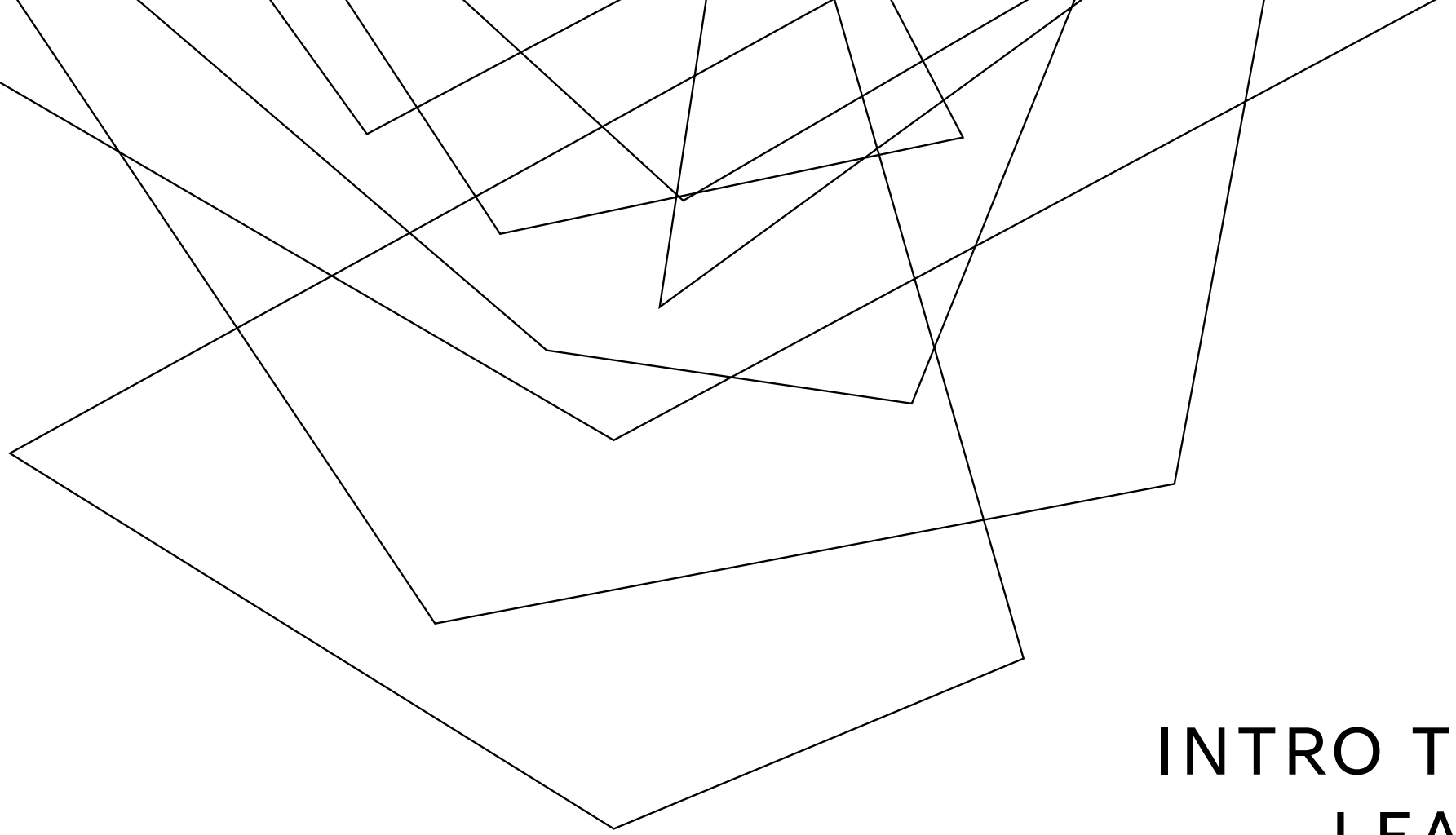

INTRO TO MACHINE LEARNING

DSI SUDS SCHOLAR BOOTCAMP 2024

SLIDES BY NAKUL UPADHYA

PRELIMINARIES

WHAT IS MACHINE LEARNING?

Study of Algorithms that: [1]

- Improve their **performance**
- At some **task**
- With **experience**

[1] Tom Mitchell, CMU 10-601 slides

WHAT IS MACHINE LEARNING?

Study of Algorithms that: [1]

- Improve their **performance**
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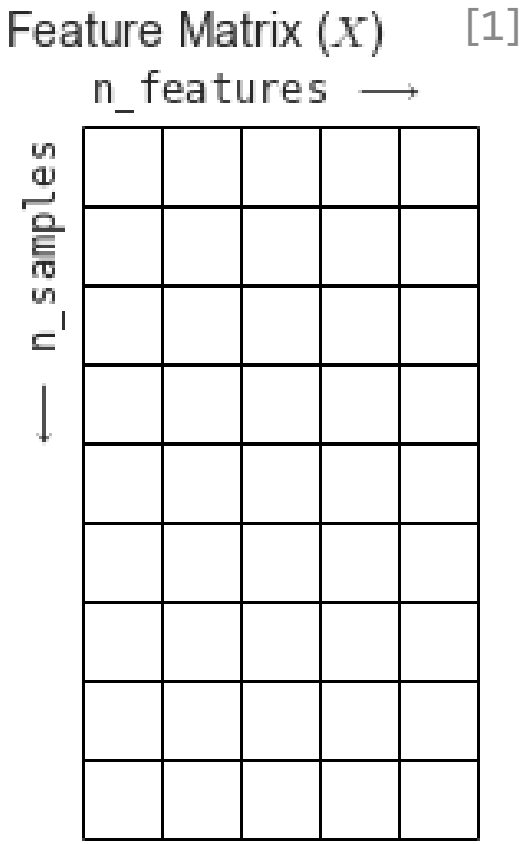
DATA AKA EXPERIENCE



- Sample: A datapoint
- Feature: an attribute of the samples

ML Algorithms learn relations between **features** across many **samples** to accomplish a task.

[1] Python Data Science Notebook – Introduction to Sci-Kit Learn – Jake Vanderplas

ML TASKS

Supervised

Uncover relations between the features and a **prediction target**

- Regression
- Classification

Semi-supervised

Self-supervised

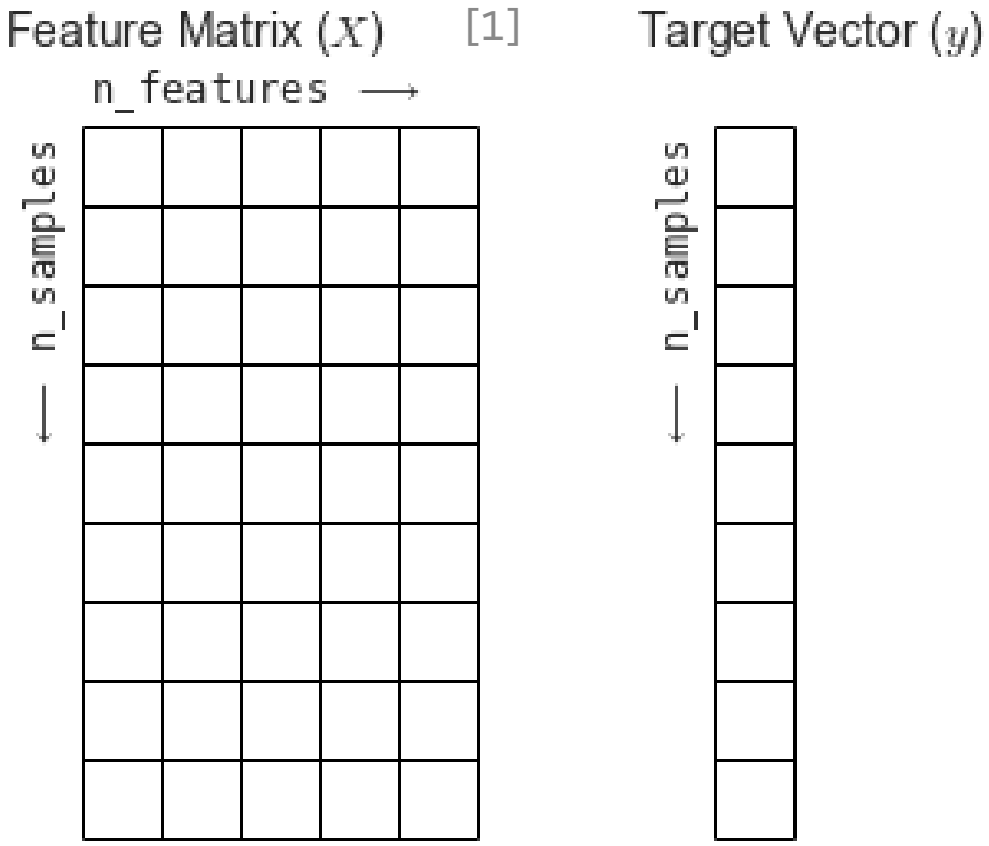
Unsupervised

Uncover hidden patterns **within the feature matrix**

- Clustering
- Dimensionality Reduction

SUPERVISED LEARNING

TERMINOLOGY



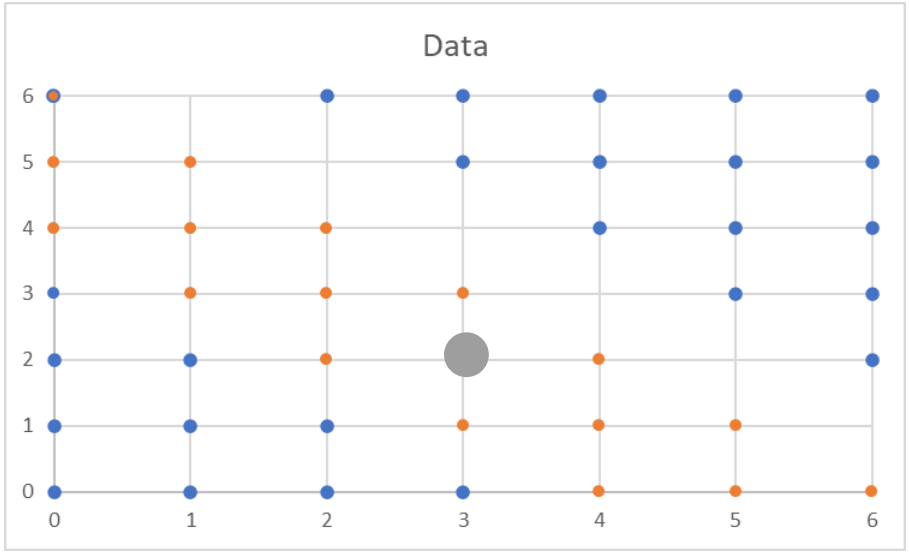
- Supervised Learning = Prediction
- Target: True Values

[1] Python Data Science Notebook – Introduction to Sci-Kit Learn – Jake Vanderplas

CLASSIFICATION VS. REGRESSION

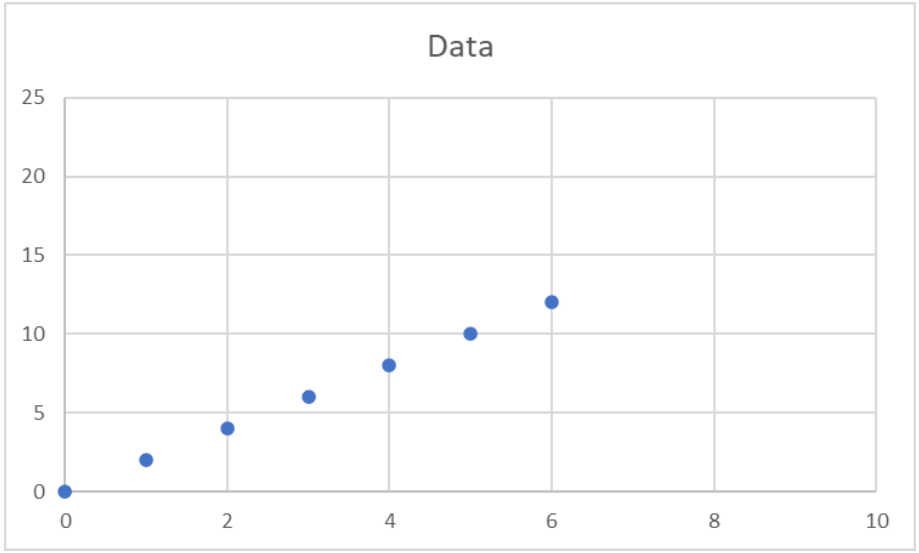
Classification

Categorical Target



Regression

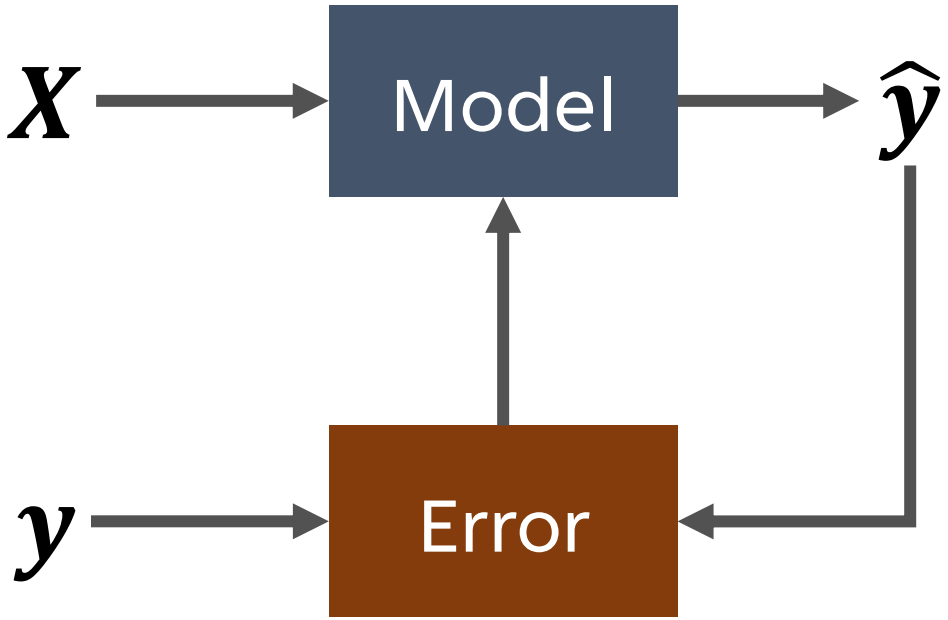
Numerical Target



CLASSIFICATION VS. REGRESSION

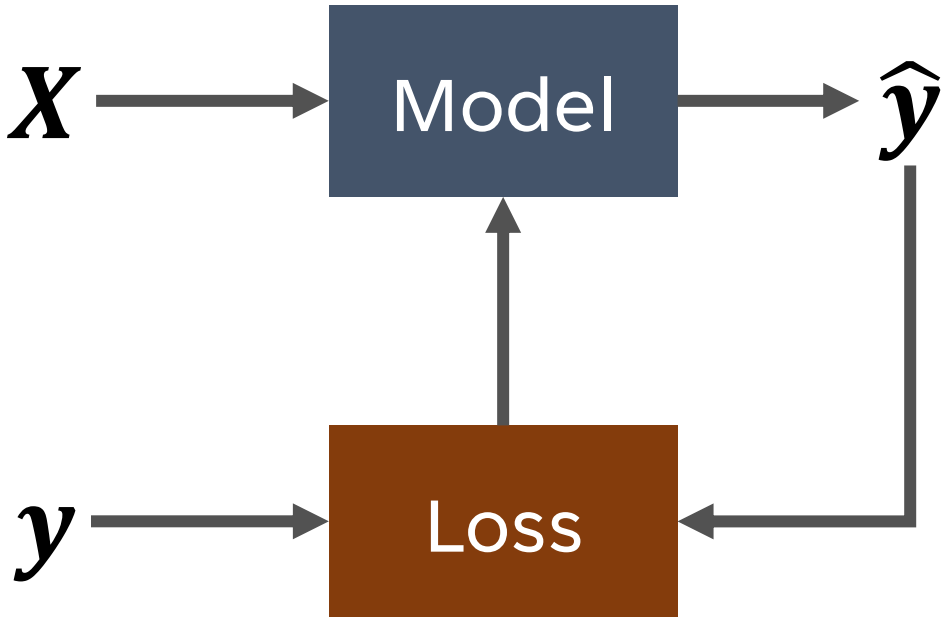
Classification	**Regression**
Categorical Target	Numerical Target
Blue vs. Orange	Age
Cancer vs. No Cancer	Income
Cat, Dog, or Bird	Sales

TRAINING A MODEL



- Make a prediction
- Calculate the error
- Update model based on error
- Repeat

TRAINING A MODEL



- Make a prediction
- Calculate the error
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REGRESSION ERROR

Mean Squared Error

$$\frac{1}{n}\sum(y_i - \hat{y}_i)^2$$

Mean Absolute Error

$$\frac{1}{n}\sum|y_i - \hat{y}_i|$$

CLASSIFICATION ERROR

Misclassification

$$\frac{Incorrect}{Total}$$

Cross-Entropy

$$-\frac{1}{n}\sum\sum y_{i,c}\log\hat{p}_{i,c}$$

Impurity

$$1-\sum p_c(1-p_c)$$

EXAMPLE: MULTIPLE LINEAR REGRESSION

$$\hat{y} = f(x) = \theta_0 + \theta_1 x_1 + \cdots + \theta_n x_n = \Theta \cdot x$$

Minimize $\frac{1}{n}\sum(y_i - \Theta \cdot x)^2$

By Updating Θ

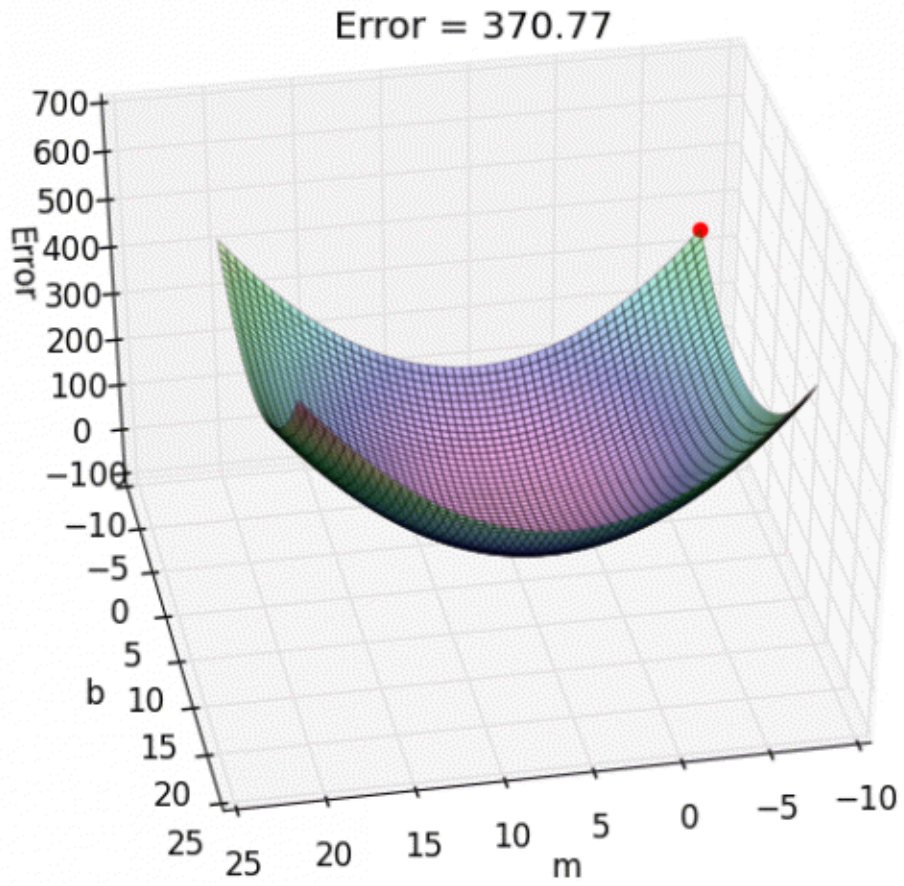
EXAMPLE: MULTIPLE LINEAR REGRESSION

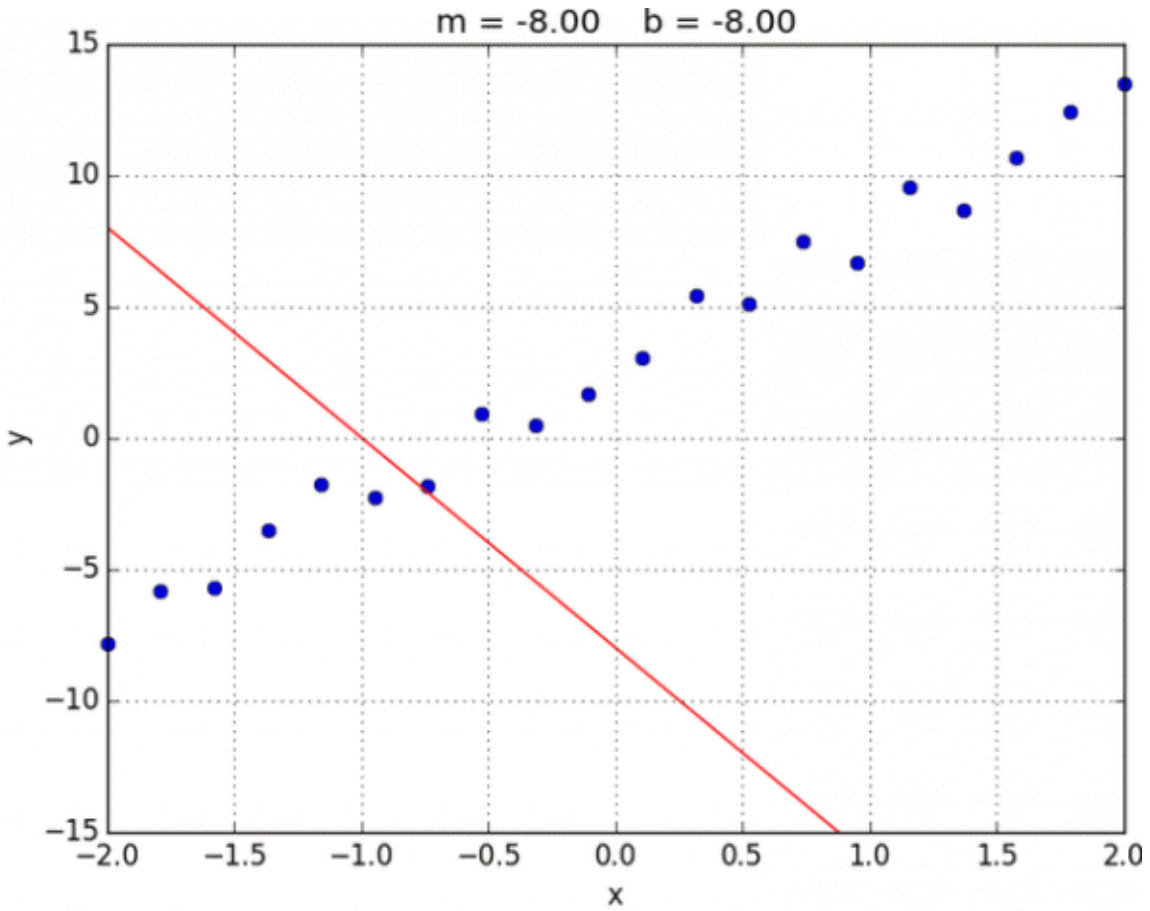
$$\hat{y} = f(x) = \theta_0 + \theta_1 x_1 + \cdots + \theta_n x_n = \Theta \cdot x$$

$$\nabla L = \frac{\partial}{\partial \Theta} \sum (y_i - \Theta \cdot x)^2$$ Gradient = Direction of Increase

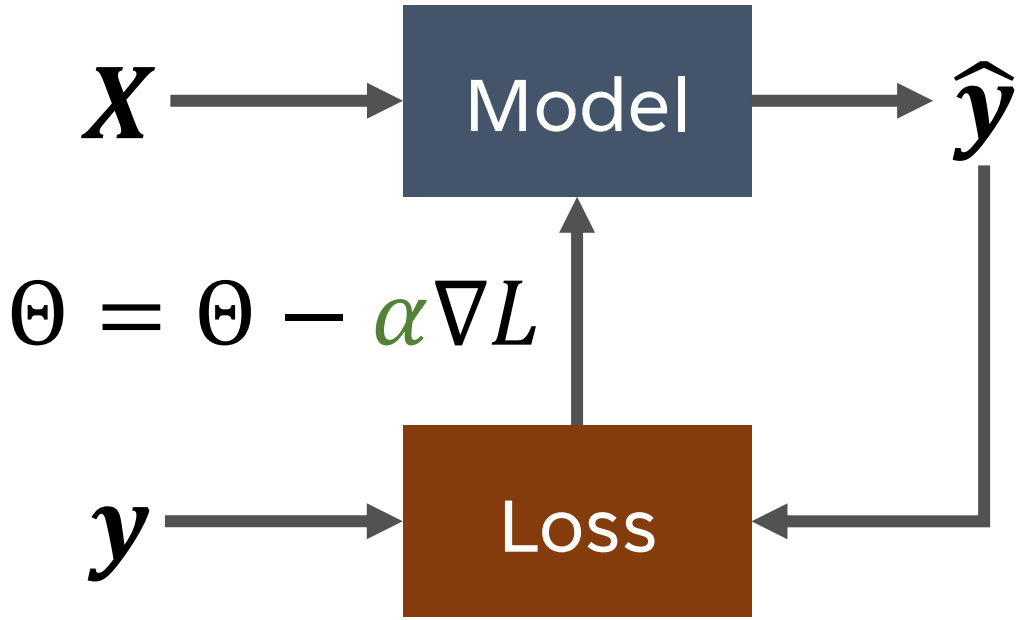
$$\Theta = \Theta - \alpha \nabla L$$ Take steps in opposite direction

EXAMPLE: LINEAR REGRESSION

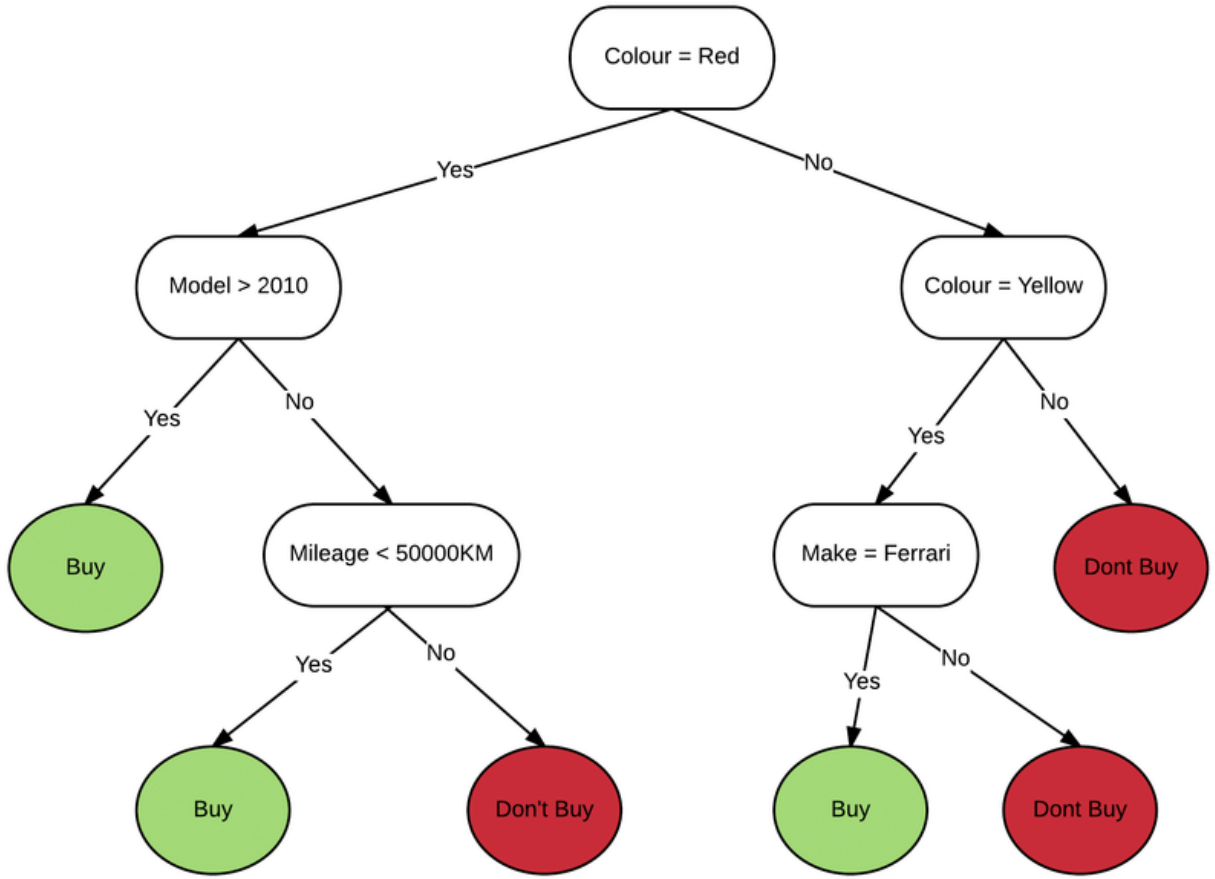




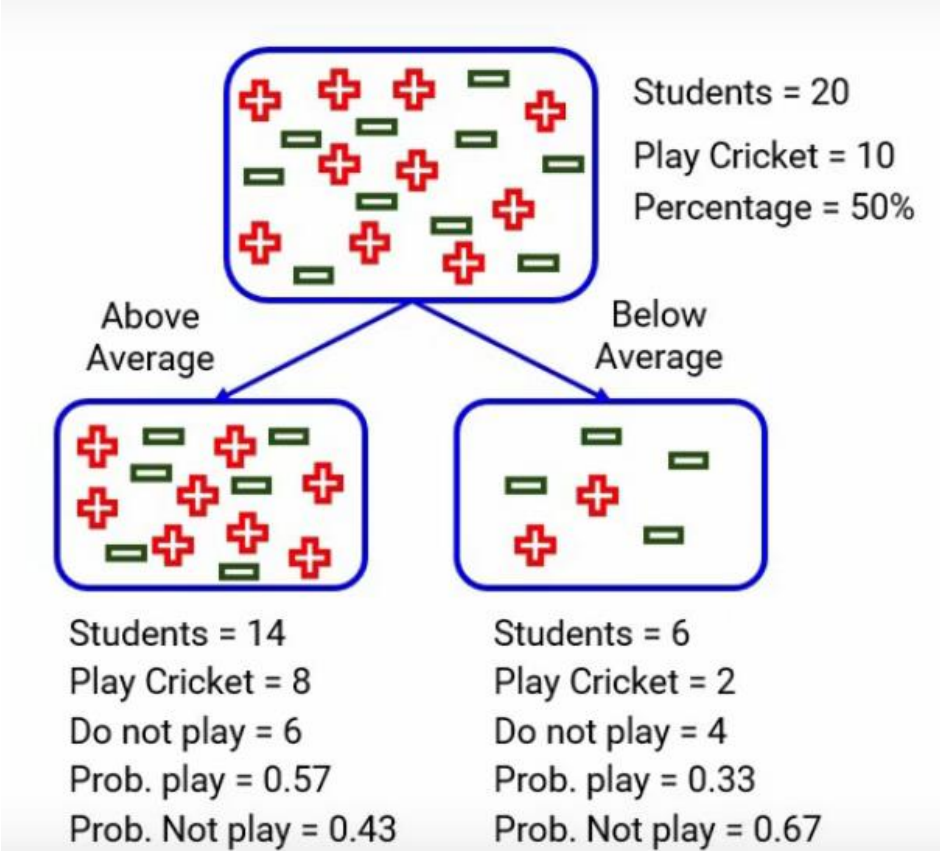
EXAMPLE: MULTIPLE LINEAR REGRESSION



EXAMPLE: DECISION TREE CLASSIFIER

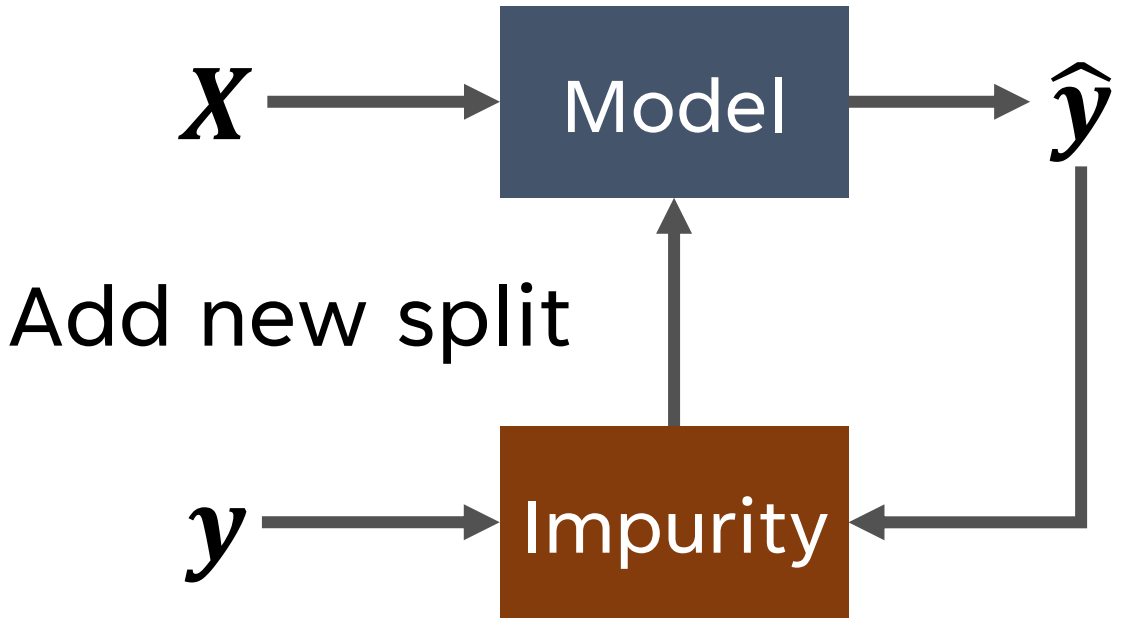


EXAMPLE: DECISION TREE CLASSIFIER



https://www.analyticsvidhya.com/blog/2021/03/how-to-select-best-split-in-decision-trees-gini-impurity/

EXAMPLE: DECISION TREE CLASSIFIER

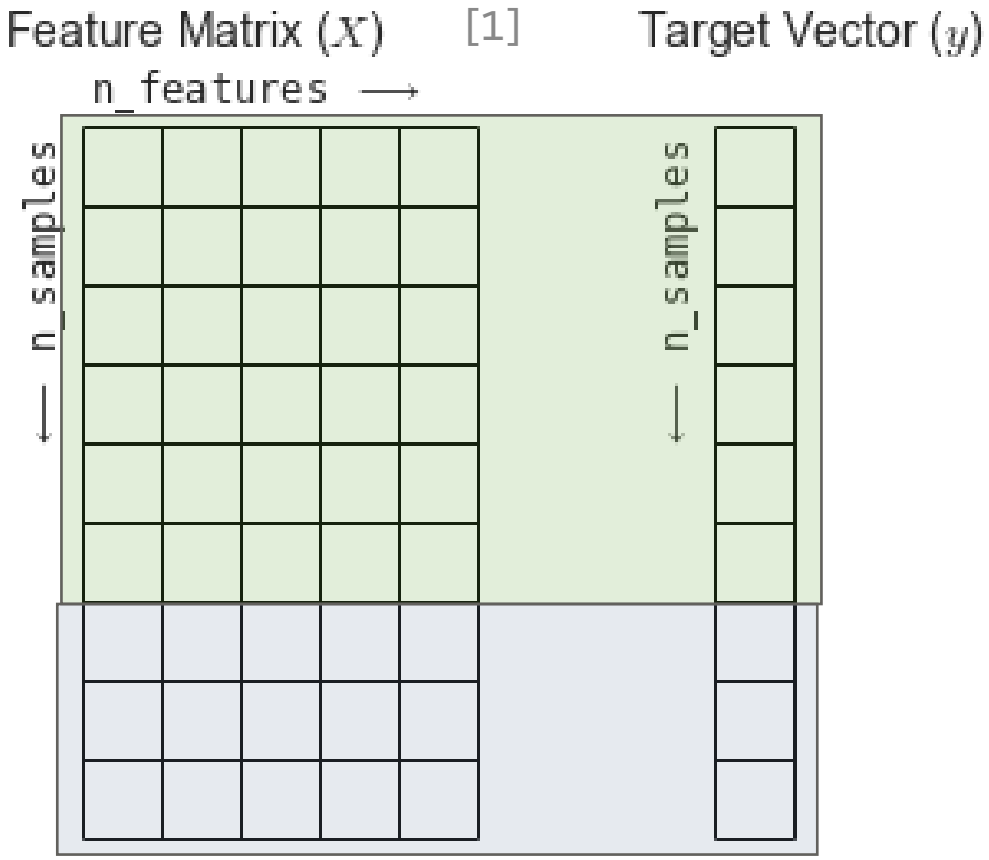


EVALUATING A TRAINED MODEL

How do we accurately judge how good a model is?

Evaluating error during training is not a good judge.

EVALUATING A MODEL

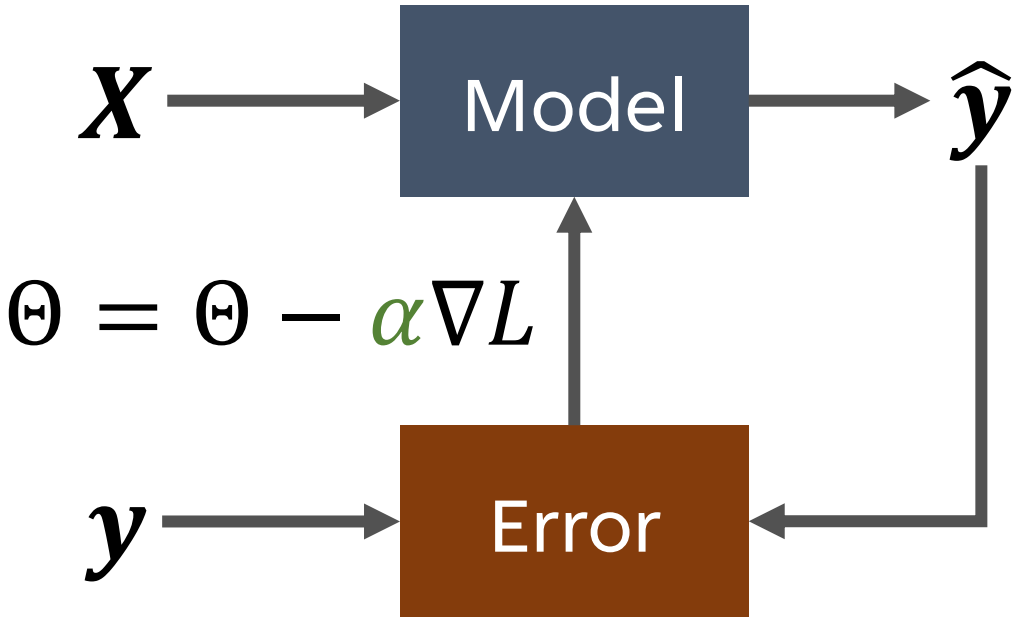


- Split the data up
- Training Set: Used to develop and train model
- Test Set: Used to evaluate model

[1] Python Data Science Notebook – Introduction to Sci-Kit Learn – Jake Vanderplas

PROBLEM: HYPERPARAMETERS

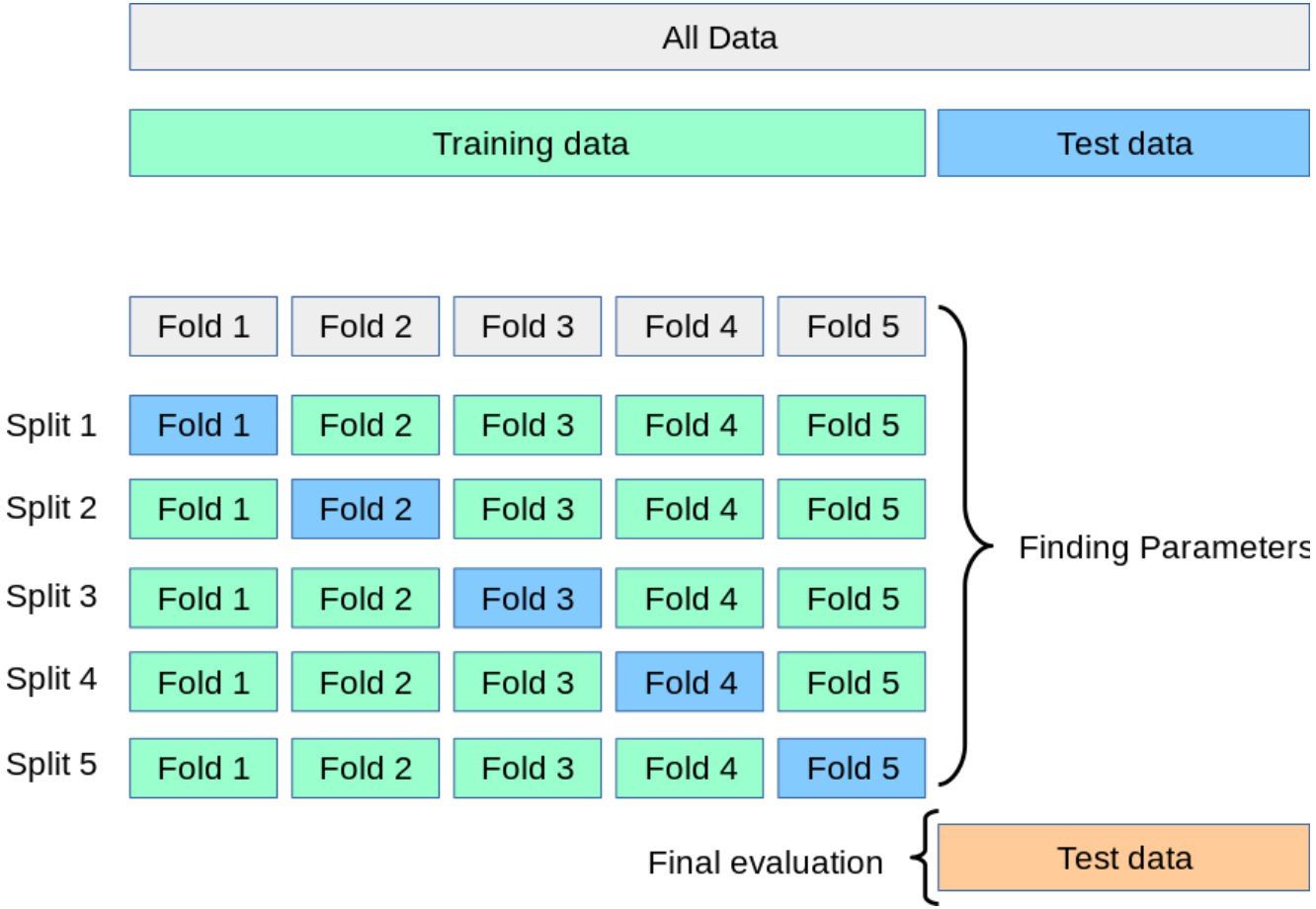
Recall training Linear Regression



How large is our step?

How many steps do we take?

K-FOLD CROSS VALIDATION



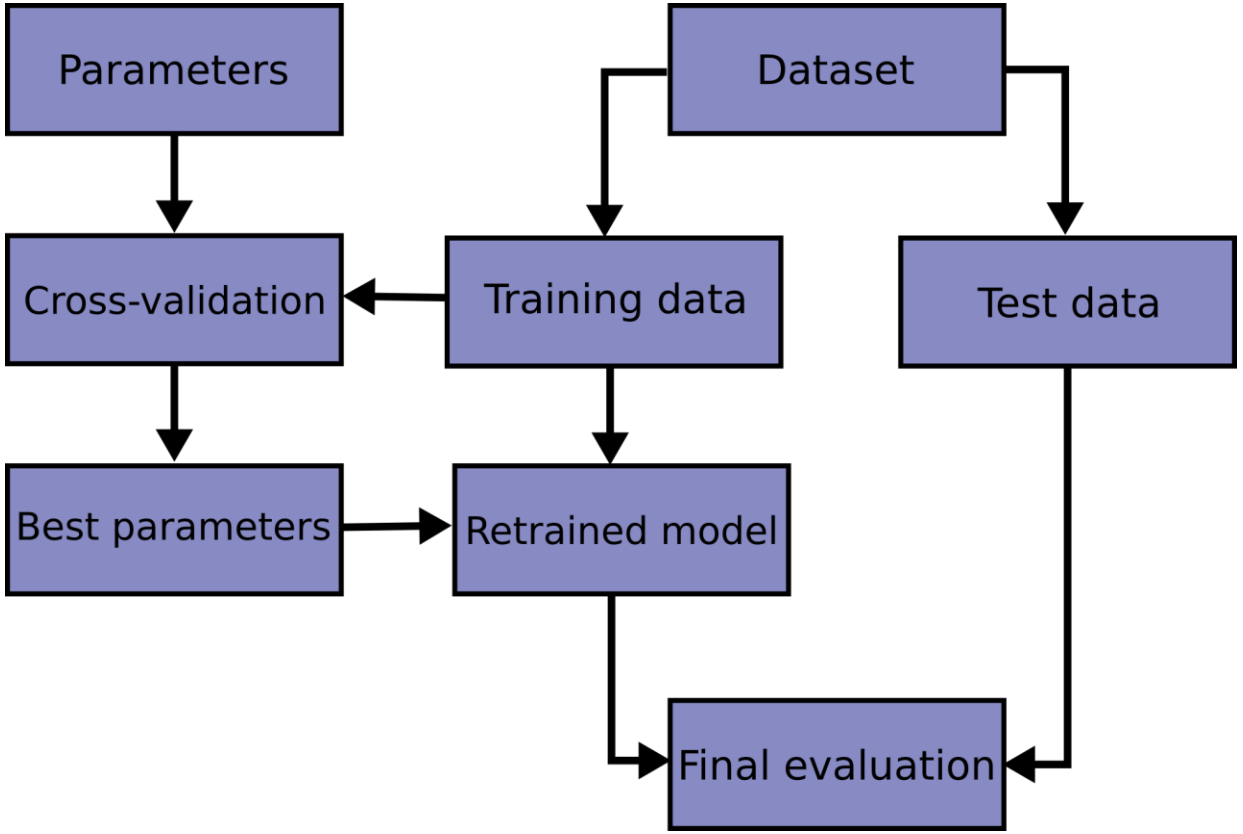
Train on all folds but one

Evaluate on last fold

Repeat with a different split

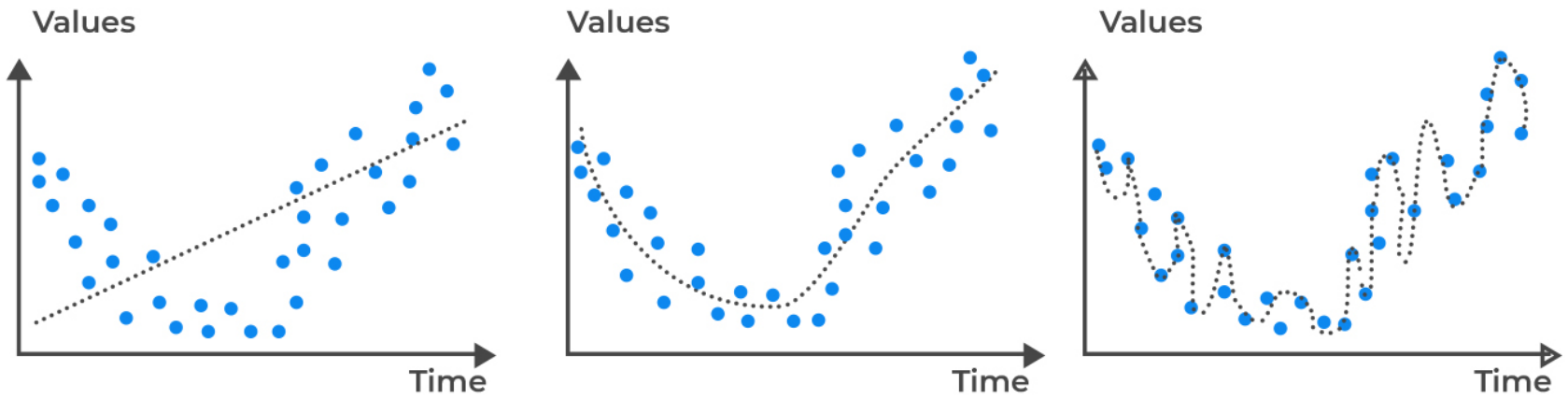
https://scikit-learn.org/stable/modules/cross_validation.html

SUPERVISED LEARNING PIPELINE



https://scikit-learn.org/stable/modules/cross_validation.html

UNDER/OVER FITTING



Underfitted

(High bias error)

Good Fit/Robust

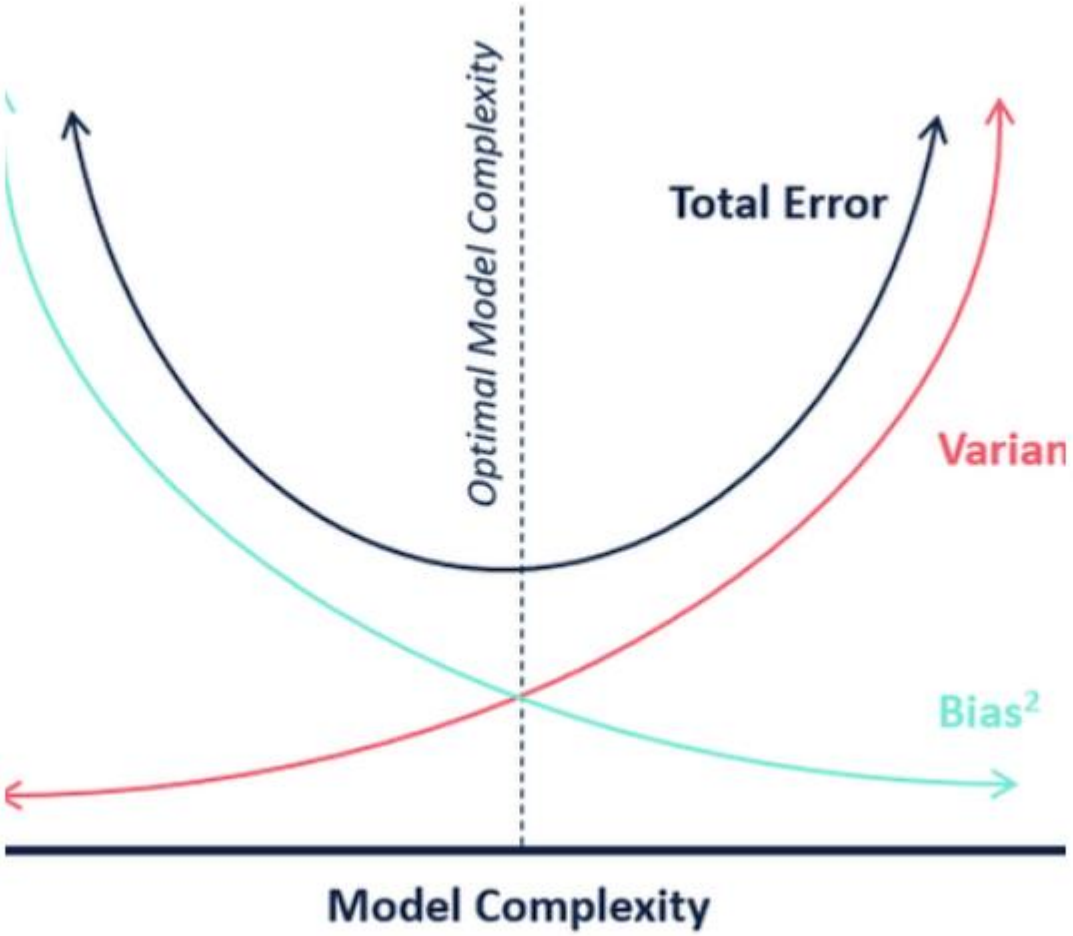
(Balance between bias and variance)

Overfitted

(High variance error)

https://analystprep.com/study-notes/cfa-level-2/quantitative-method/overfitting-methods-addressing/

BIAS-VARIANCE TRADEOFF



https://www.analyticsvidhya.com/blog/2020/08/bias-and-variance-tradeoff-machine-learning/

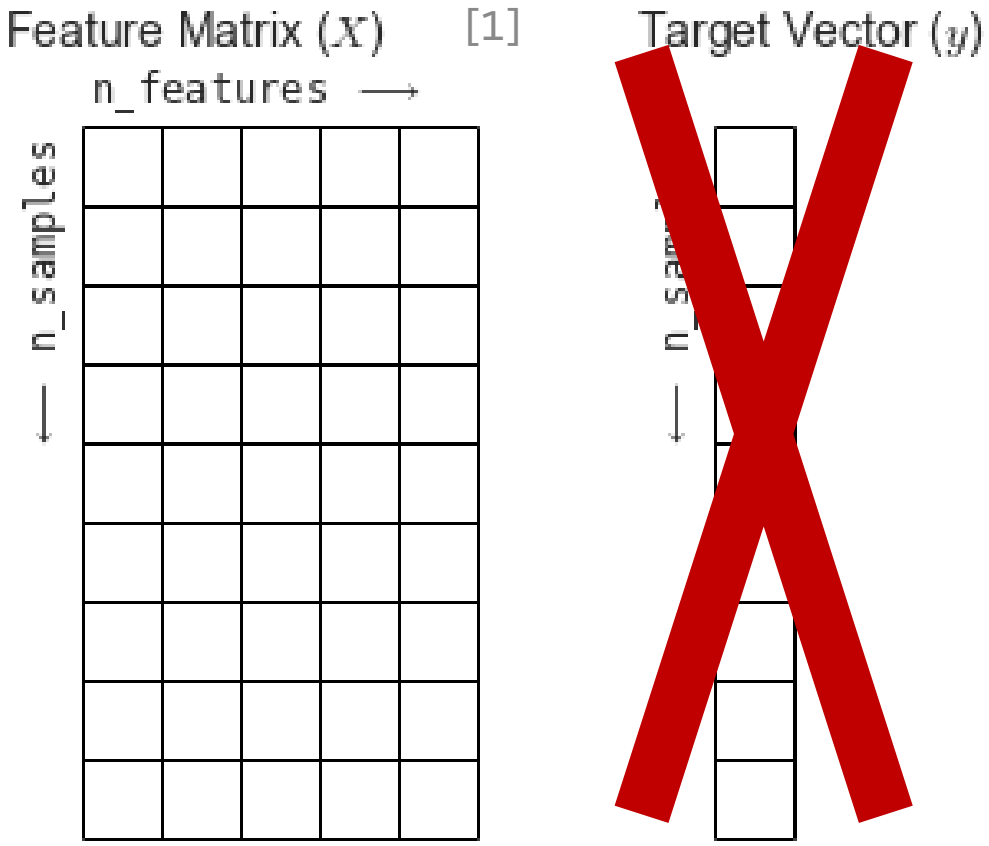
WORKSHOP

UNSUPERVISED LEARNING

THOUGHT EXERCISE

What is the correct grouping of these pictures?

UNSUPERVISED SETTING

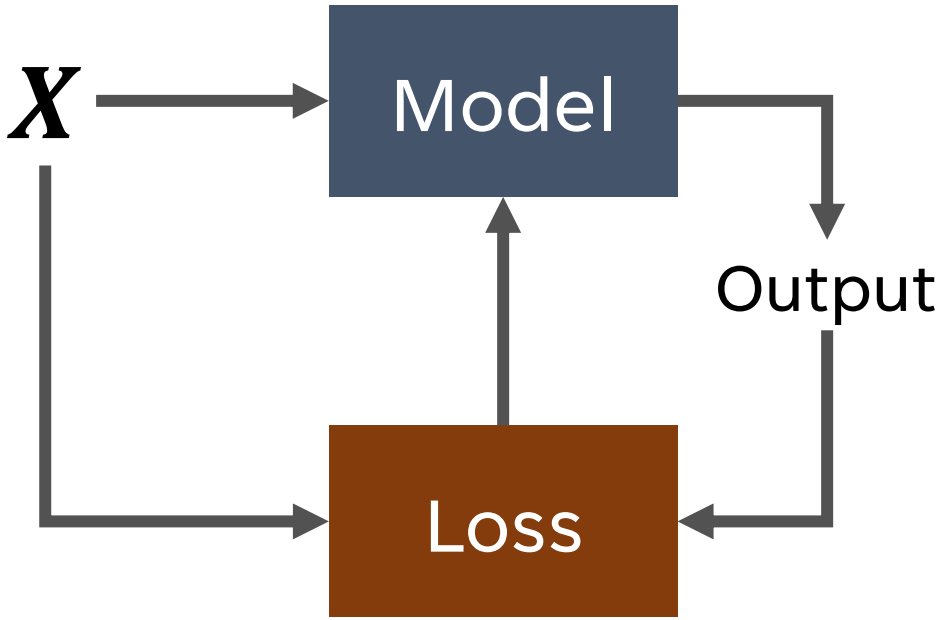


There are no “targets”

Unsupervised Learning = Finding patterns in the features

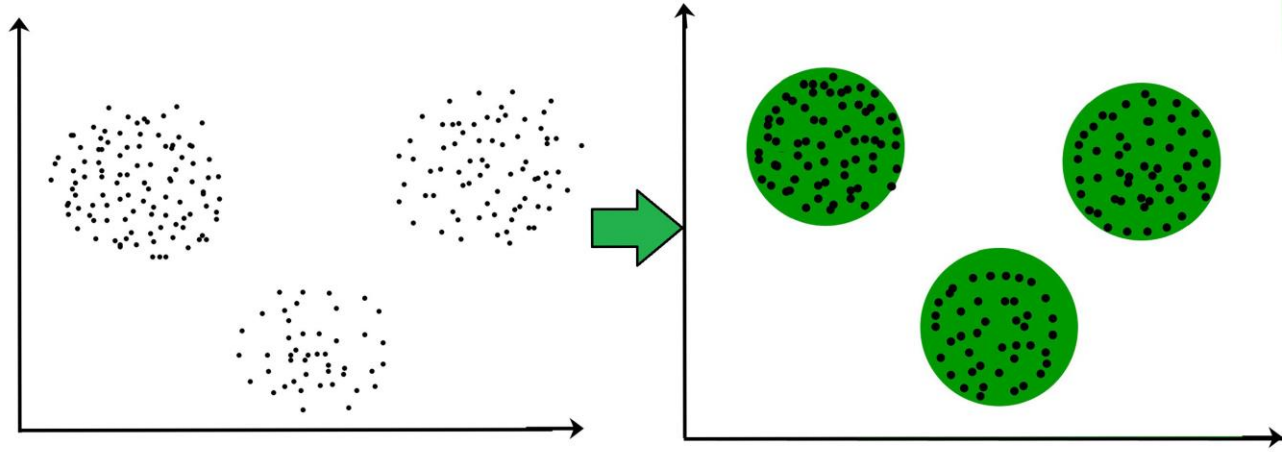
[1] Python Data Science Notebook – Introduction to Sci-Kit Learn – Jake Vanderplas

TRAINING A MODEL



- Loss is defined only by input points and model output
- No True Labels

CLUSTERING



Find Groups in the data

Creating teams based on personality scores and skills

Identifying customer profile groups

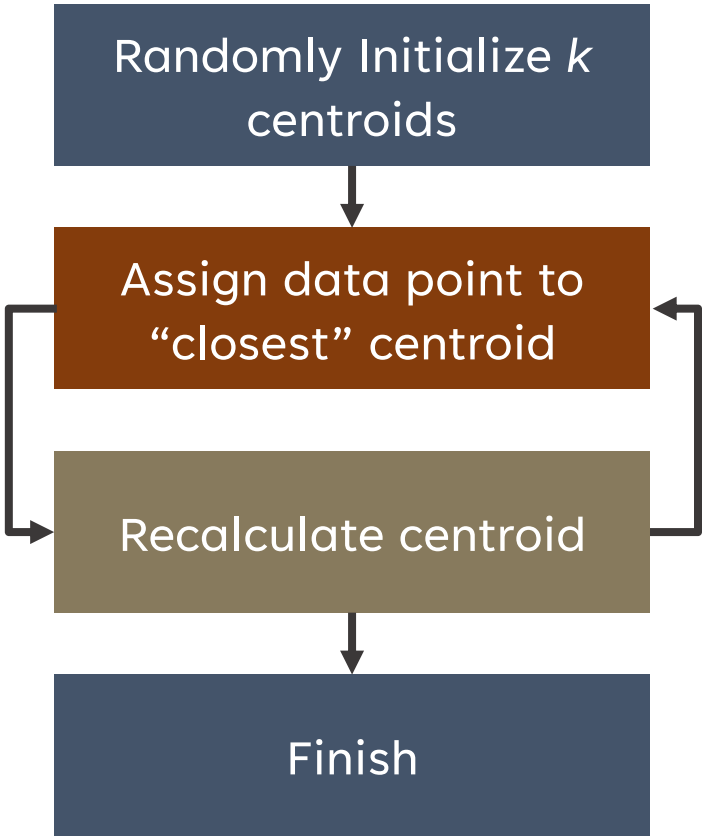
EXAMPLE: K-MEANS CLUSTERING

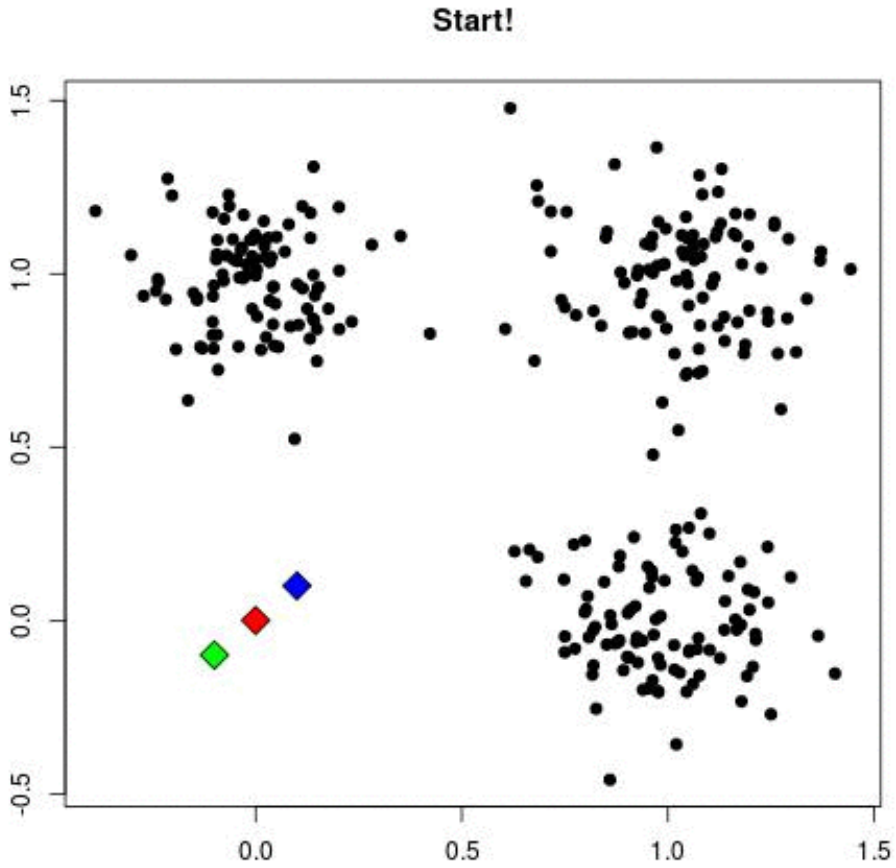
Goal: Group the datapoints into K Clusters

$$\text{Minimize } \frac{1}{n}\sum\sum w_{i,k}\|x_i - z_k\|^2$$

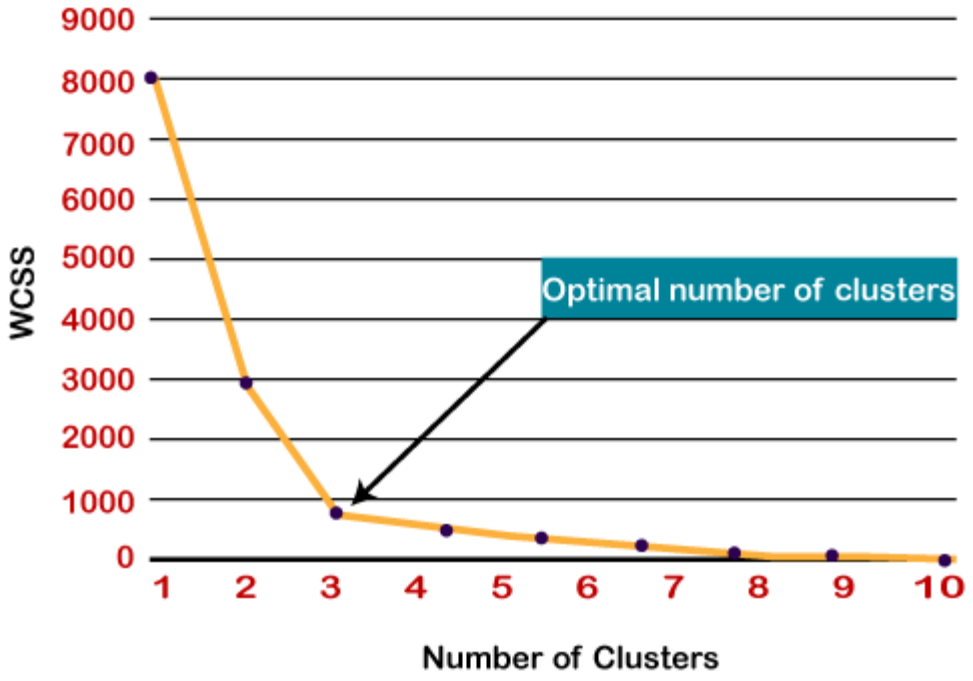
- $w_{i,k}$: is point *i* in cluster *k*
- z_k: Average of all points in cluster *k* (centroid)

EXAMPLE: K-MEANS CLUSTERING



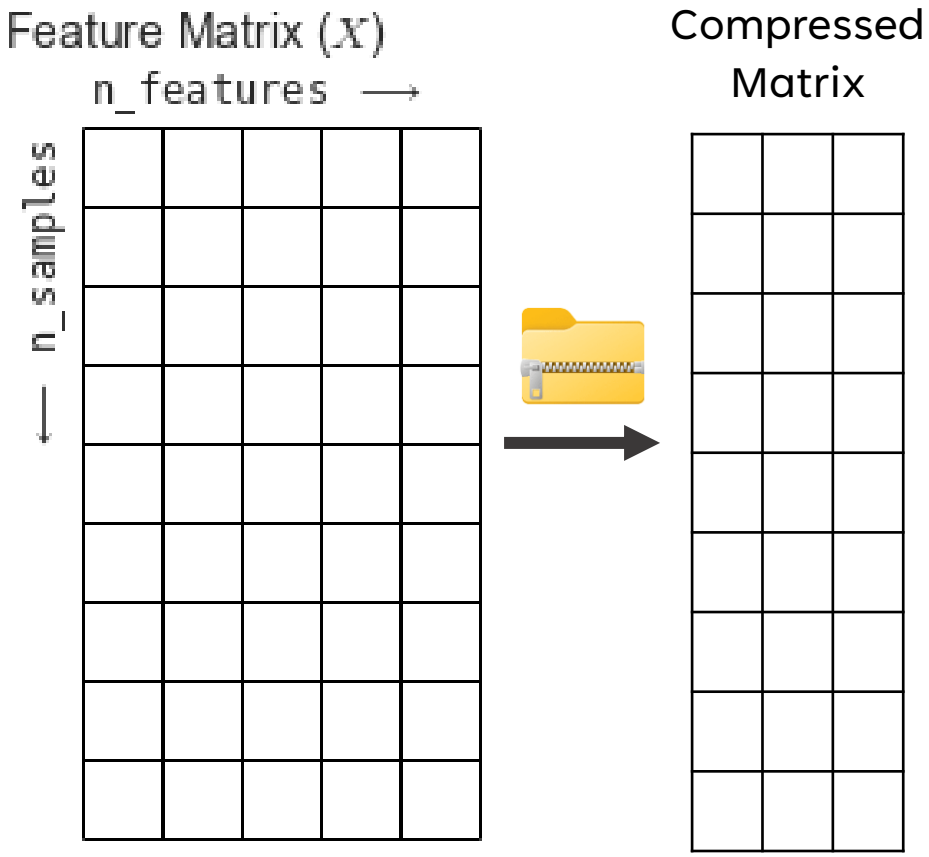


EXAMPLE: K-MEANS CLUSTERING



- Test different number of clusters and plot inertia
- Find the “elbow”

DIMENSIONALITY REDUCTION

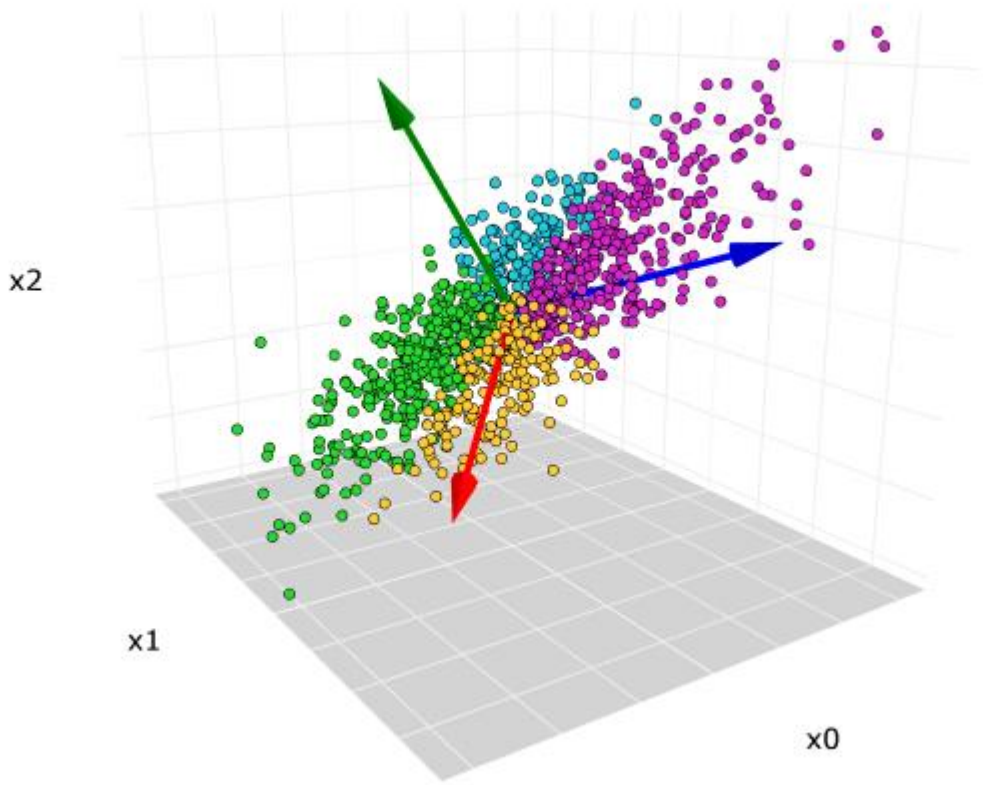


Find Groups in the data

Creating teams based on personality scores and skills

Identifying customer profile groups

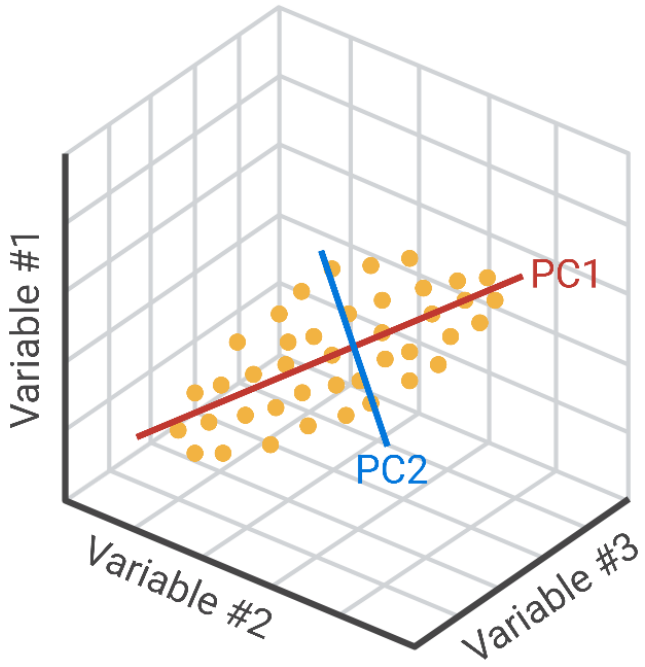
EXAMPLE: PCA



- Find the “components” that capture the most variance in the data
- N_Components <= N_Features

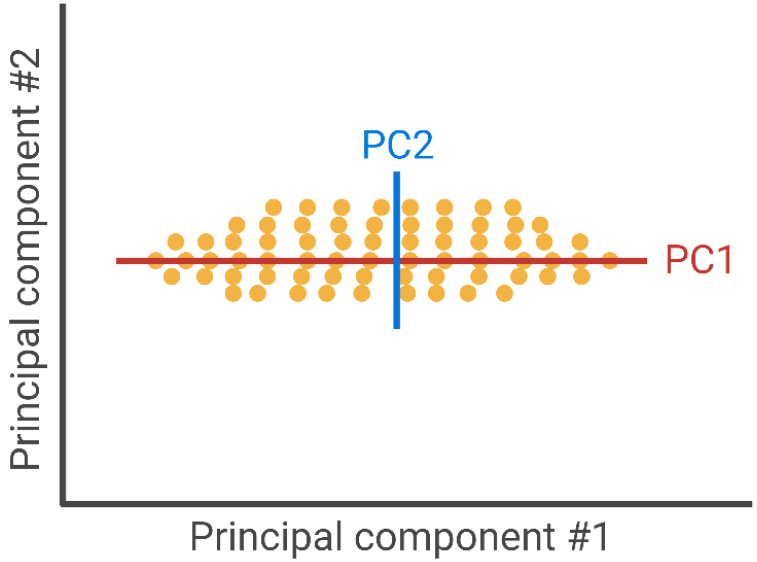
EXAMPLE: PCA

Original data (high-dimensions)



PCA dimensionality reduction

Lower-dimensional embedding



- Maximize variance along PC1
- Minimize residuals along PC2

WORKSHOP