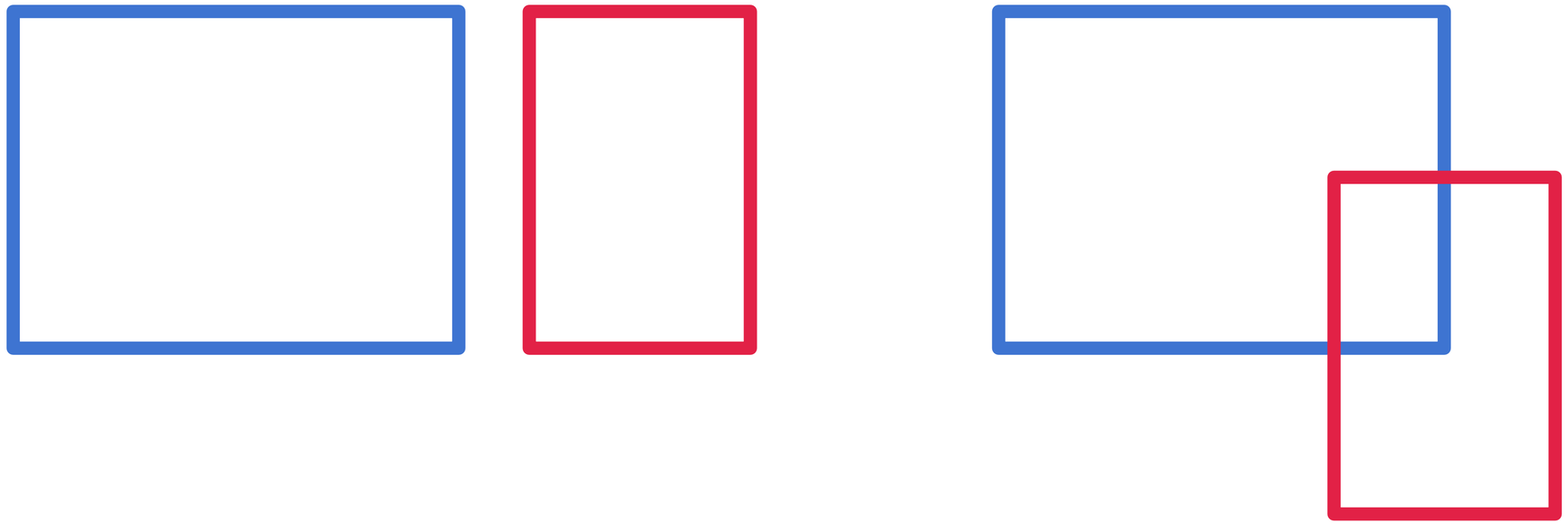


Skill Levels

- بهبود مدلسازی ریاضی
- مدلسازی یک مساله به فرم ریاضی
- کد کردن یک الگوریتم ریاضی
- کد کردن یک مدل ریاضی
- فهمیدن یک کد آماده

Example

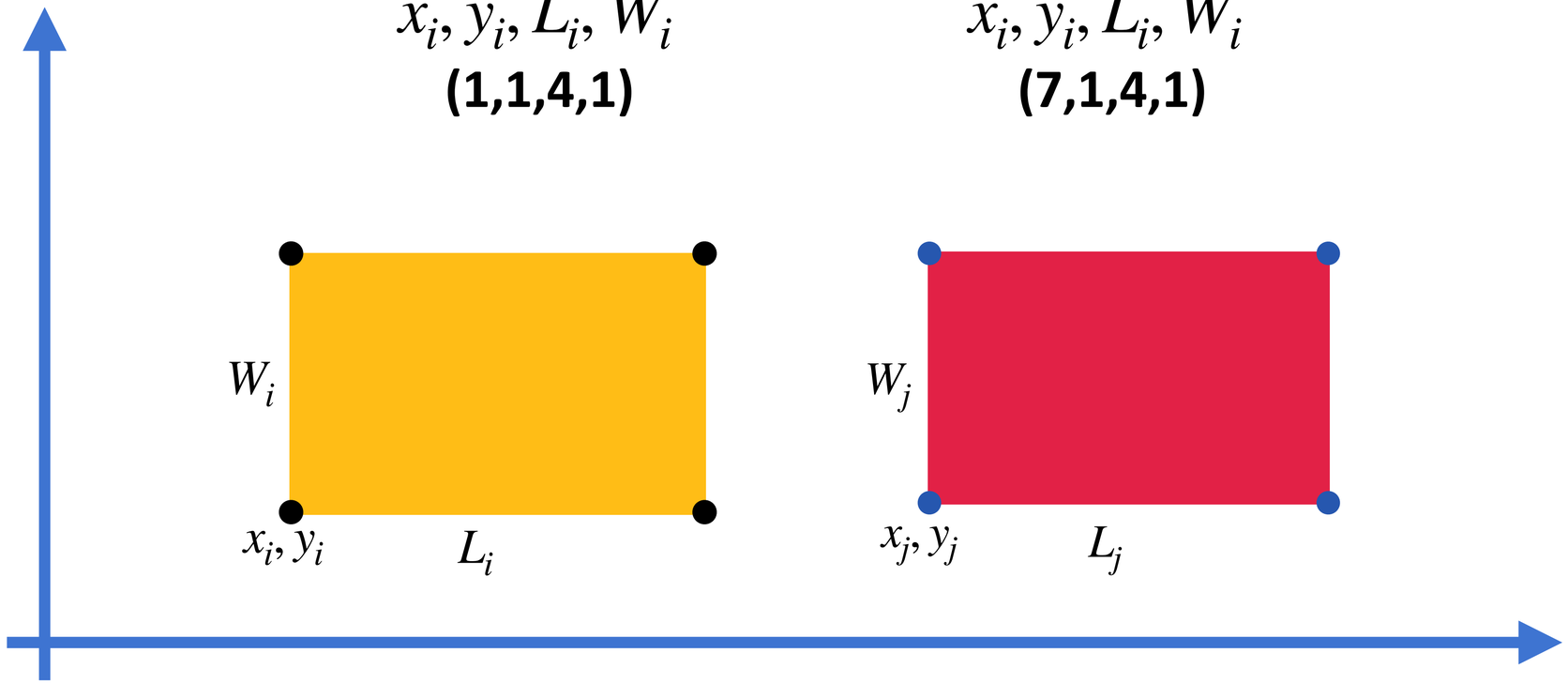
Are these rectangles overlapping ?



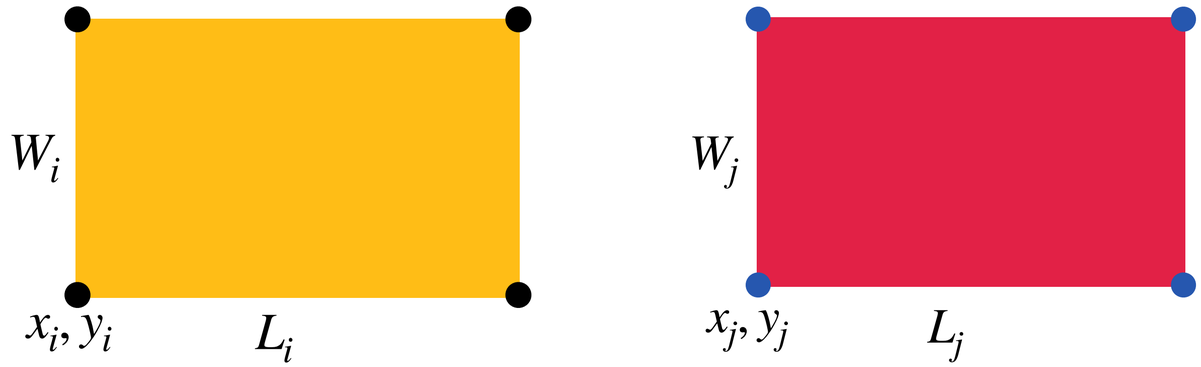

W
L
(X,Y)

x_i, y_i, L_i, W_i
(1,1,4,1)

x_i, y_i, L_i, W_i
(7,1,4,1)



x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i x_i, y_i, L_i, W_i



$$x_i + L_i - M(1 - R_{i,j}) \leq x_j$$

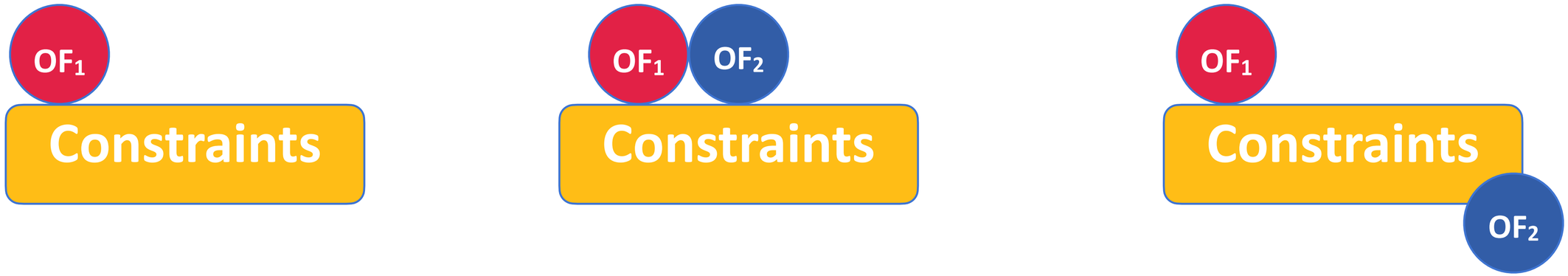
J is in the right hand side of I

$$x_i + L_i + MR_{i,j} \geq x_j$$

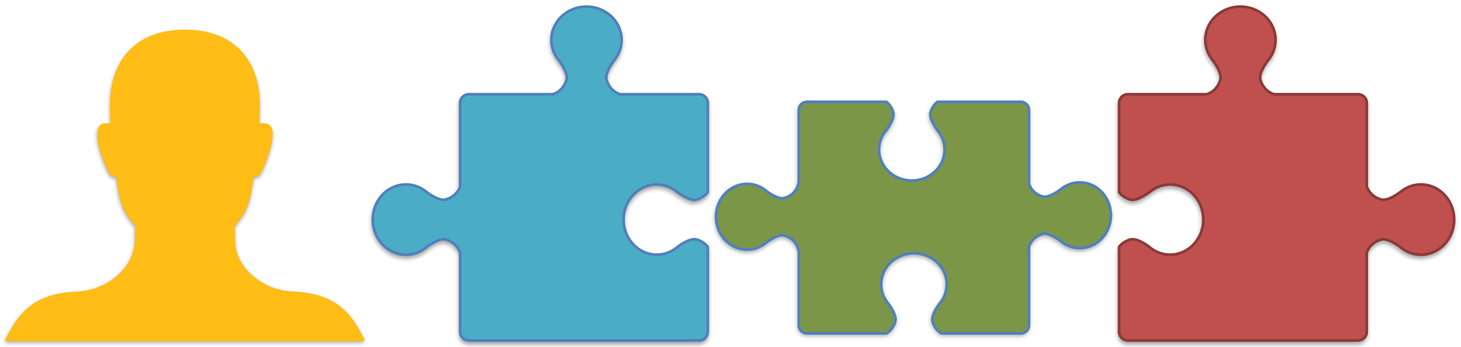
$$x_i \geq 0$$

$$R_{i,j} \in \{0,1\}$$

Optimisation Types

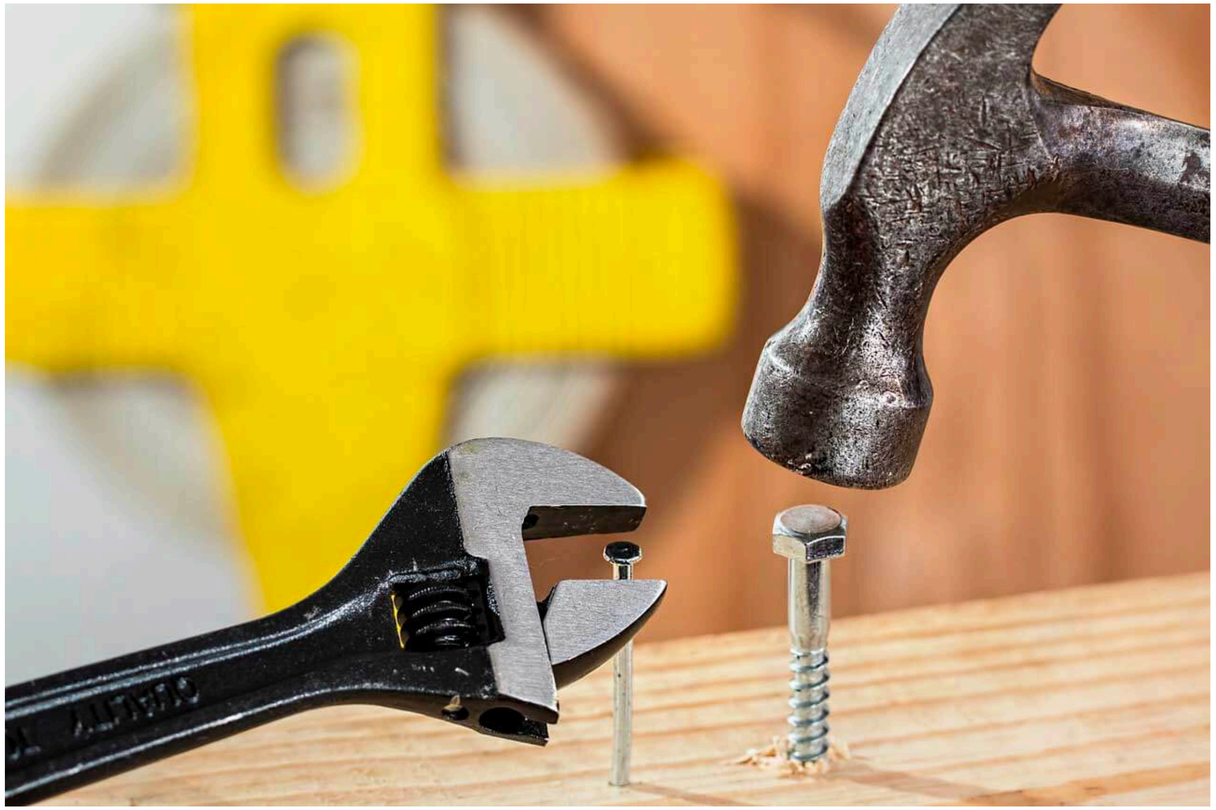


Optimisation modelling steps



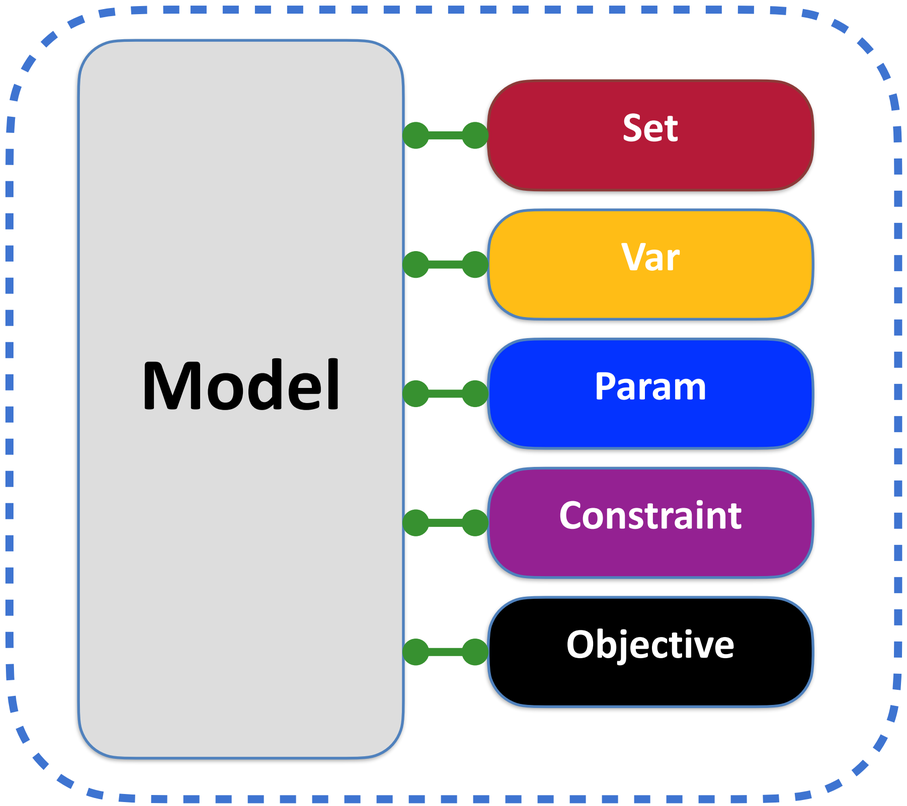
- CBC
- GLPK
- IPOPT
- Gurobi
- CPLEX

Right Tool for Right Problem



	LP	MIP	MIQP	QCP	NLP
CBC	✓	✓			
GLPK	✓	✓			
IPOPT	✓				✓
Gurobi	✓	✓	✓	✓	
CPLEX	✓	✓	✓	✓	

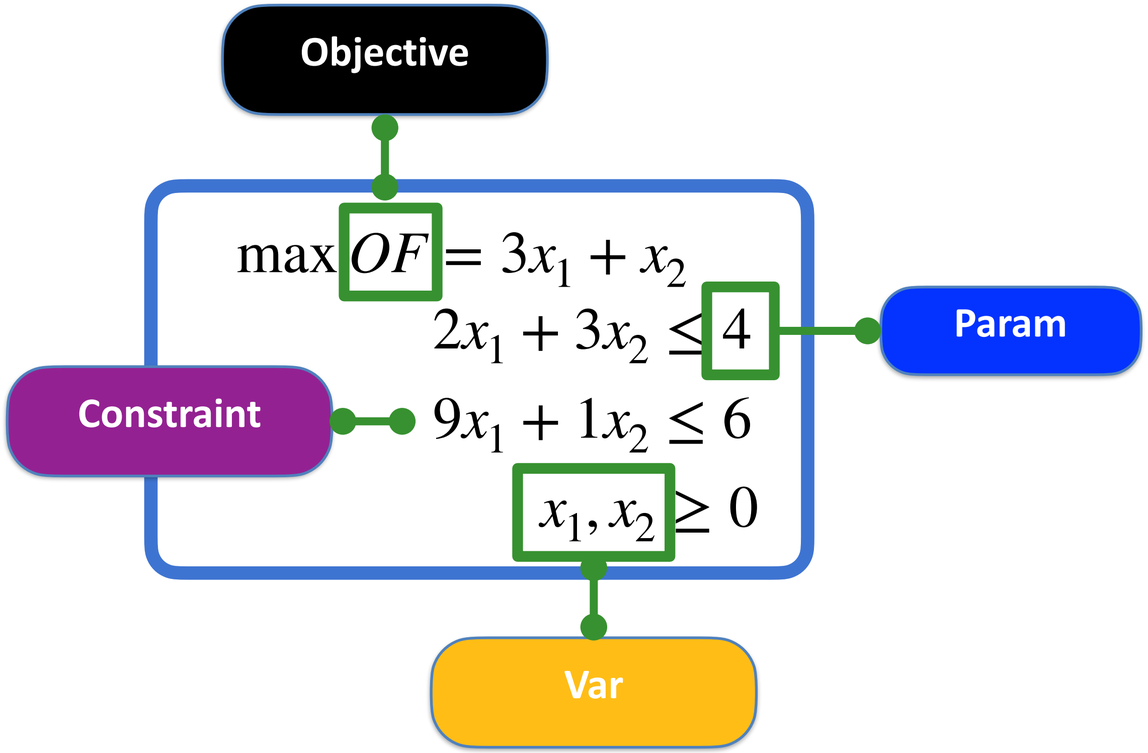
Pyomo Elements



Solve

Visualisation

Pyomo Example



Python code

```
[1]:
1 from pyomo.environ import *

[2]:
1 model = AbstractModel()
2 model.x1 = Var(initialize=0, within=NonNegativeReals)
3 model.x2 = Var(initialize=0, within=NonNegativeReals)
4 model.C1   = Constraint(expr=2*model.x1+3*model.x2<=4)
5 model.C2   = Constraint(expr=9*model.x1+ model.x2<=6)
6 model.obj1 = Objective(expr=3*model.x1+model.x2, sense=maximize)

[3]:
1 opt = SolverFactory('glpk')
2 instance = model.create_instance()

[4]:
1 results = opt.solve(instance)
2 print('OF= ',value(instance.obj1))

OF=  2.64
```

Code

Pyomo Example

$$
\begin{aligned}
\text{Minimize} \quad & Z = 2x_1 + 3x_2 - x_1^2 - 2x_2^2 \\
\text{subject to} \quad & x_1 + 3x_2 \leq 6 \\
& 5x_1 + 2x_2 \leq 10 \\
& x_1 \geq 0, i = 1, 2.
\end{aligned}
$$

Code

Session 2

Graph Colouring

- Find the minimum number of colours for paining this graph
  no two connected nodes have the same colours

$$\min_{X_{i,c},y} OF = y$$

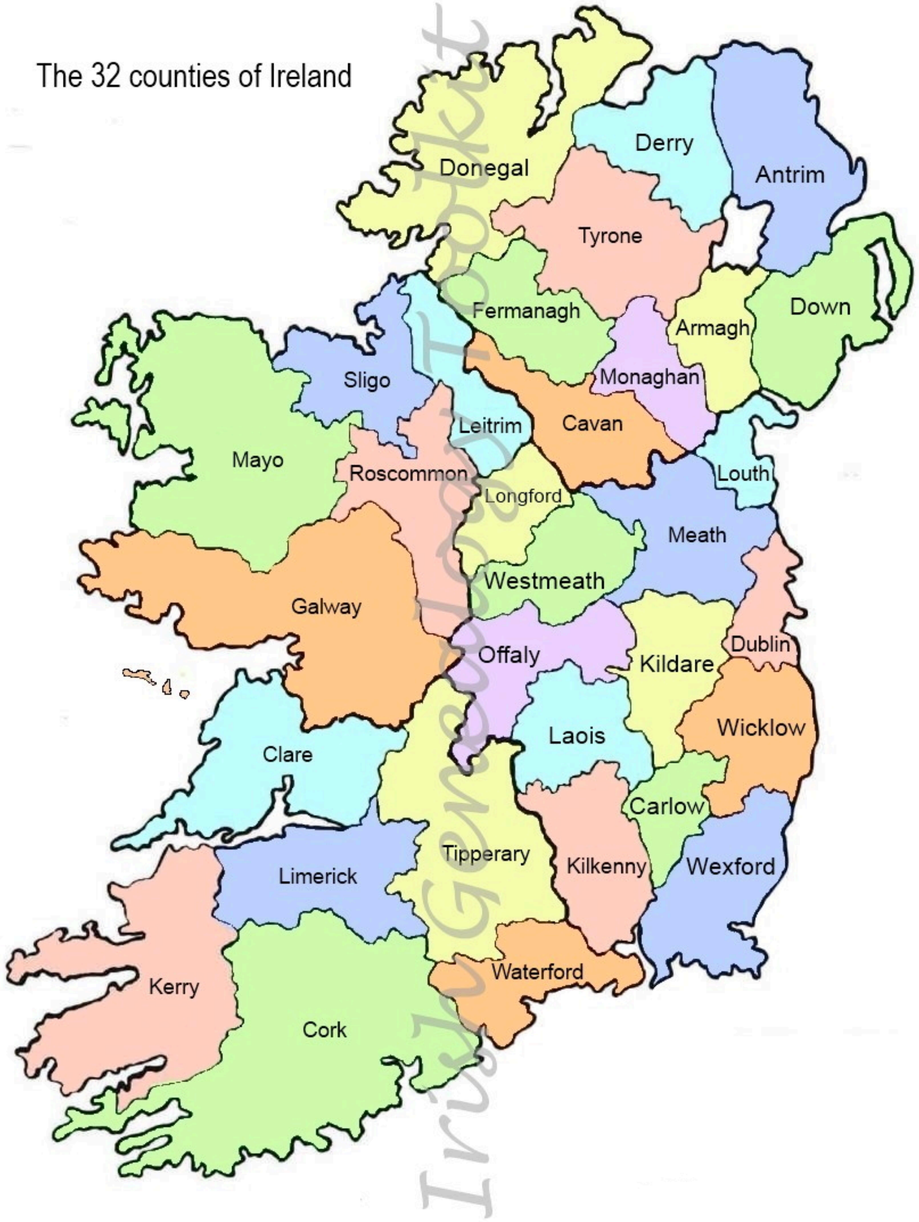
$$\forall i,j,c \quad (X_{i,c} + X_{j,c})L_{i,j} \leq 1$$

$$\forall i,c \qquad y \geq cX_{i,c}$$

$$\forall i \qquad \sum_{c} X_{i,c} = 1$$

Code

type of each variable?



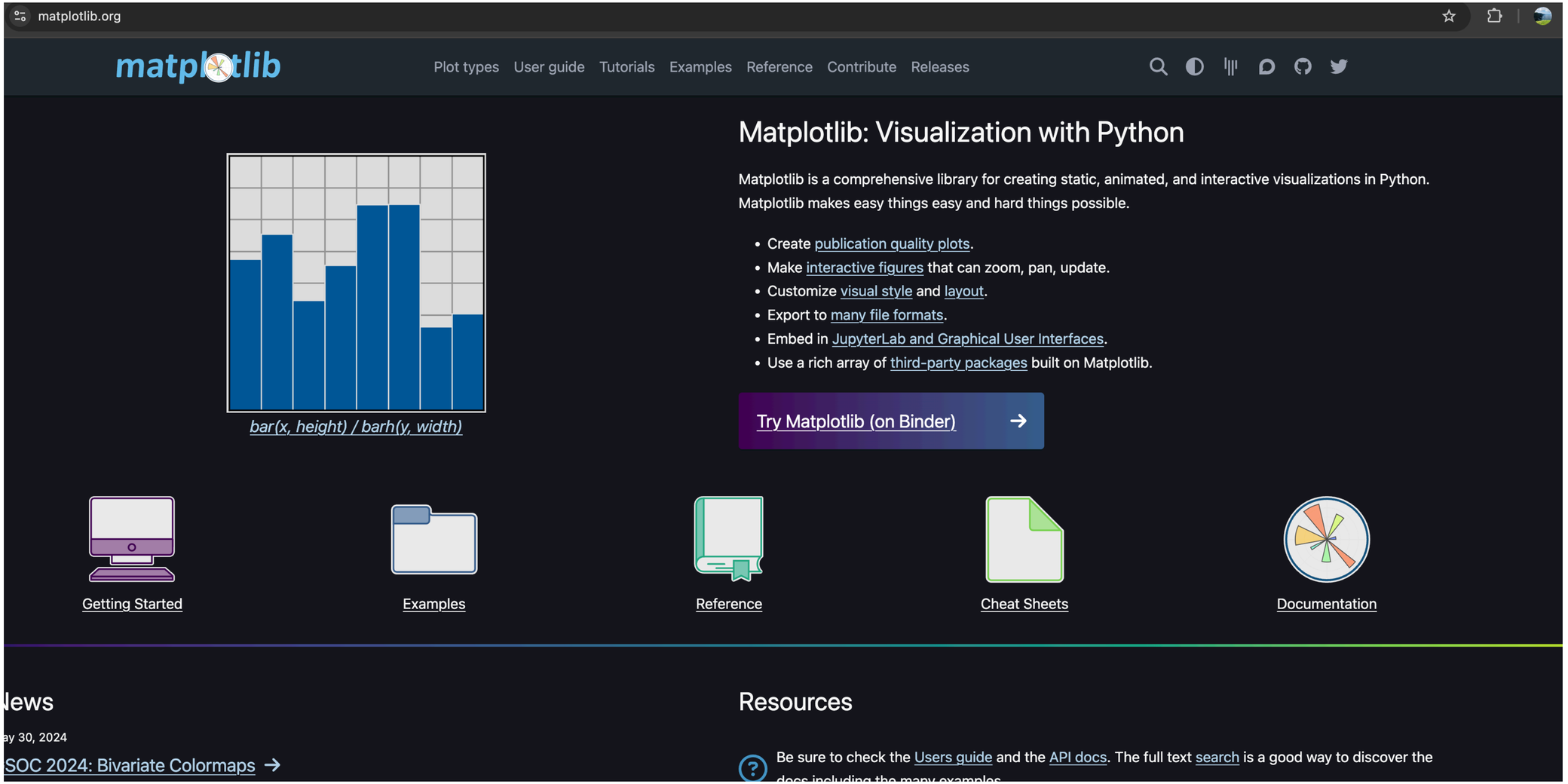
Python Tips

Data storage

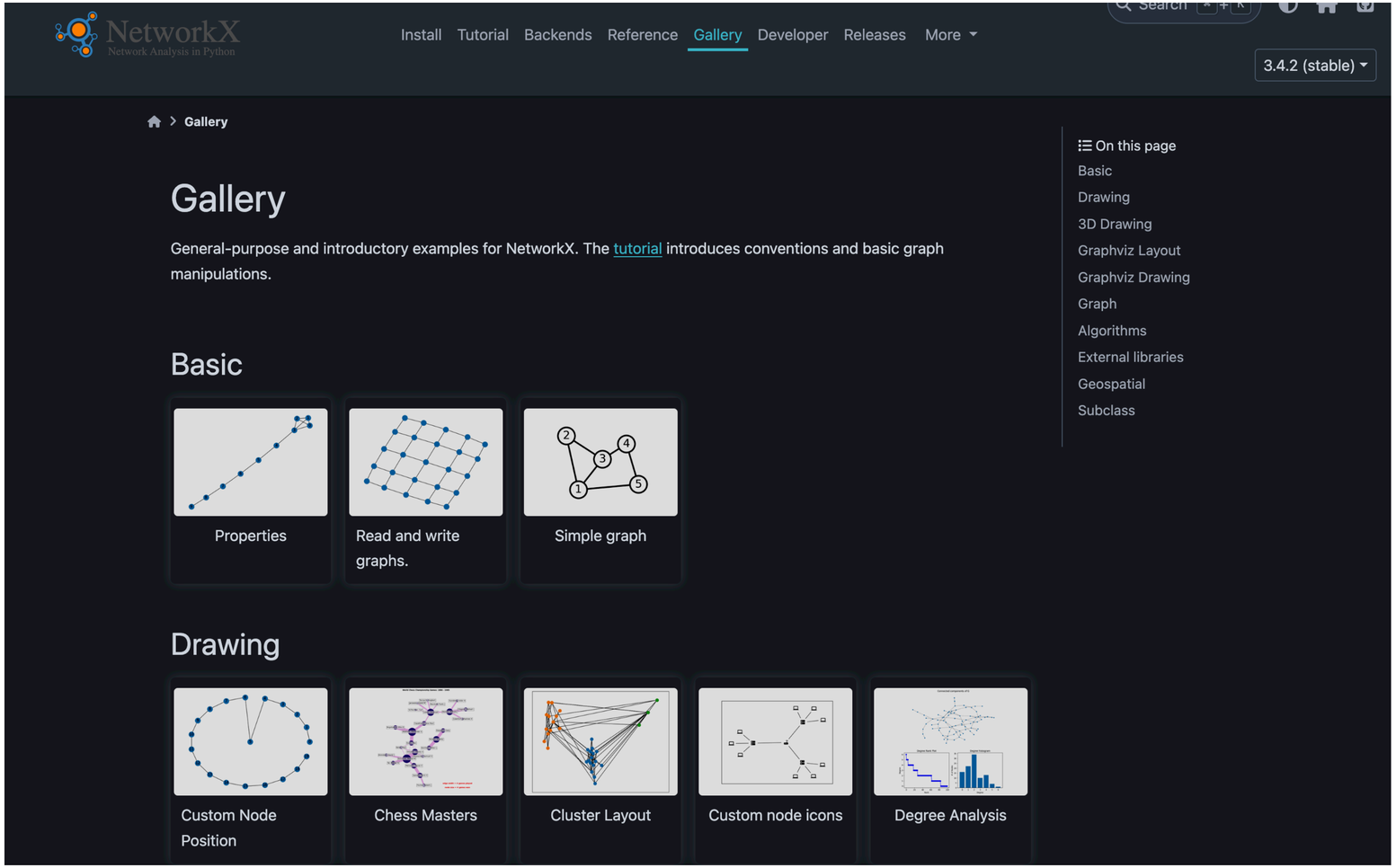
- DataFrame
- Array
- List
- Tuple
- Dictionary
- Set
- json
- …?

Code

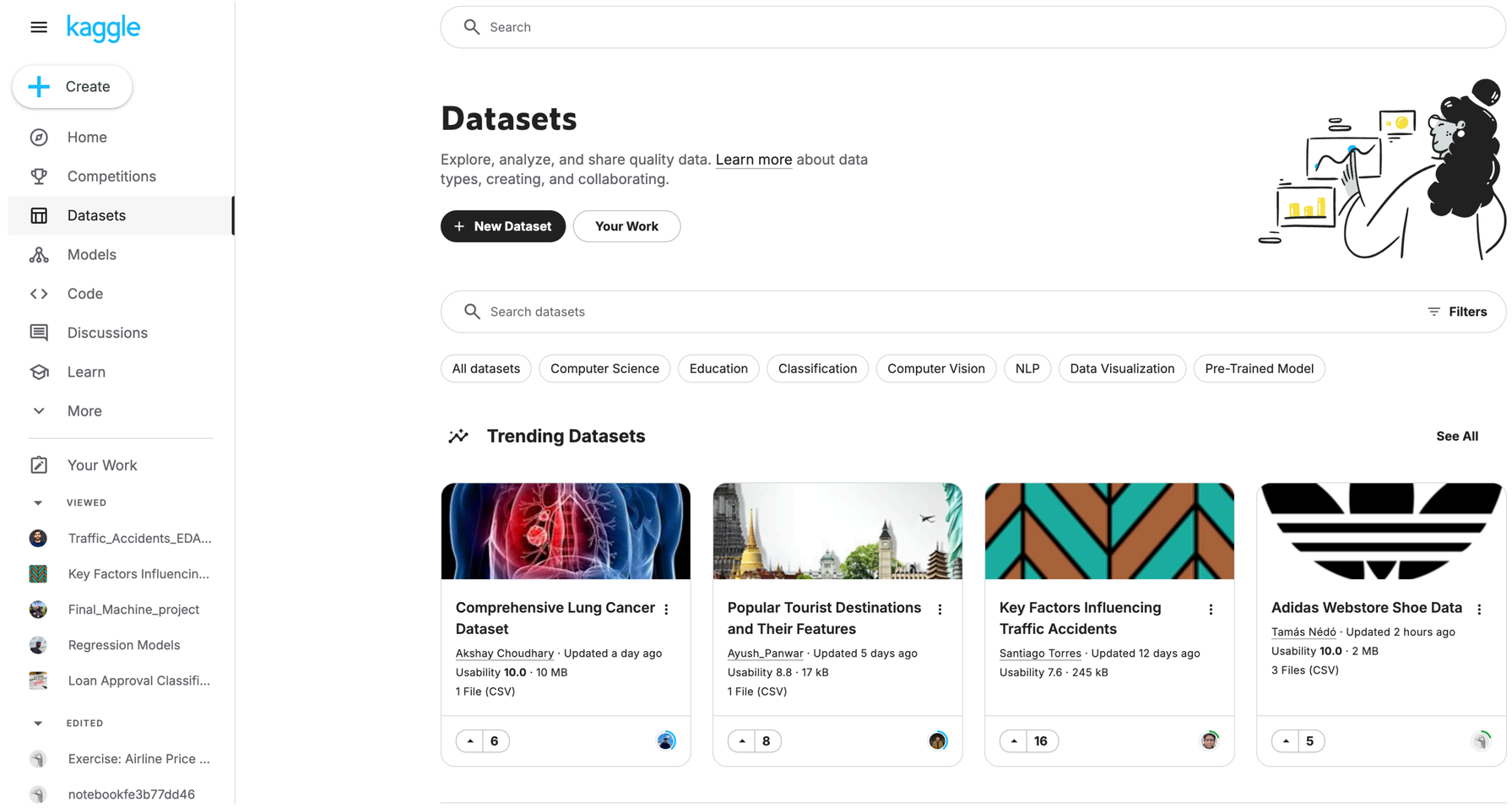
Python Visualisation



Python Graphs



DataSets + resources



Read more

https://towardsdatascience.com/variance-sample-vs-population-3ddbd29e498a

https://adam-rumpf.github.io/documents/kkt_intro.pdf