

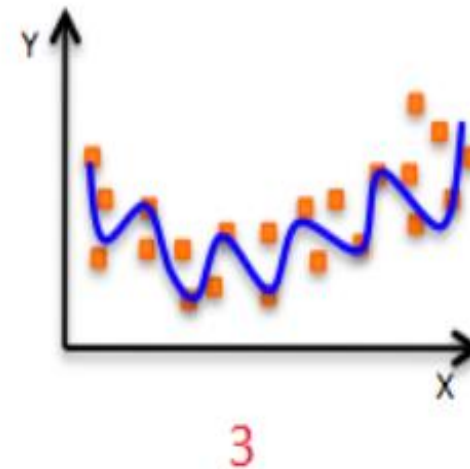
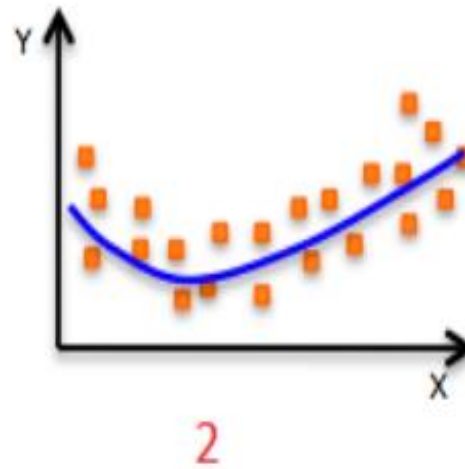
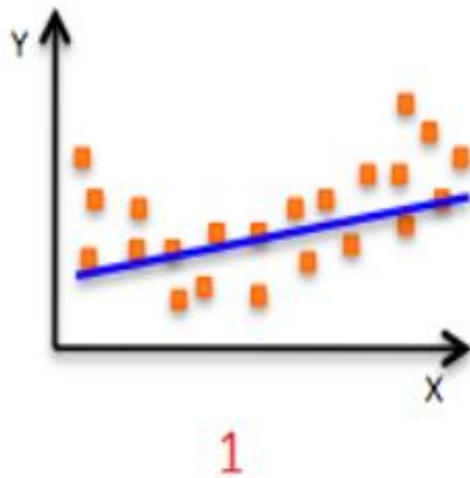
Modul 3

Supervised Learning 1

Data Science Program

Regression Overview

Which one is your preference?



Regression Overview

OVERFITTING

- Fits the data too well
- Too complex
- High variance, low bias
- Learns noise in training data

Solutions:

- ✓ Reduce number of features
- ✓ Increase training samples

Question: How do we know that our model is overfitting or underfittinh?

UNDERFITTING

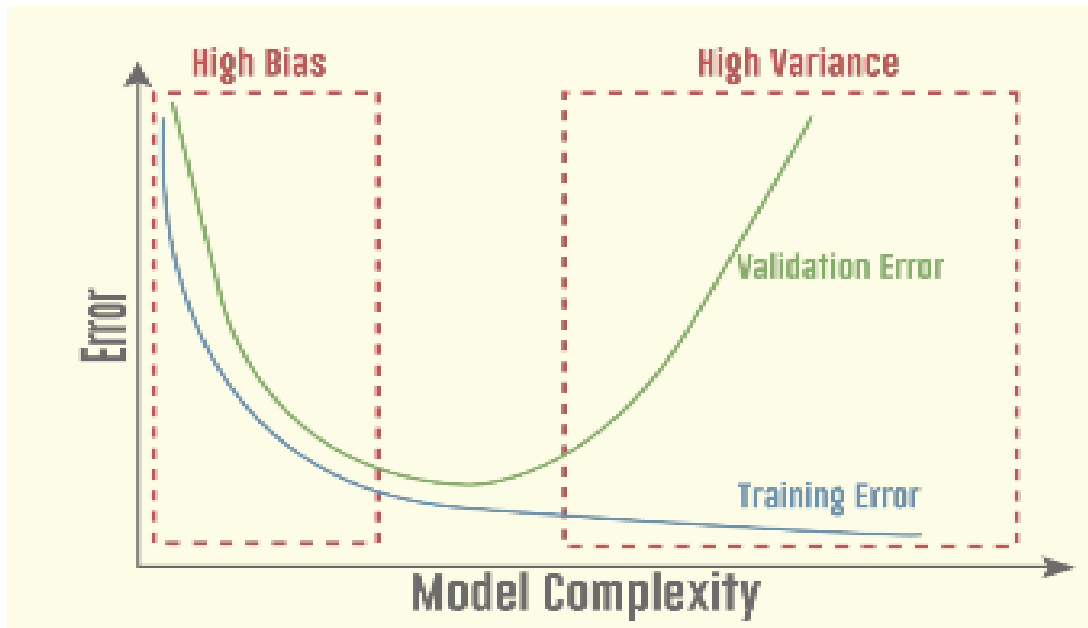
- Simple model
- High bias, low variance
- Doesn't capture underlying data trend

Solutions:

- ✓ Train more complex model
- ✓ Obtain more features

How can you know whether model has High Bias or High Variance ?

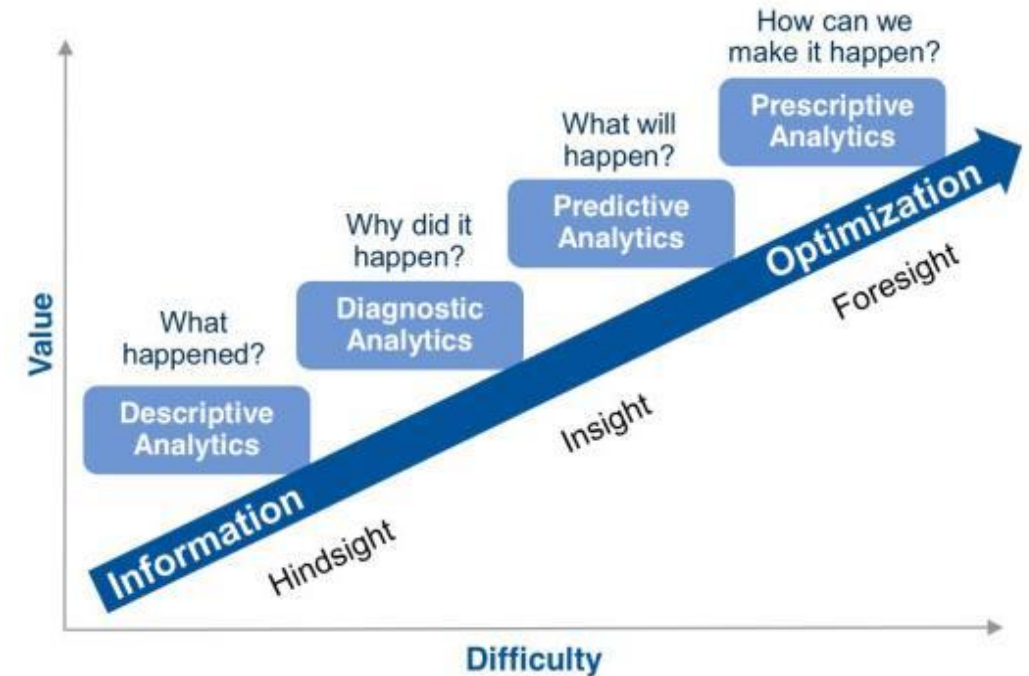
- High Training Set Error and High Validation Set Error ->
 - High Bias (Underfitting)
- Low Training Set Error and High Validation Set Error ->
 - High Variance (Overfitting)



Data Analysis

Types of Data Analysis

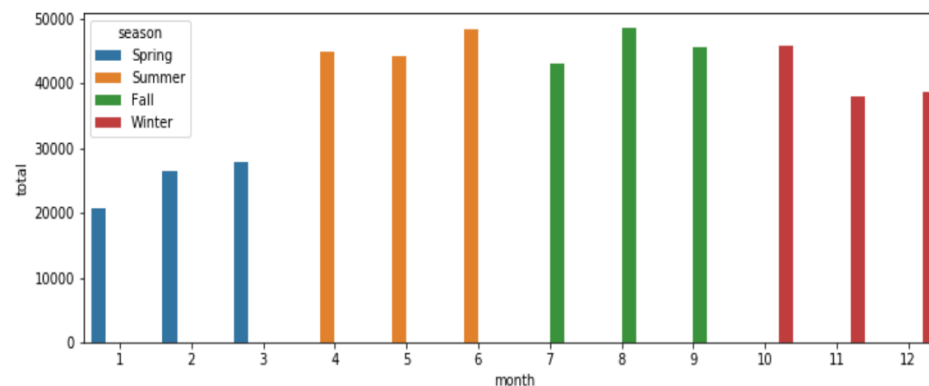
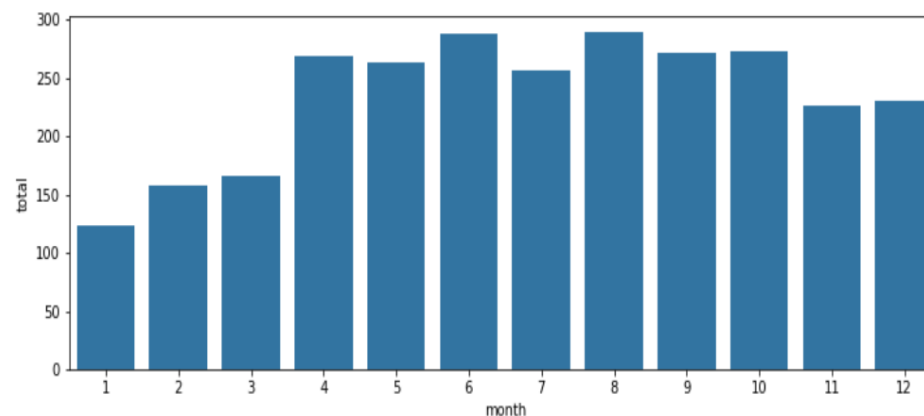
- **Descriptive** (BI, Data mining)
Understand historical data.
Look for reasons behind past success/failures.
- **Predictive** (Forecasting)
Determine probable future outcome.
- **Prescriptive** (Optimization)
Goes beyond predicting future outcome.
Suggest action to benefit from prediction.



GOAL : Get actionable insights, smarter decision, better business outcomes

Descriptive Analytics

Bike Sharing usage
In Washington DC



Usage peaks during Summer and Fall

Predictive Modeling

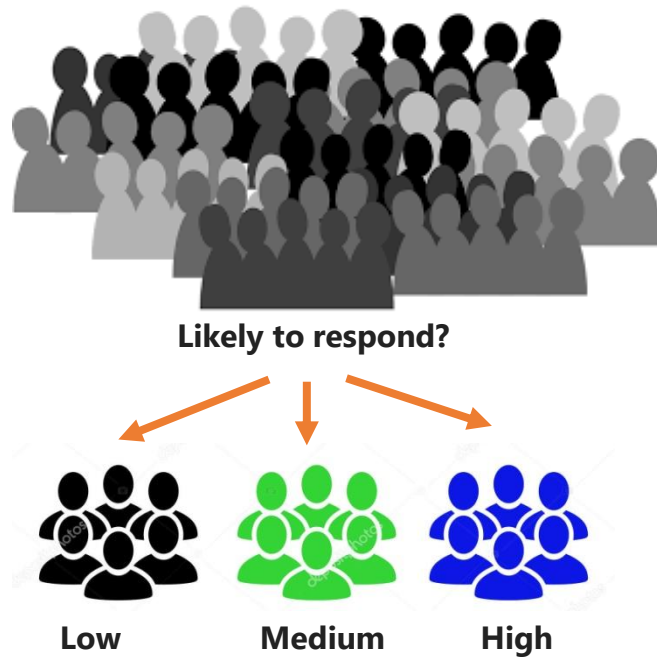


Churn Analysis



Credit Scoring

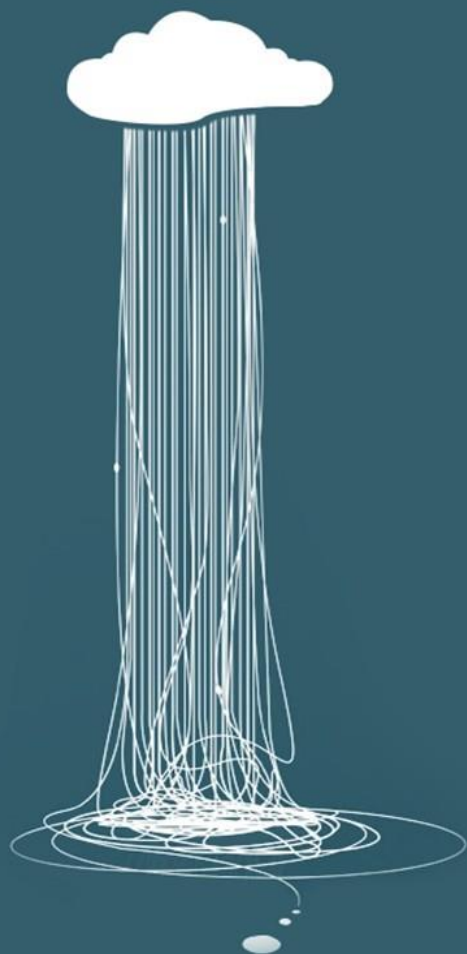
Predictive Modeling



Propensity Analysis



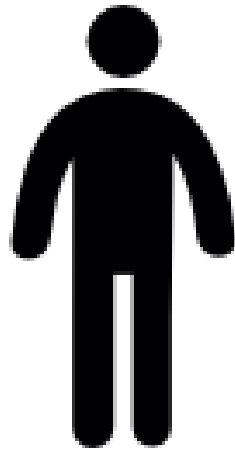
Human Resources
"The Rising Star"



Will this evening be raining?

Machine Learning

What's the difference between **Human** and **Computer**?



Learn from experience

VS

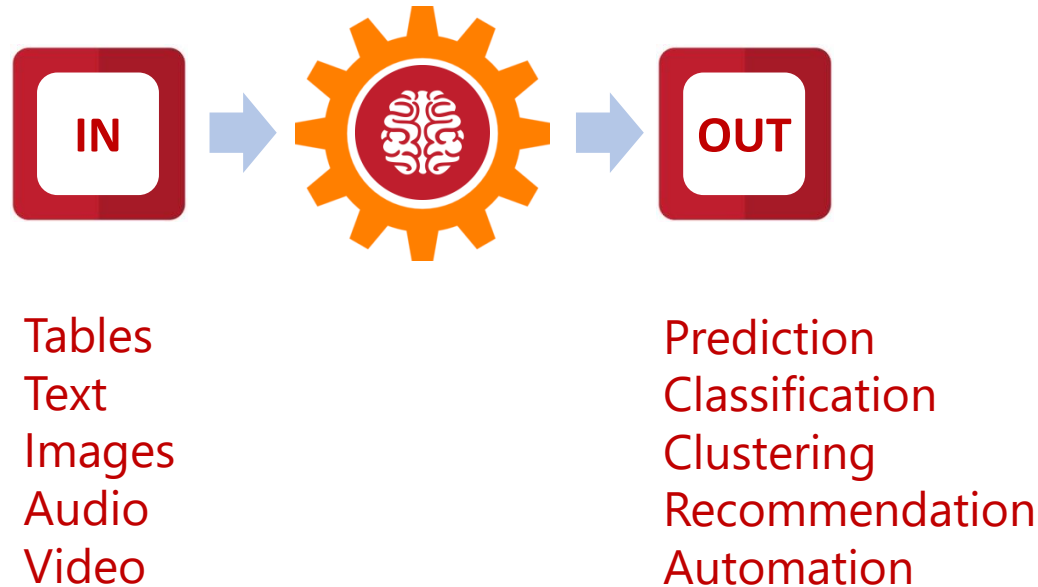


Follow instruction

Learn from ~~experience~~ data

Machine Learning

Technique to give computers ability to **learn from data** without explicitly programmed



More Applications:

- Recommendation system
- Shopping basket analysis
- Decision making for self-driving cars

What is not Machine Learning?

- Calculating average
- Most occurring events
- Calculate highest grade

Illustration



\$10.99 ~~\$199.99~~

★★★★★ 4.3
(502 ratings)



The Complete Machine Learning Course with Python

Frequently Bought Together



The Complete Machine Learning Course with...

Codestars by Rob Percival, Anth...

★★★★★ 4.3 (508)

~~\$199.99~~



Machine Learning with TensorFlow + Real-Life...

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Durable Selimut Mobil Car Body Cover For Daihatsu Ayla

Barang Terkait



Durable Selimut Mobil Car Body Cover For Daihatsu Terios &

Rp542.000

Cicilan mulai 45rb/bln



★★★★★ 1 ulasan

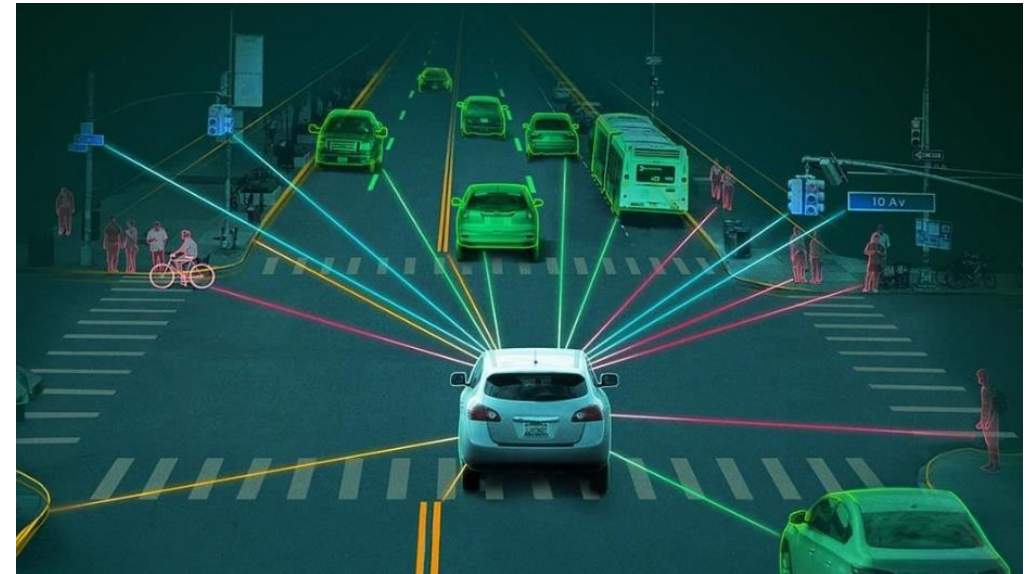
Cover Mobil Daihatsu Ayla

Rp650.000

Cicilan mulai 54rb/bln

Illustration

What self driving cars see

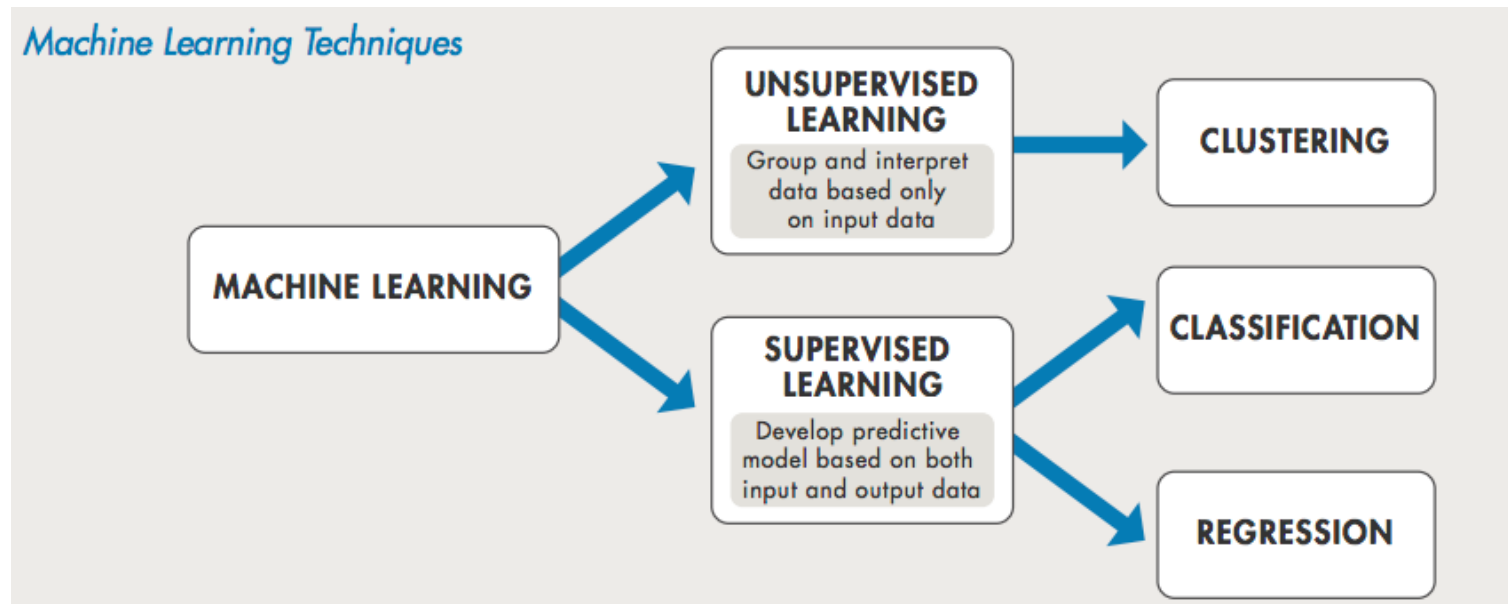


Left: <http://fortune.com/2015/10/16/how-tesla-autopilot-learns/>

Right: <https://driverless.wonderhowto.com/news/multi-cores-ai-computer-parallelism-gaming-chips-drive-cars-0178965/>

Techniques

Some call it Machine Learning Algorithm



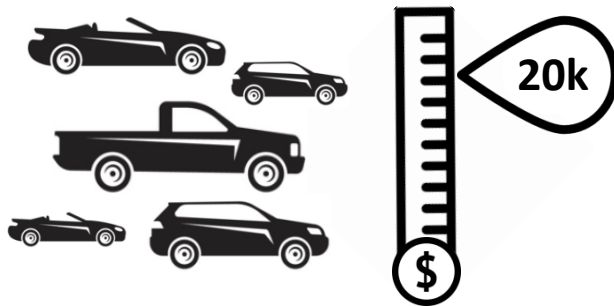
Unsupervised Learning: Do not have target variable to estimate / predict.

Supervised Learning: Generate function that **map** inputs to desired outputs.

Applications

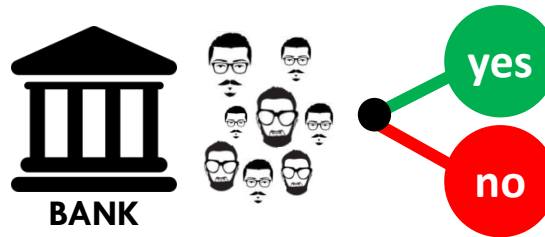
REGRESSION

PREDICT VALUE



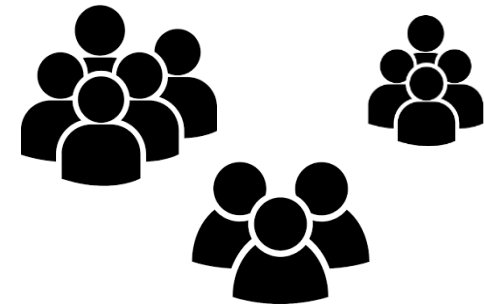
CLASSIFICATION

PREDICT CATEGORY




CLUSTERING

GROUP OBJECT



Illustration

▪ Regression


BRAND	TYPE	CYLINDER	ENG-SIZE	STROKE	MAX-RPM		PRICE
Brand-A	sedan	four	109	3.4	5500	 $f(x)$	13950
Brand-A	sedan	five	136	3.4	5500		17450
Brand-B	sedan	four	108	2.8	5800		16430
Brand-B	sedan	four	108	2.8	5800		16925
Brand-C	hatchback	three	61	3.03	5100		5151
Brand-C	hatchback	four	90	3.11	5400		6295
Brand-D	hatchback	four	90	3.23	5500		5572
Brand-D	hatchback	four	90	3.23	5500		6377

Input
Predictor
Independent Var
X

Output
Response
Dependent Var
Y

Illustration

▪ Classification

BRAND	TYPE	CYLINDER	ENG-SIZE	STROKE	MAX-RPM		RISK
Brand-A	sedan	four	109	3.4	5500	 $f(x)$	POS
Brand-A	sedan	five	136	3.4	5500		POS
Brand-B	sedan	four	108	2.8	5800		POS
Brand-B	sedan	four	108	2.8	5800		POS
Brand-C	hatchback	three	61	3.03	5100		NEG
Brand-C	hatchback	four	90	3.11	5400		NEG
Brand-D	hatchback	four	90	3.23	5500		NEG
Brand-D	hatchback	four	90	3.23	5500		NEG

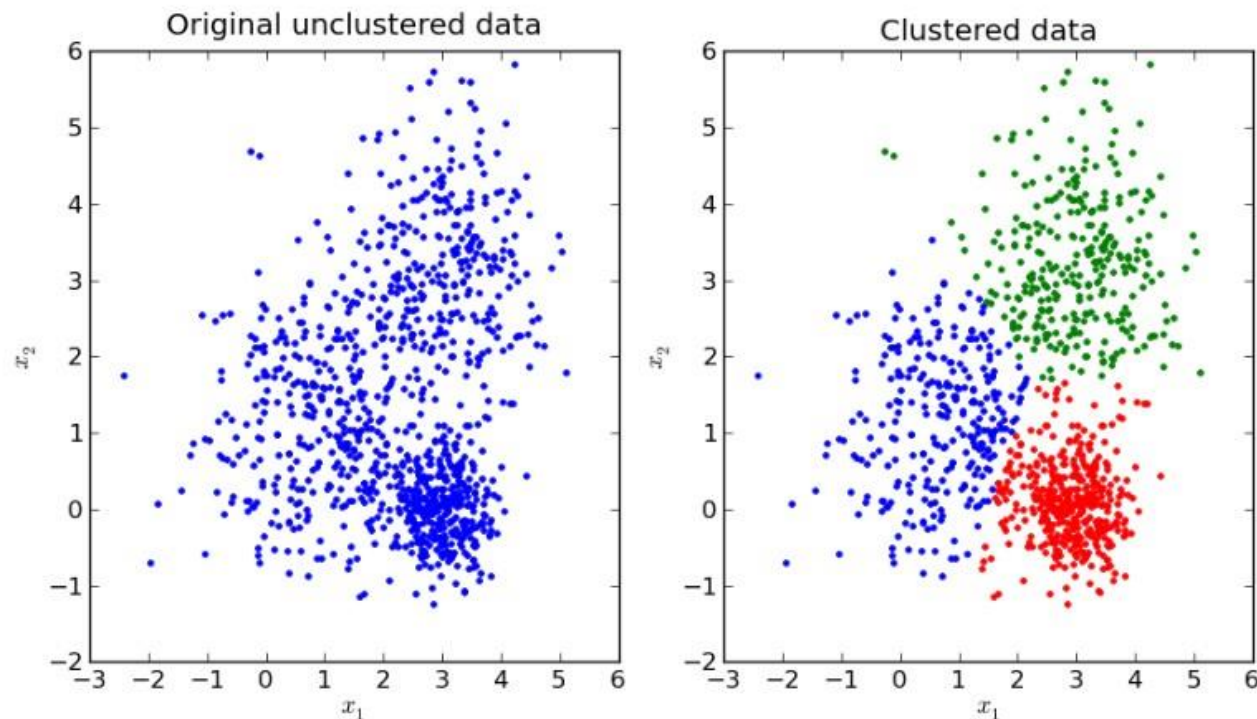
Input
Predictor
Independent Var
X

Output
Response
Dependent Var
Y

Illustration

- Clustering

Input
Predictor
Independent Var
 X



Predictive Model

Today we're focusing on two predictive Models

- Logistic Regression
- Decision Tree

Note:

Other models: Discriminant Analysis, K-Nearest Neighbour (KNN), Support Vector Machine (SVM), Ensemble – Bagging, Random Forest, Boosting, etc

Logistic Regression - Why not Linear Model?

Simple Linear Model

$$y = \alpha + \beta x + \varepsilon$$

where,

y: Dependent variable (continuous)

x: Independent variable

Why can't we use Linear Regression to model binary responses?

- Model must produce predicted probability that are between 0 and 1
- Linear model produces dependent that vary from $-\infty$ to $+\infty$
- Dependent variable (y) is not normally distributed
- Variability of dependent variable (y) is not constant

GLM – Generalized Linear Model

- **GLM** is a **flexible generalization of ordinary linear regression** that allows for dependent variables that have **error distribution models other than a normal distribution**.
- GLM generalizes linear regression by allowing the linear model to be related to the dependent variable via a ***link function***

$$g(E(y)) = \alpha + \beta x + \varepsilon$$

$g()$ is the *link function*

Link function relates the **expected value of the dependent** to the **linear predictors**

GLM – Generalized Linear Model

- In logistic regression, expected value of response is probability of ‘**success**’ event to occur.
 - ‘Success’ $\rightarrow Y=1$. $P(\text{‘Success’} \mid x) = \pi(x)$
 - ‘Failure’ $\rightarrow Y=0$. $P(\text{‘Failure’} \mid x) = 1 - \pi(x)$
- Link function relates **expected value** of the response to the **linear predictor**.
- Link function for Logistic Regression is **Logit**

$$\text{logit}[\pi(x)] = \ln \left[\frac{\pi(x)}{1 - \pi(x)} \right] = \alpha + \beta x$$

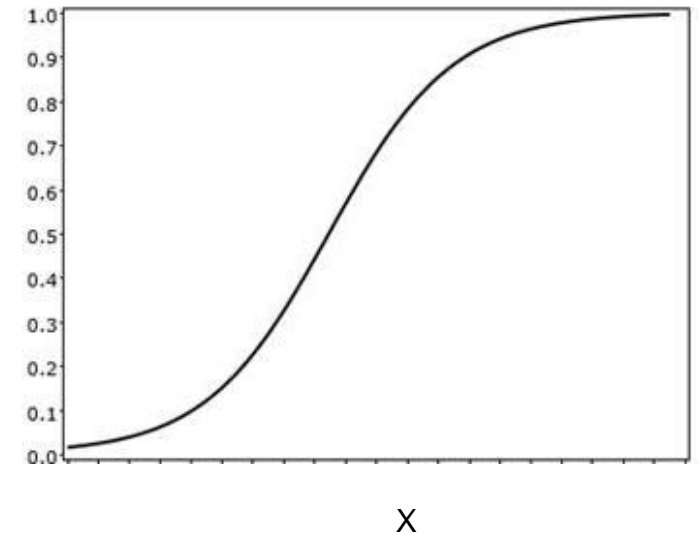
Logistic Regression Model

$$\text{logit}[\pi(x)] = \log \left[\frac{\pi(x)}{1-\pi(x)} \right] = \alpha + \beta x$$



$$\pi(x) = \frac{\exp(\alpha + \beta x)}{1 + \exp(\alpha + \beta x)}$$

$$P(\text{'Success'}|X)$$
$$\pi(x) = \frac{\exp(\alpha + \beta x)}{1 + \exp(\alpha + \beta x)}$$



- With logit link function, $\pi(x)$ varies between 0 and 1
- Value of α and β is obtained using Maximum Likelihood Estimation (MLE). Different to Linear regression which using Ordinary Least Square (OLS)
- MLE link : https://en.wikipedia.org/wiki/Maximum_likelihood_estimation

Assumptions

- Doesn't need linear relationship between dependent and independent variables. However it assumes **linear relationship** between **link function** and **independent variable** in logit model.
- Error / residuals do not need to be normally distributed
- Homoscedasticity is not required
- Binary logistic regression requires dependent variable to be binary. While ordinal logistic regression requires dependent variable to be ordinal
- Observation to be independent of each other. Not a repeated measurement.
- Requires no or only little of multicollinearity among independent variables.
- Requires large sample data for stable result. Complex issue, but refer to work by Peduzzi *et al.* (1996), minimum sample is $N = 10 k / p$, where k is number of independent variables and p is the smallest proportion of dependent variable. If result is < 100 , then make it 100 at the minimum. Long (1997)

Encoding Categorical Var

- There are ML algorithms that supports categorical value without further manipulation, but there are also algorithms that do not.
- Need to turn categorical value into numerical value
- *One Hot Encoding*: Process by which categorical variables are converted into form that could be accepted by ML algorithm.
- Pandas support encoding using *get_dummies*. It creates dummy variables.

Sample	Category	Numerical
1	Human	1
2	Human	1
3	Penguin	2
4	Octopus	3
5	Alien	4
6	Octopus	3
7	Alien	4



One
Hot
Encoder

Sample	Human	Penguin	Octopus	Alien
1	1	0	0	0
2	1	0	0	0
3	0	1	0	0
4	0	0	1	0
5	0	0	0	1
6	0	0	1	0
7	0	0	0	1

Model Evaluation

▪ Confusion Matrix

NxN matrix where N is the number of classes being predicted. Some definitions:

- **Accuracy** : Proportion of total number of predictions that were correct
- **Precision** (Positive Predictive Value) : Proportion of positive cases that were correctly identified.
- **Negative Predictive Value** : Proportion of negative cases that were correctly identified.
- **Sensitivity (Recall)** : Proportion of actual positive cases which are correctly identified.
- **Specificity** : Proportion of actual negative cases which are correctly identified.

		Predicted	
		No	Yes
Actual	No	TN	FP
	Yes	FN	TP

TN True Negative
FP False Positive
FN False Negative
TP True Positive

Model Performance

Accuracy $= (TN+TP)/(TN+FP+FN+TP)$

Precision $= TP/(FP+TP)$

Sensitivity $= TP/(TP+FN)$

Specificity $= TN/(TN+FP)$

Model Evaluation

Accuracy : Proportion of total number of predictions that were correct

		Predicted	
		No	Yes
Actual	No	TN	FP
	Yes	FN	TP

$$\text{Accuracy (Correct Rate)} = (\text{TP} + \text{TN}) / N$$

Model Evaluation

Sensitivity : Proportion of total number of predictions that were correct

		Predicted	
		No	Yes
Actual	No	TN	FP
	Yes	FN	TP

$$\text{Sensitivity} = \text{TP} / (\text{TP} + \text{FN})$$

Model Evaluation

Specificity : Proportion of actual negative cases which are correctly identified

		Predicted	
		No	Yes
Actual	No	TN	FP
	Yes	FN	TP

$$\text{Specificity} = \text{TN} / (\text{TN} + \text{FP})$$

Imbalanced Classification

- It is scenario where the number of observations belonging to one class is **significantly lower** than those belonging to the other class.
- Example: Fraud case, Rare disease identification, Customer Default
- In this situation, predictive model result could be inaccurate.
- ML algorithm are usually designed to improve accuracy by reducing error. They don't take into account class distribution. The model works better in the majority class.
- Handling: Resample, Use advance ML algorithm

Illustration:

Total observation : 1000

Fraud event : 50

Non-fraud event : 950

Event rate : 5%

Model Evaluation

▪ AUC - ROC

AUC : Area under curve

ROC : Receiver Operating Characteristic

Plot between True Positive Rate (TPR) and False Positive Rate (FPR) for different cut-off points.

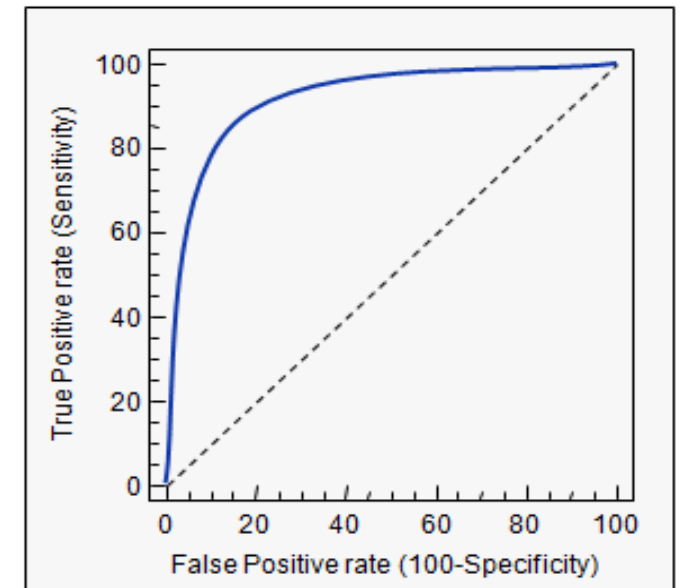
Y-axis : True Positive Rate = Sensitivity = Recall

X-axis : False Positive Rate = 1-Specificity

		Predicted	
		No	Yes
Actual	No	TN	FP
	Yes	FN	TP

Specificity = $TN / (TN + FP)$

Sensitivity = $TP / (TP + FN)$



Model Evaluation

How ROC is drawn?

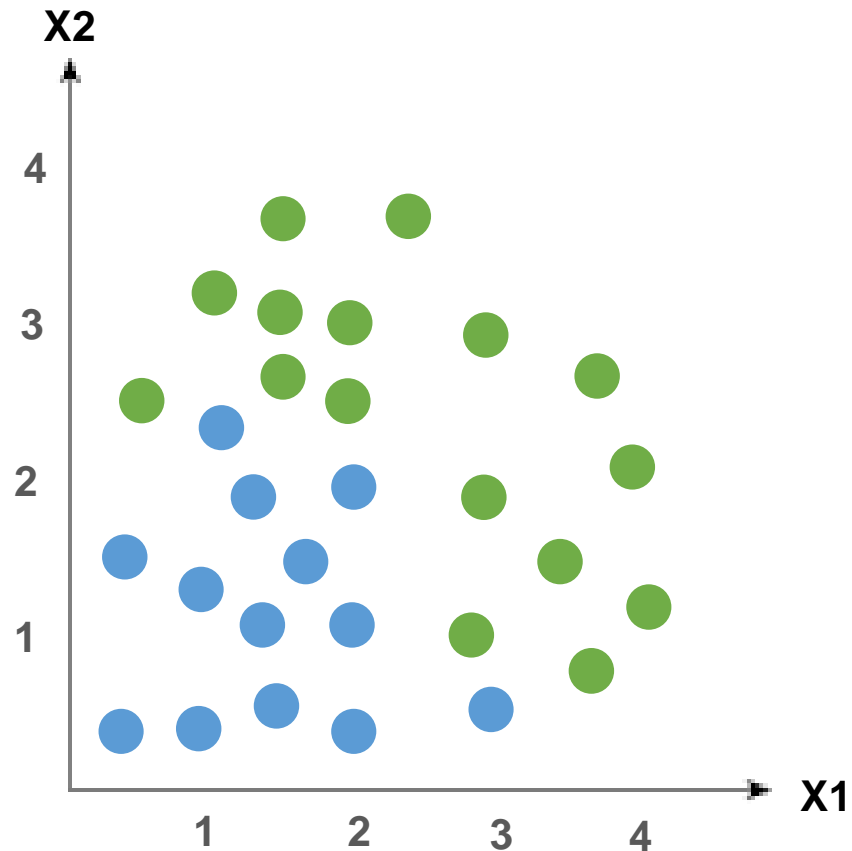
- Plot between True Positive Rate (TPR) and False Positive Rate (FPR) for different cut-off points.
- Suppose now you decrease this threshold level. Then there are chances that what were being earlier classified as zeros will be reclassified as ones

Interpretation guide

- The larger the AUC, the better the model
- ROC curve along diagonal is a random classification
- Model with ROC below diagonal has worse prediction than model which makes prediction randomly

Actual class	Model output	Predicted class (cut off 0.5)	Predicted class (cut off 0.45)
1	0.6	1	1
1	0.5	1	1
1	0.5	1	1
1	0.45	0	1
1	0.44	0	0
—	—	—	—
0	0.5	1	1
0	0.5	1	1
0	0.45	0	1
0	0.45	0	1
0	0.4	0	0
—	—	TPR=3/5, FPR=2/5	TPR=4/5, FPR=4/5

Decision Tree - Basic Idea

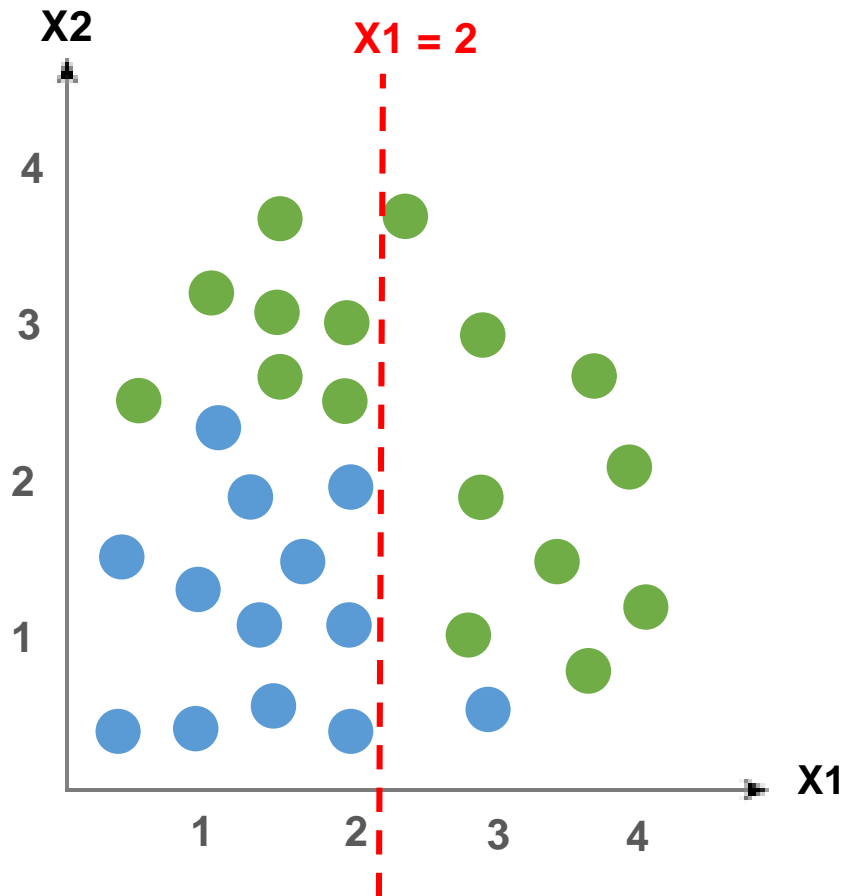


● 16 obs.

● 13 obs.

- Find the best splitter between ● & ●
- Best splitter is the one results most homogenous element in each class

Basic Idea



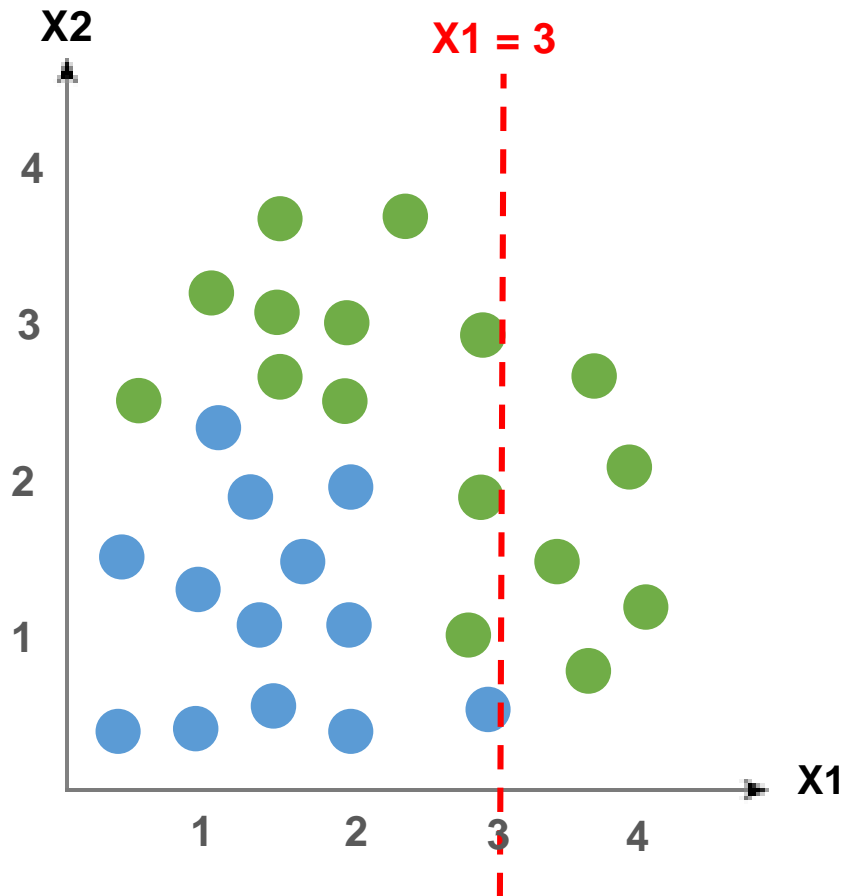
- Splitting at $X1 = 2$
- Split to 2 classes

Class $X1 < 2$ ● 7 obs.
 ● 12 obs.

Class $X1 > 2$ ● 9 obs.
 ● 1 obs.

How good is this split?

Basic Idea



- Splitting at $X1 = 3$
- Split to 2 classes

Class $X1 < 3$ ● 11 obs.
 ● 13 obs.

Class $X1 > 3$ ● 5 obs.
 ● 0 obs.

Is this split better?

Entropy

Given dataset D, consists of 2 class YES and NO.

Proportion of Yes is **p**, while proportion of No is **(1-p)**

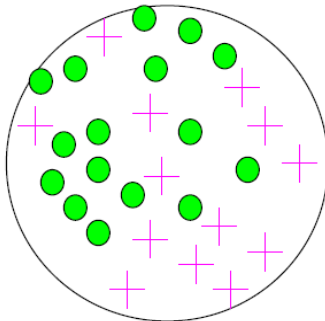
Entropy of the dataset:

$$D(E) = -p \cdot \log_2(p) - (1 - p) \cdot \log_2(1 - p)$$

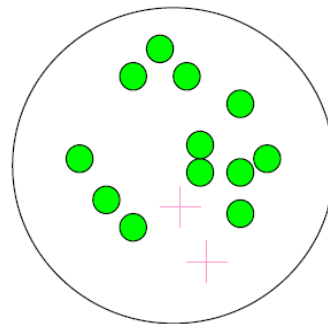
Dataset with all-YES or all-NO will have $D(E) = 0$.

Entropy is a measure of heterogeneity

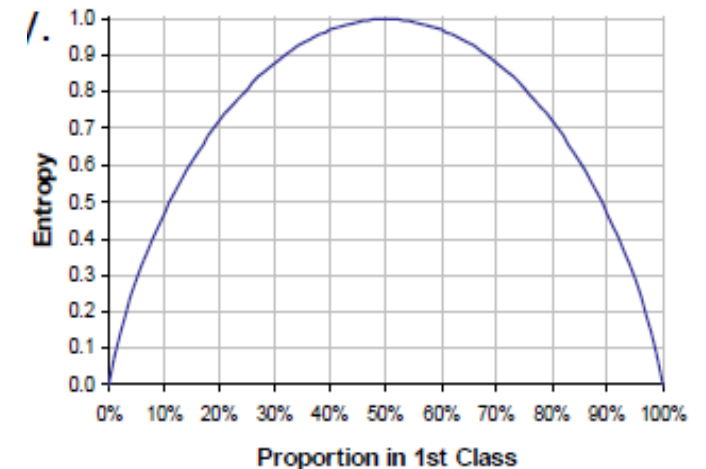
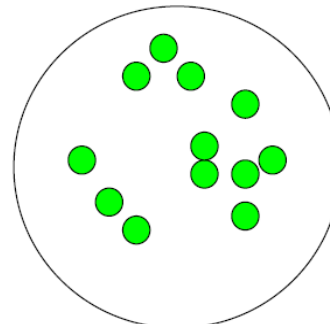
Very impure group



Less impure



Minimum impurity



Information Gain

- Let's say dataset D is split into several groups D1, D2, ... , Dk based on variable V.
- For every Di, Entropy can be calculated as E(Di)

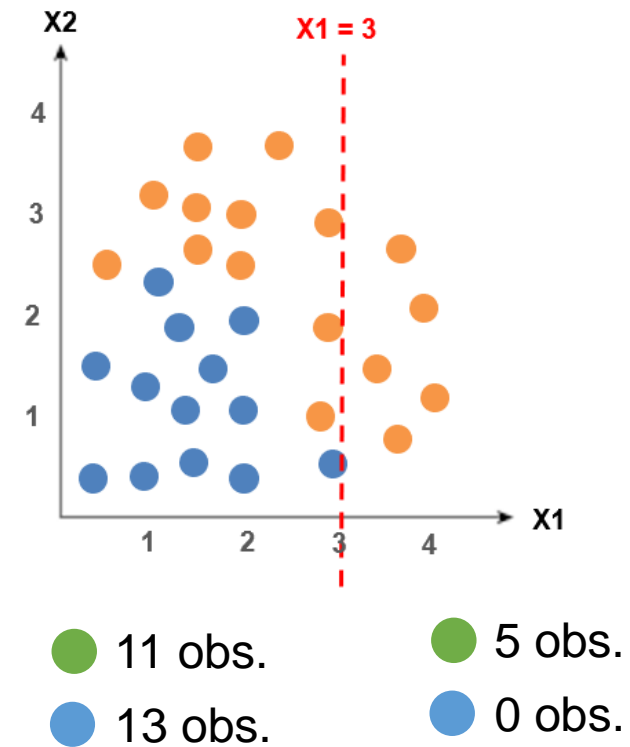
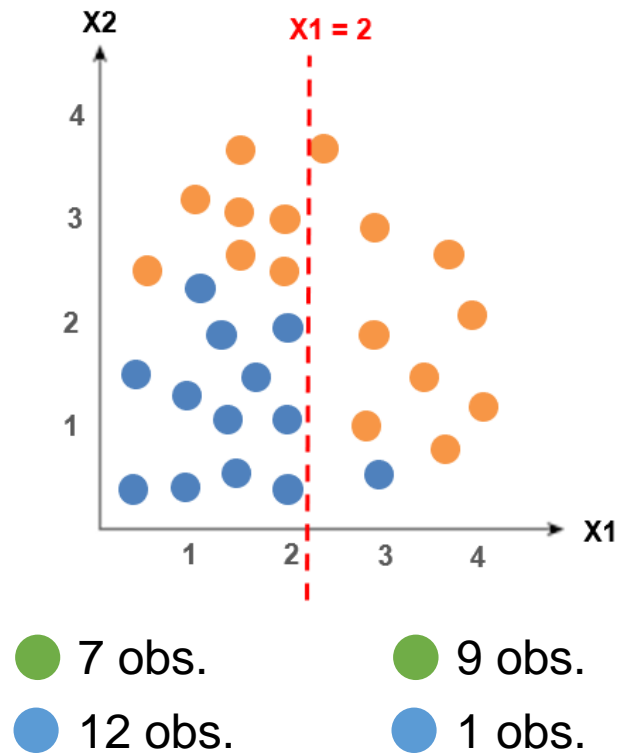
- Information Gain:

$$IG(D, V) = E(D) - \sum_{i=1}^k \frac{|D_i|}{|D|} E(D_i)$$

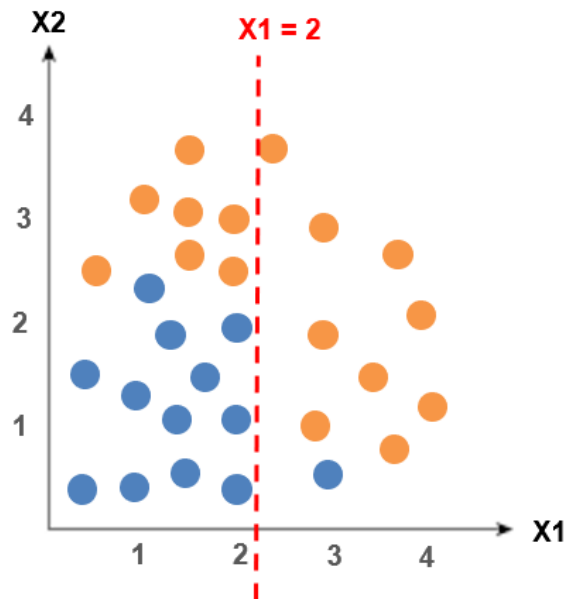
- More homogenous group will have higher Information Gain Value

Back to Basic Idea

Which one is better?

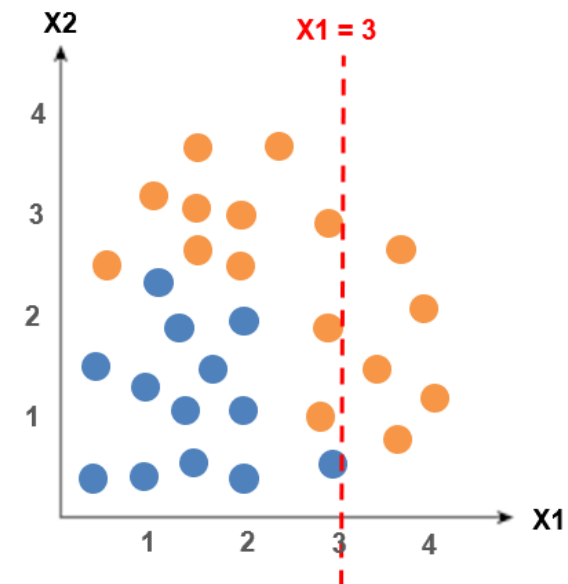


Basic Idea



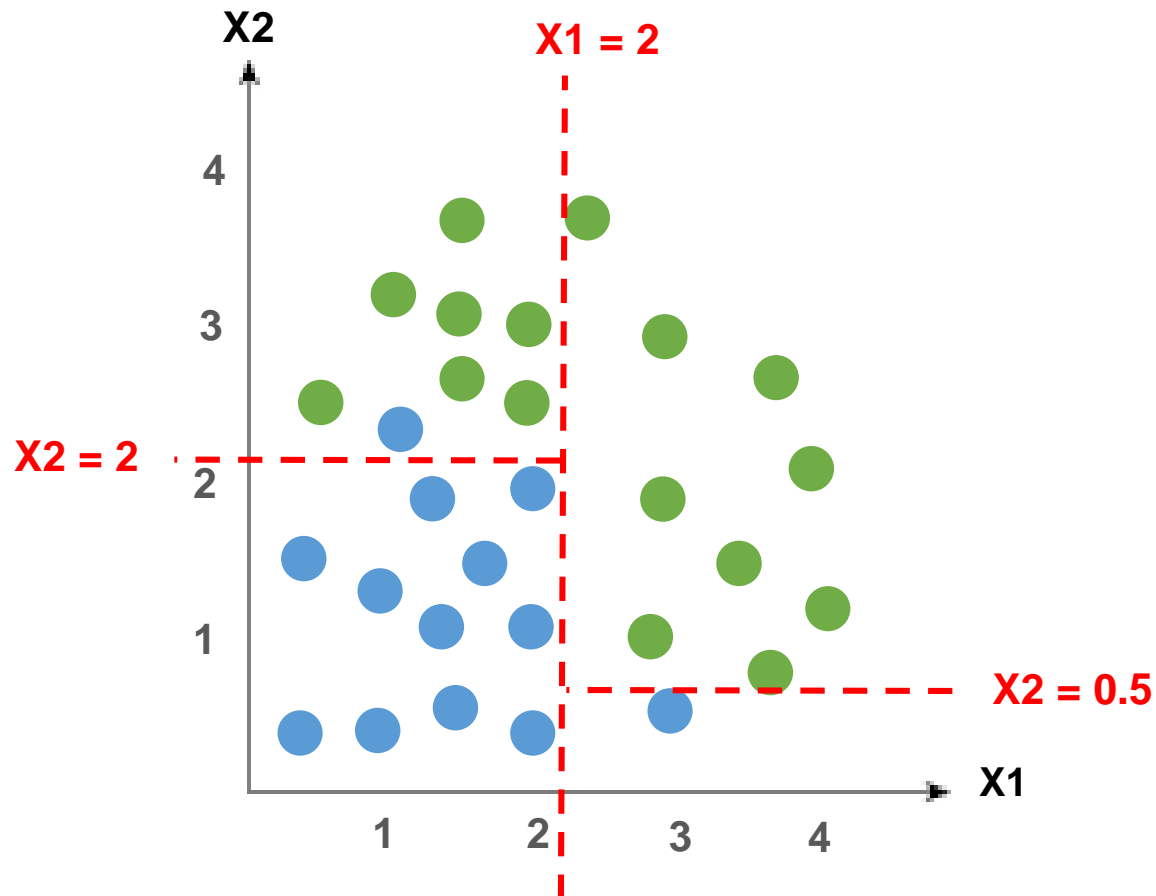
● 16 obs.
● 13 obs.
 $E = 0.99$

● 7 obs. ● 9 obs.
● 12 obs. ● 1 obs.
 $E = 0.95$ $E = 0.47$
 $IG = 0.21$



● 11 obs. ● 5 obs.
● 13 obs. ● 0 obs.
 $E = 0.99$ $E = 0$
 $IG = 0.17$

Basic Idea – Continue Splitting

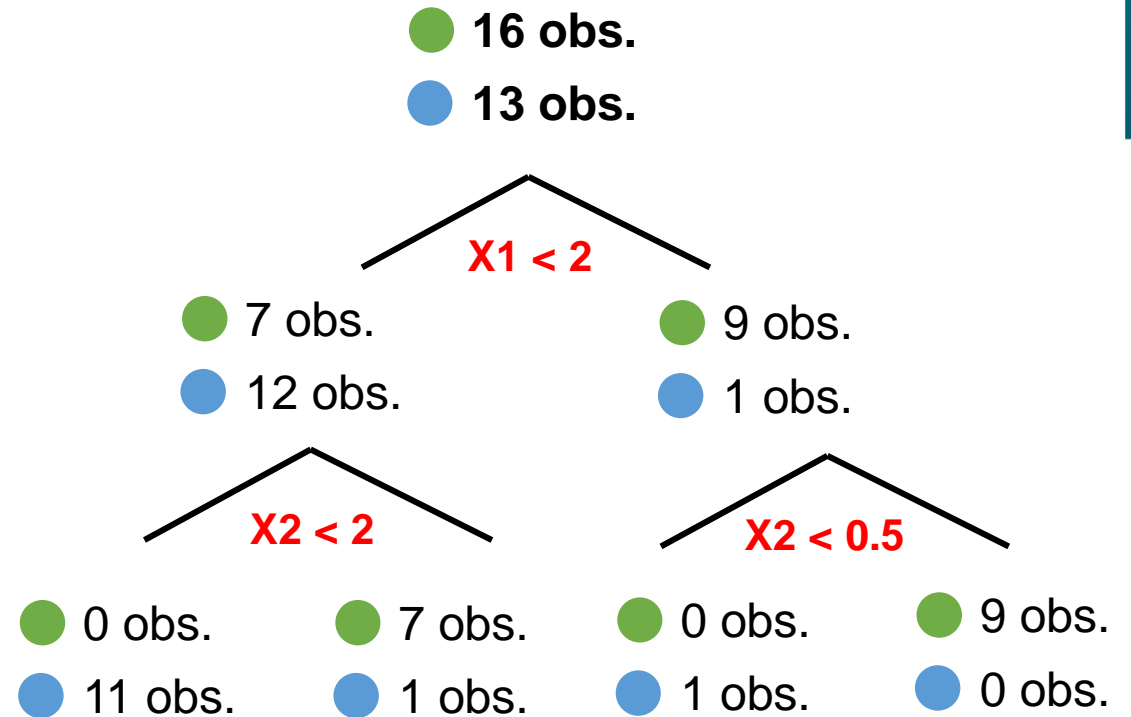
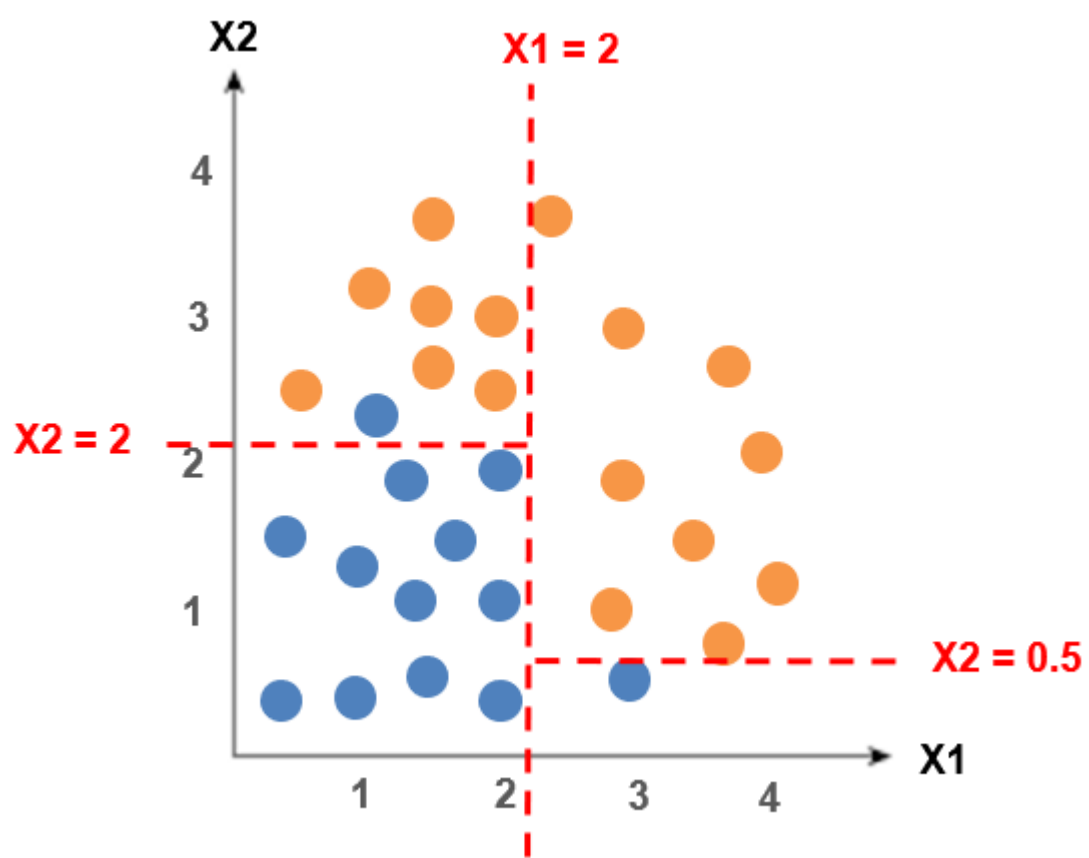


Continue splitting on each group.

At $X_2 = 2$ for class $X_1 < 2$

At $X_2 = 0.5$ for class $X_1 > 2$

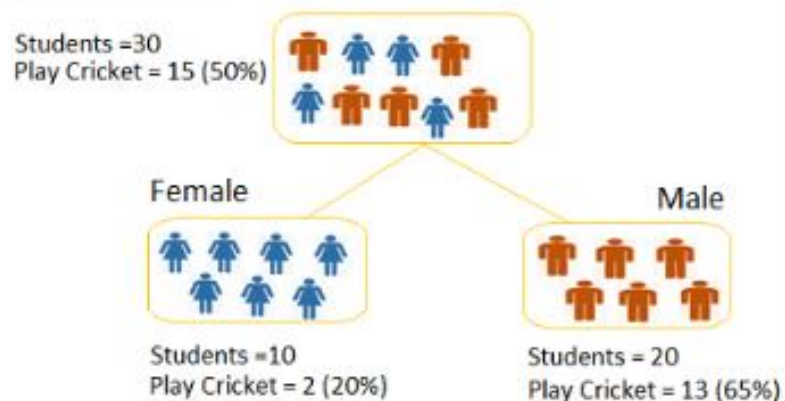
Basic Idea – Continue Splitting



GINI index

- The higher the GINI value means more homogenous class
- Steps in calculate GINI for a split
 - Calculate Gini for sub-nodes.
Formula sum of square of probability for success and failure (p^2+q^2).
 - Calculate Gini for split using weighted Gini score of each node of that split.

Split on Gender



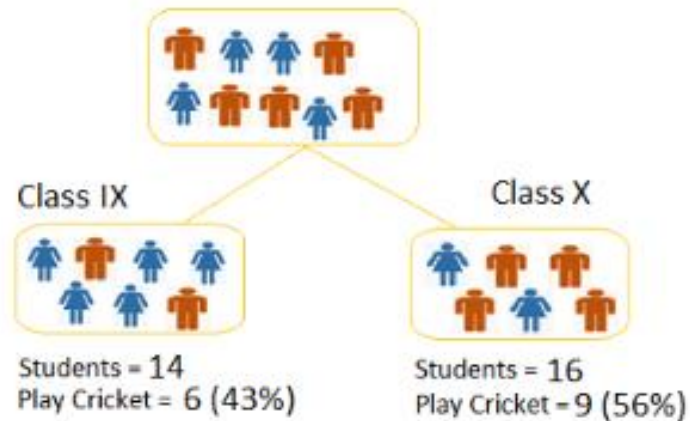
Calculate, Gini for sub-node Female
 $= (0.2)*(0.2)+(0.8)*(0.8)=0.68$

Gini for sub-node Male
 $= (0.65)*(0.65)+(0.35)*(0.35)=0.55$

Calculate weighted Gini for Split Gender
 $= (10/30)*0.68+(20/30)*0.55 = 0.59$

GINI index

Split on Class



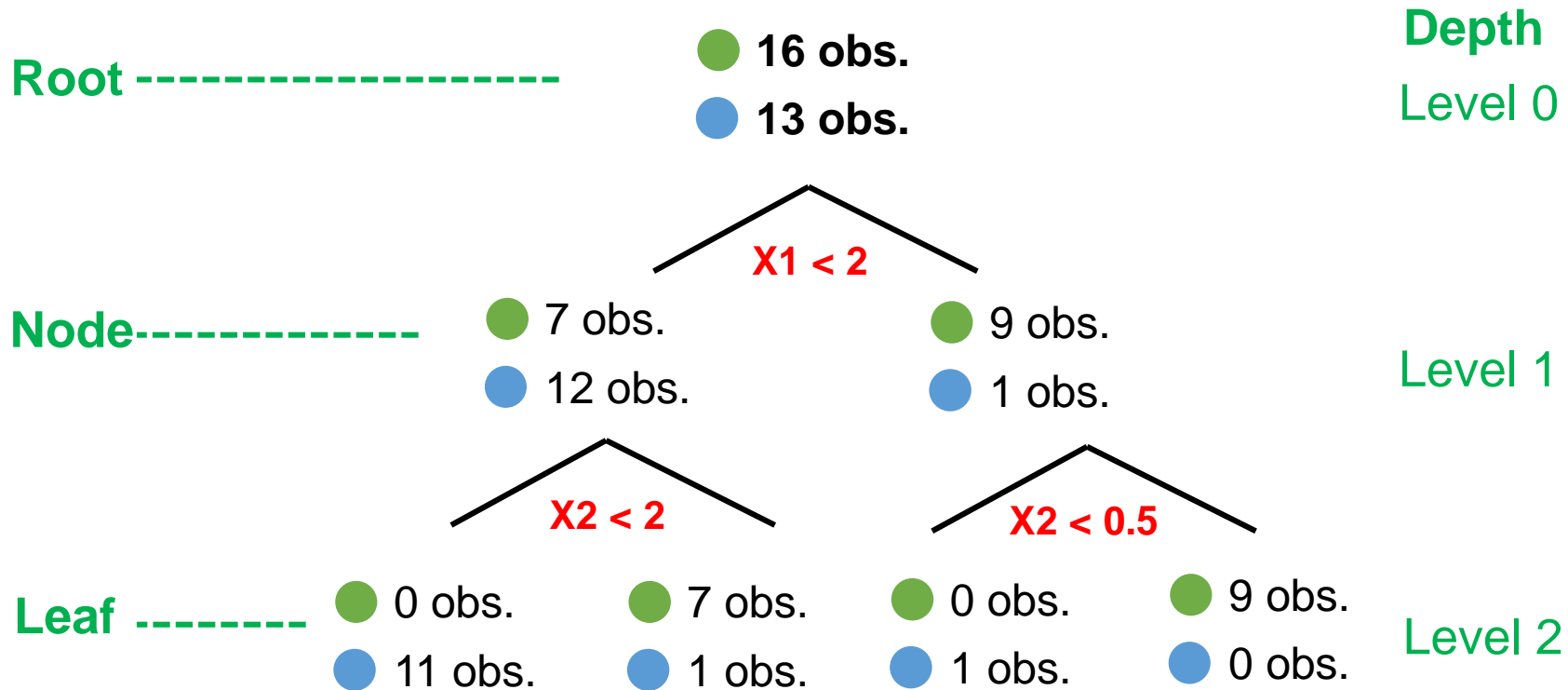
Gini for sub-node Class IX
 $= (0.43)*(0.43)+(0.57)*(0.57)=0.51$

Gini for sub-node Class X
 $= (0.56)*(0.56)+(0.44)*(0.44)=0.51$

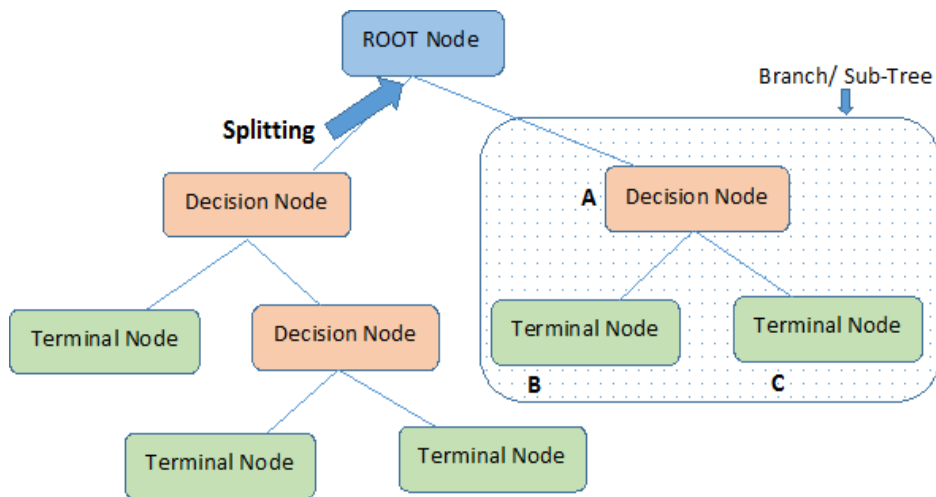
Calculate weighted Gini for Split Class
 $= (14/30)*0.51+(16/30)*0.51 = \mathbf{0.51}$

Gini score for *Split on Gender* is higher than *Split on Class*, hence, the node split will take place on Gender.

Terminologies



Terminologies



Note:- A is parent node of B and C.

Root Node: Represent entire population / sample

Splitting: Process of dividing a node into two or more sub-nodes.

Decision Node: Sub-node that splits into further sub-nodes

Leaf/Terminal Node: Nodes that do not split

Pruning: Remove sub-nodes of a decision node. It is the opposite of splitting.

Branch / Sub-Tree: A sub section of entire tree is called branch or sub-tree.

Parent and Child Node: A node, which is divided into sub-nodes is called parent node of sub-nodes where as sub-nodes are the child of parent node

Basic Algorithm

Perform 3 steps for every single Node and its splitting result

- **Step-1**
Find best splitter on each variable
- **Step-2**
Select best variable for splitting
- **Step-3**
Perform splitting based on result on Step-2.
Check if the splitting should stop.

Stop-splitting Condition

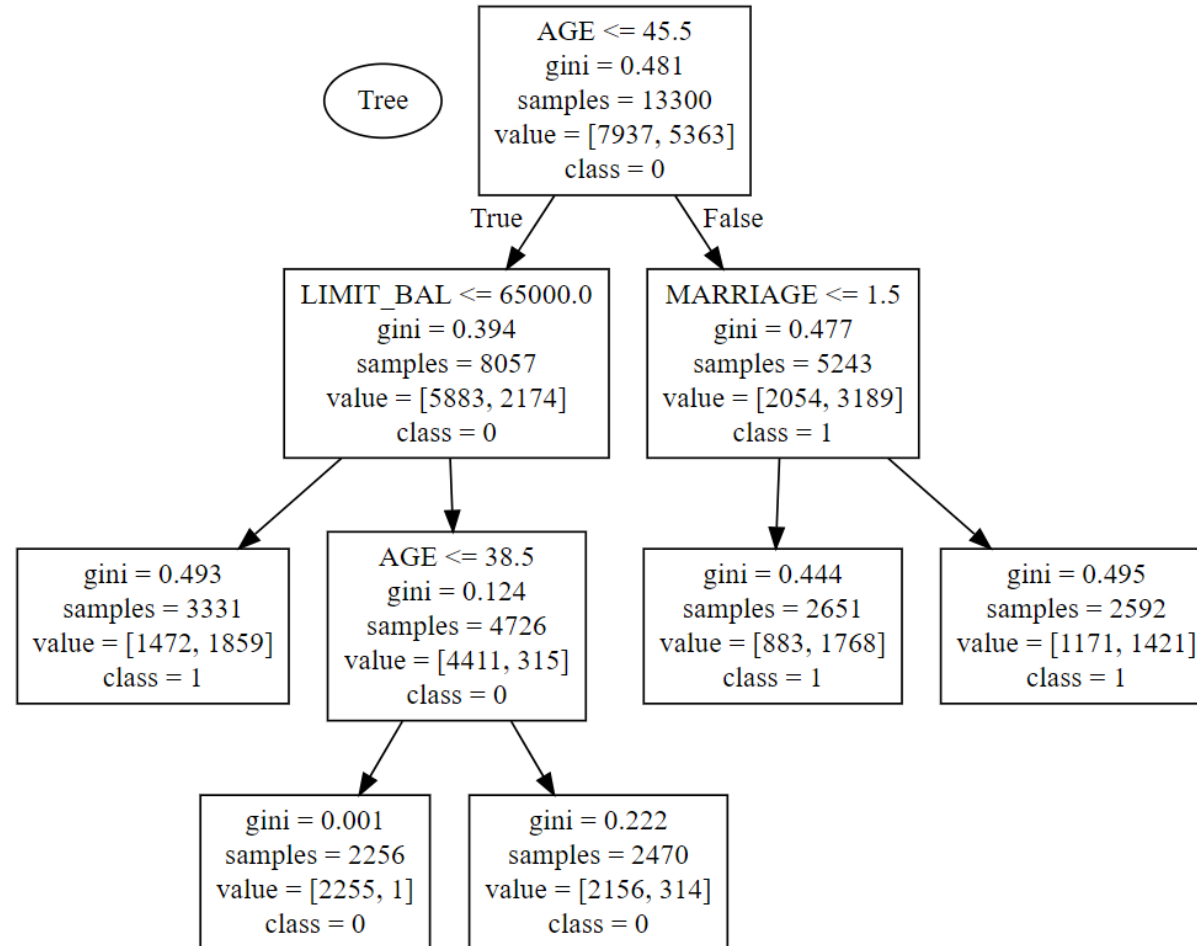
Splitting will stop if any of below conditions met

- Node contains only 1 class of response variable
- Number of observation in a node before splitting is less than pre-defined number
- Number of observation in a node after splitting is less than pre-defined number
- Tree depth has reach its maximum

There are parameters in the software to control the Tree Size

- Minimum sample of node split
- Minimum sample of terminal
- Maximum depth of tree
- Maximum number of terminal node

Illustration



Adv-Disadvantages

Advantages

- Easy to understand
- Useful in data exploration. Information of importance variables, variables which relates each other.
- Data type is not a constraint (works for numerical and categoric too)
- Non parametric, have no assumption about distribution

Disadvantages

- Over fitting
- Loses information of continuous numeric variable when it categorized into different categories

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