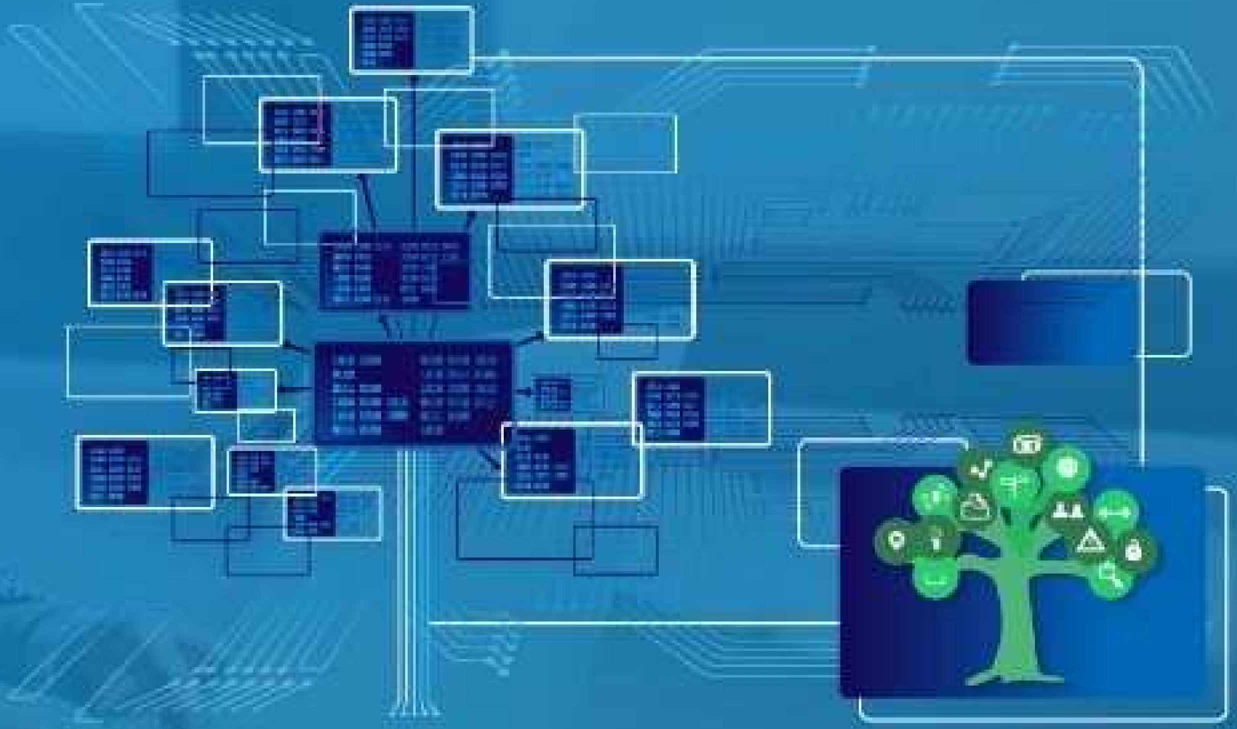
Decision Tree Algorithm



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https://www.edureka.co/machine-learning-certification-training

Agenda for Today's Session

- What is Classification?
- Types of Classification
- Classification Use case
- What is Decision Tree?
- Terminologies associated to a Decision Tree
- Visualizing a Decision Tree
- Writing a Decision Tree Classifier form Scratch in Python using CART Algorithm

What is Classification?

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What is Classification?

"Classification is the process of dividing the datasets into different categories or groups by adding label"

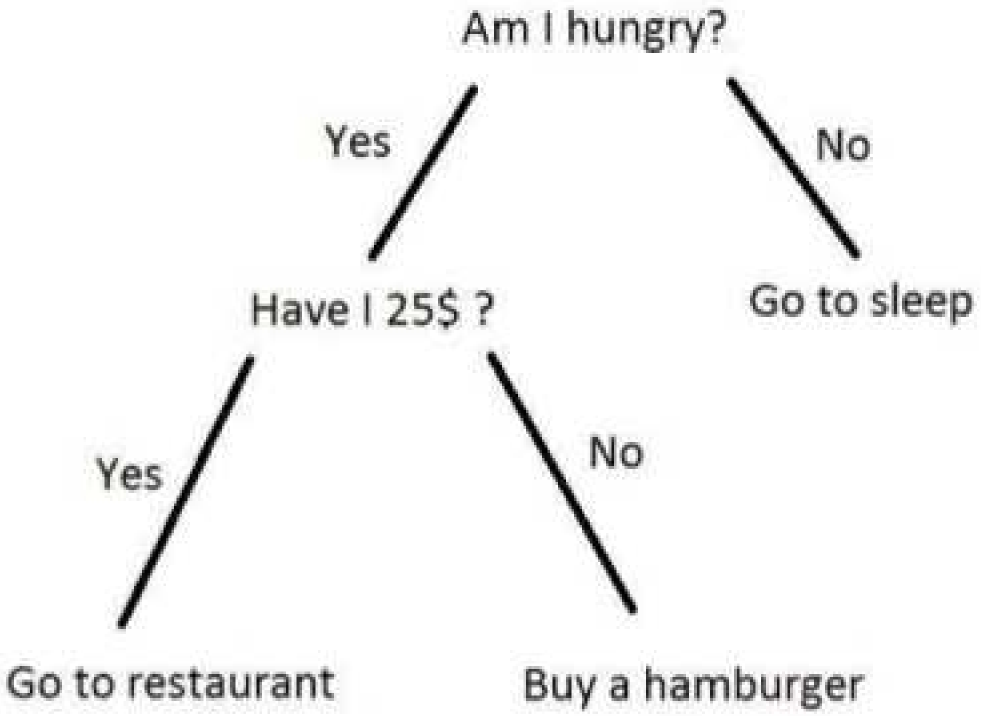
- **Note:** It adds the data point to a particular labelled group on the basis of some condition"

Types of Classification

- ● Decision Tree
- ○ Random Forest
- ○ Naïve Bayes
- ○ KNN

Decision Tree

- Graphical representation of all the possible solutions to a decision
- Decisions are based on some conditions
- Decision made can be easily explained



Am I hungry?

Yes

No

Have I 25$?

Go to sleep

Yes

No

Go to restaurant

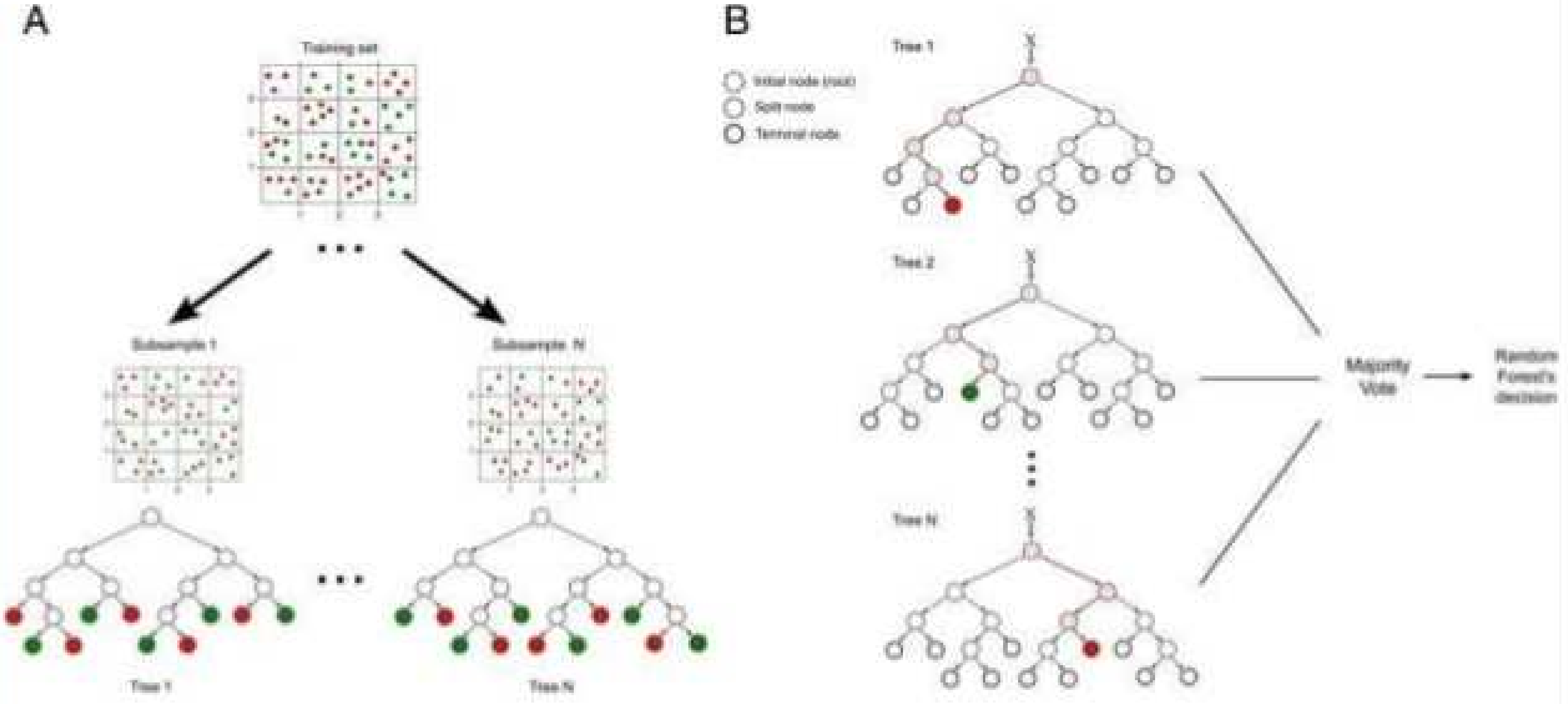
Buy a hamburger

Types of Classification

- Decision Tree
- Random Forest
- Naïve Bayes
- KNN

Random Forest

- Builds multiple decision trees and merges them together
- More accurate and stable prediction
- Random decision forests correct for decision trees' habit of overfitting to their training set
- Trained with the “bagging” method

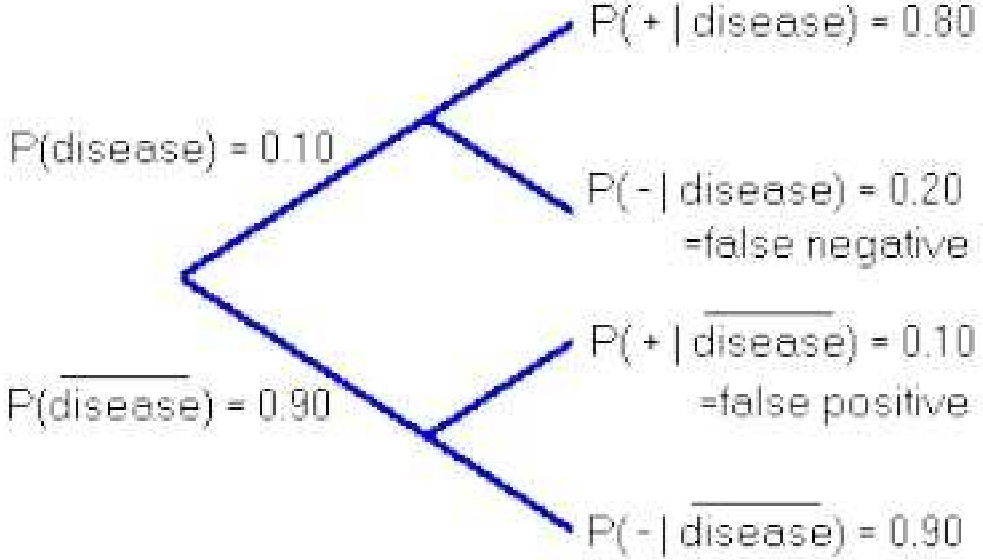


Types of Classification

- ● Decision Tree
- ● Random Forest
- ● Naïve Bayes
- ○ KNN

Naïve Bayes

- Classification technique based on Bayes' Theorem
- Assumes that the presence of a particular feature in a class is unrelated to the presence of any other feature

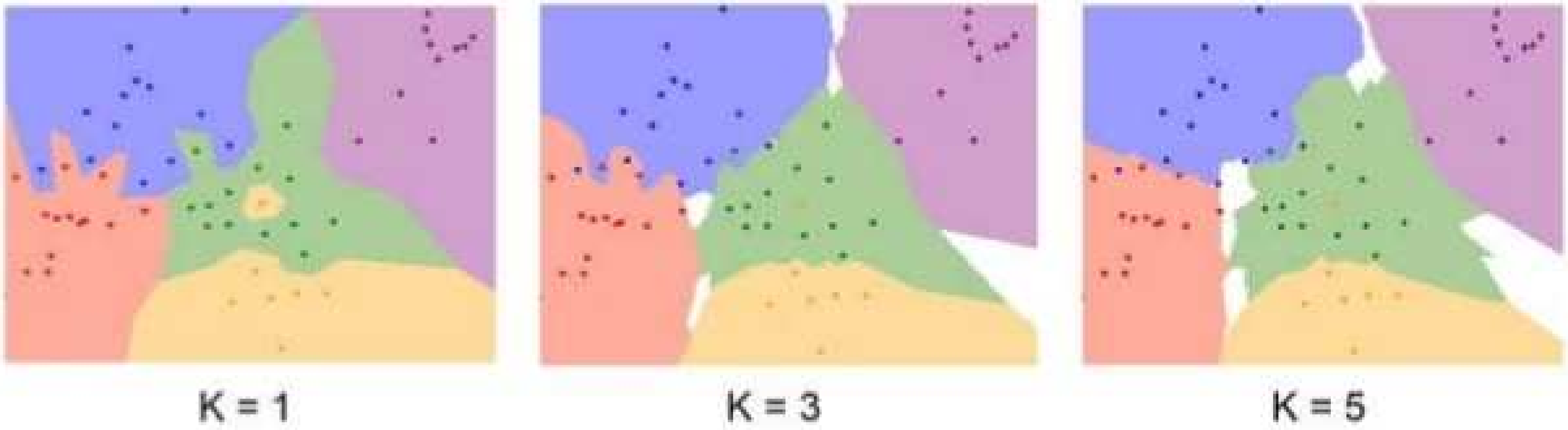

P(+ | disease) = 0.80
P(disease) = 0.10
P(- | disease) = 0.20
=false negative
P(+ | $\overline{\text{disease}}$) = 0.10
=false positive
P($\overline{\text{disease}}$) = 0.90
P(- | $\overline{\text{disease}}$) = 0.90

Types of Classification

- Decision Tree
- Random Forest
- Naïve Bayes
- KNN

K-Nearest Neighbors

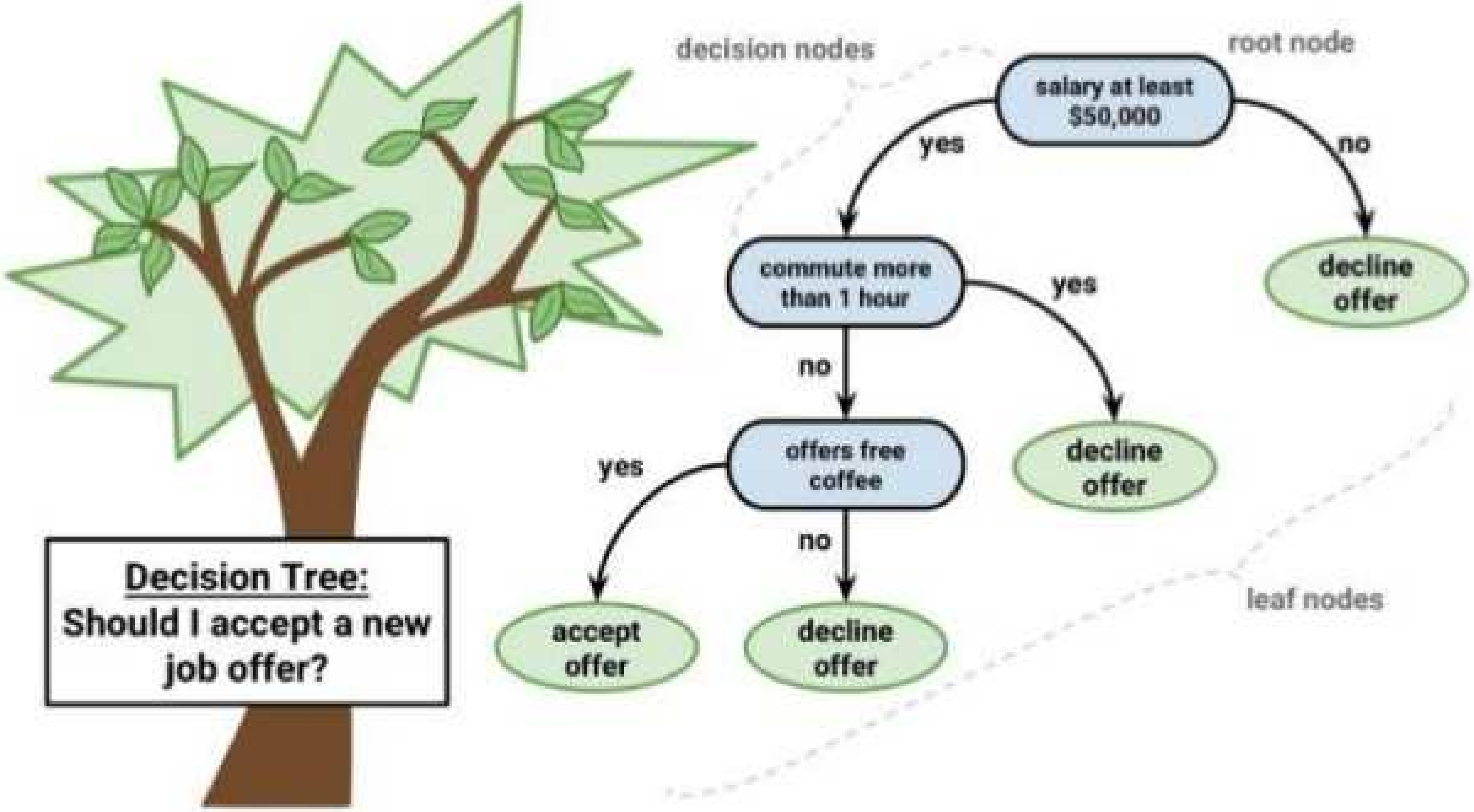
- Stores all the available cases and classifies new cases based on a similarity measure
- The "K" is KNN algorithm is the nearest neighbors we wish to take vote from.



What is Decision Tree?

What is Decision Tree?

“A decision tree is a graphical representation of all the possible solutions to a decision based on certain conditions”



Machine Leaning
Training Using
Python

Understanding a Decision Tree

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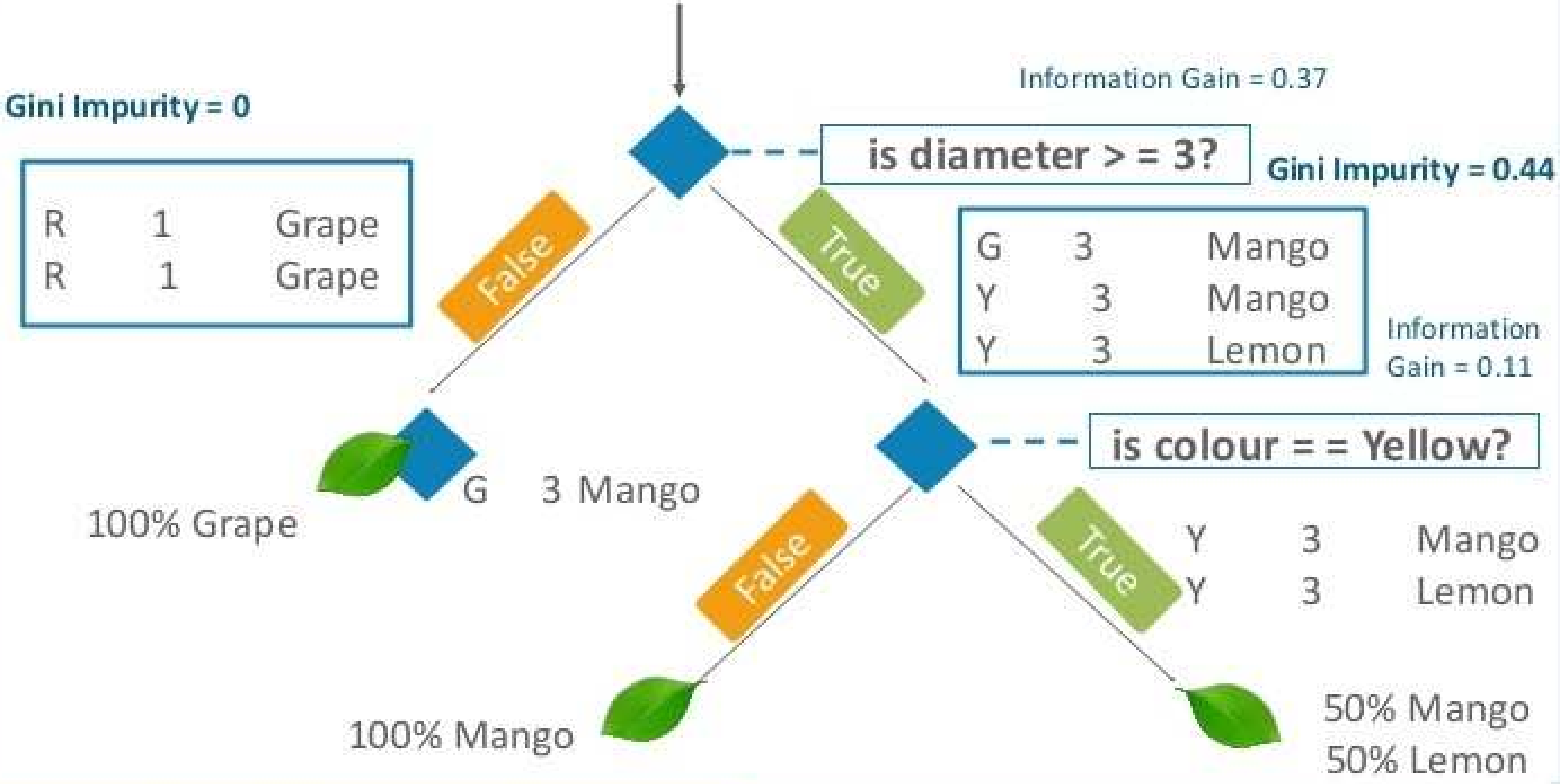
Dataset

This is how our dataset looks like!

Colour	Diameter	Label
Green	3	Mango
Yellow	3	Mango
Red	1	Grape
Red	1	Grape
Yellow	3	Lemon

Decision Tree

Color	Diam	Label
Green	3	Mango
Yellow	3	Lemon
Red	1	Grape
Yellow	3	Mango
Red	1	Grape



Information Gain = 0.37

is diameter > = 3?

Gini Impurity = 0.44

Gini Impurity = 0

R	1	Grape
R	1	Grape

G	3	Mango
Y	3	Mango
Y	3	Lemon

Information Gain = 0.11

is colour = = Yellow?

100% Grape

G 3 Mango

Y	3	Mango
Y	3	Lemon

100% Mango

50% Mango
50% Lemon

What is Decision Tree?

Green	3	Mango
Yellow	3	Lemon
Yellow	3	Mango

Is the colour green?

Is the diameter >=3

Is the colour yellow

TRUE

False

Decision Tree Terminologies

Decision Tree Terminology

Pruning

Opposite of Splitting, basically removing unwanted branches from the tree

Branch/SubTree

Formed by splitting the tree/node

Parent/Child Node

Root node is the parent node and all the other nodes branched from it is known as child node

Splitting

Splitting is dividing the root node/sub node into different parts on the basis of some condition.

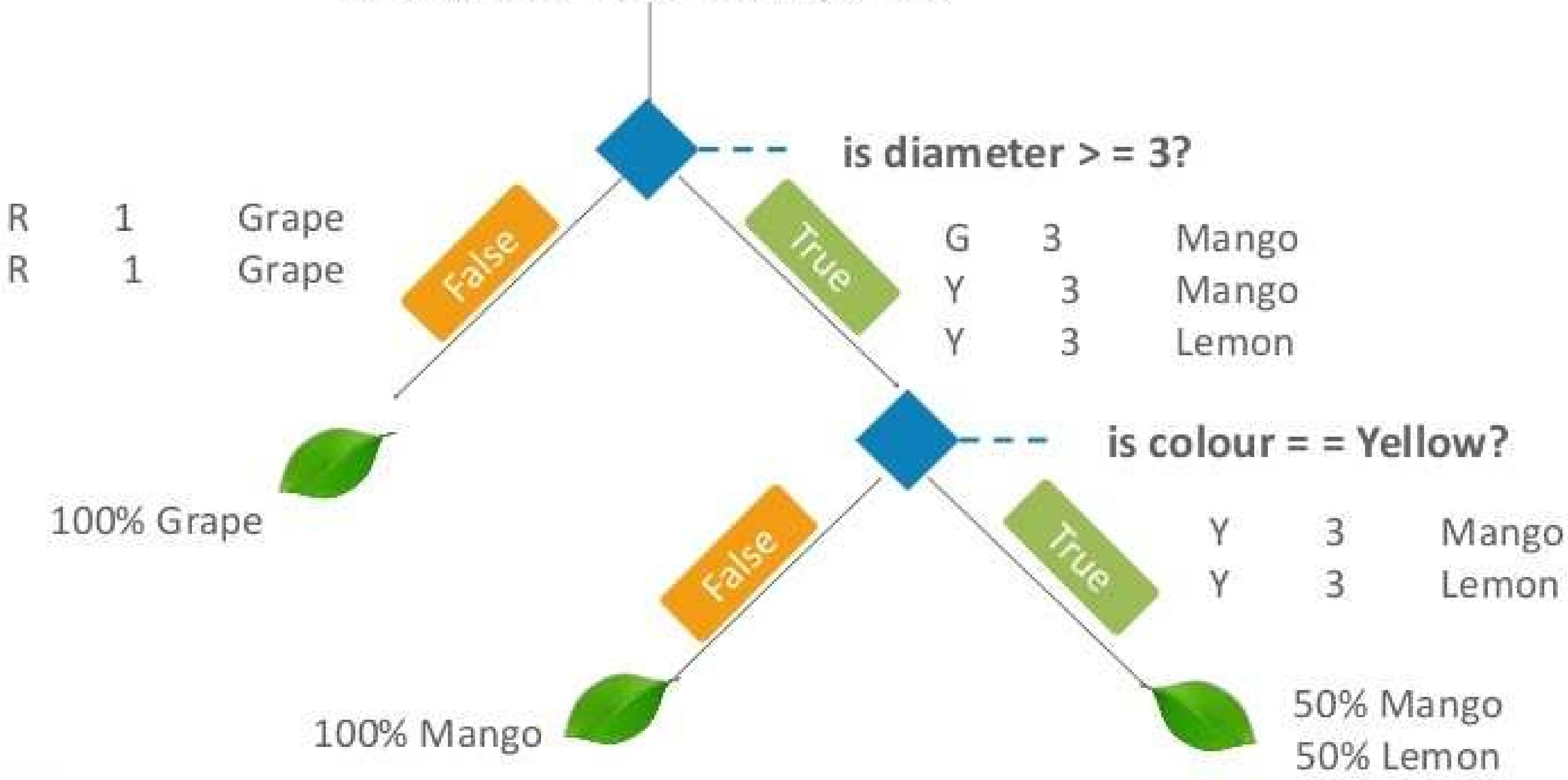
Root Node

It represents the entire population or sample and this further gets divided into two or more homogenous sets.

Leaf Node

Node cannot be further segregated into further nodes

Color	Diam	Label
Green	3	Mango
Yellow	3	Lemon
Red	1	Grape
Yellow	3	Mango
Red	1	Grape



R	1	Grape
R	1	Grape

G	3	Mango
Y	3	Mango
Y	3	Lemon

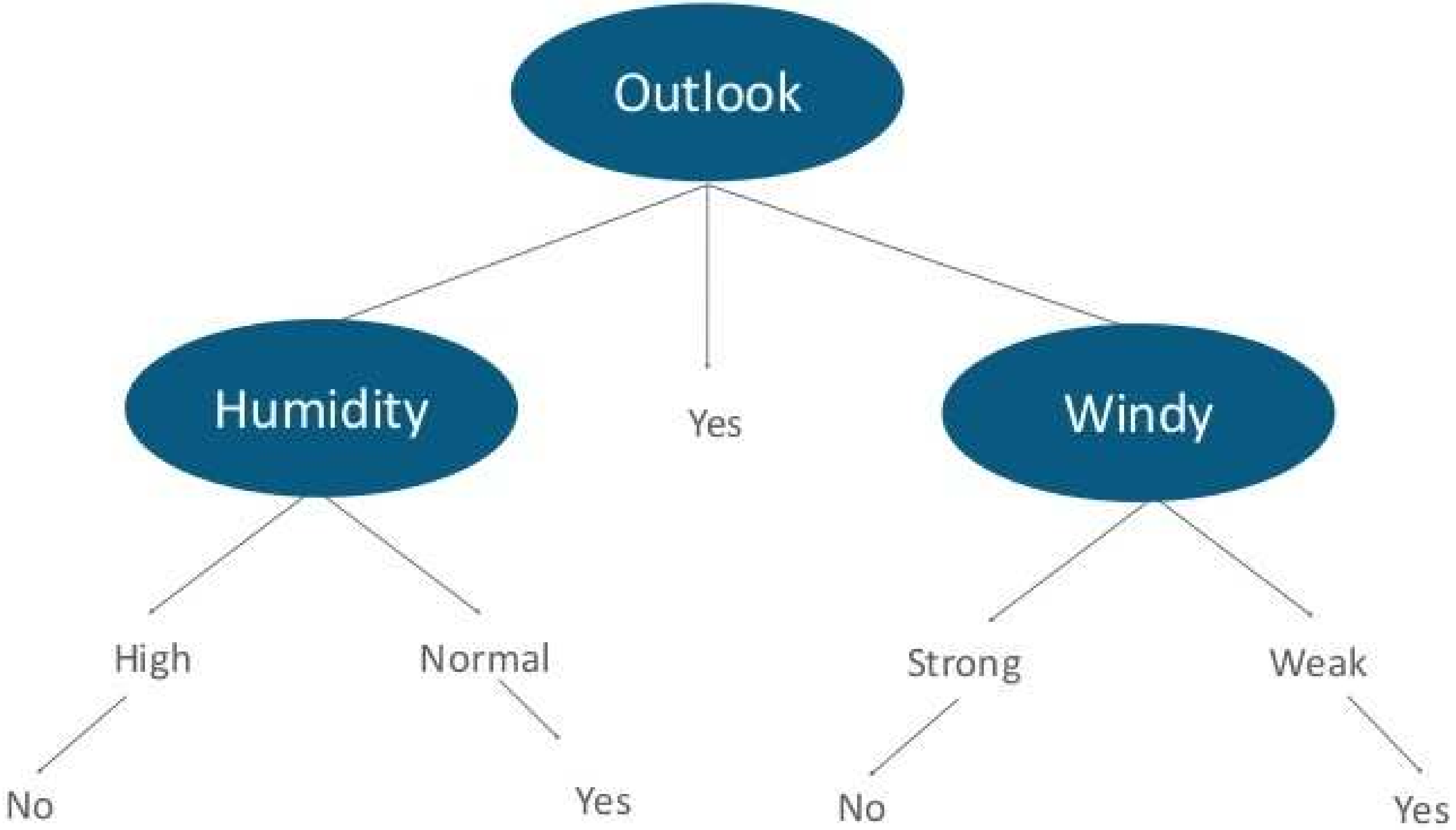
Y	3	Mango
Y	3	Lemon

CART Algorithm

Let’s First Visualize the Decision Tree

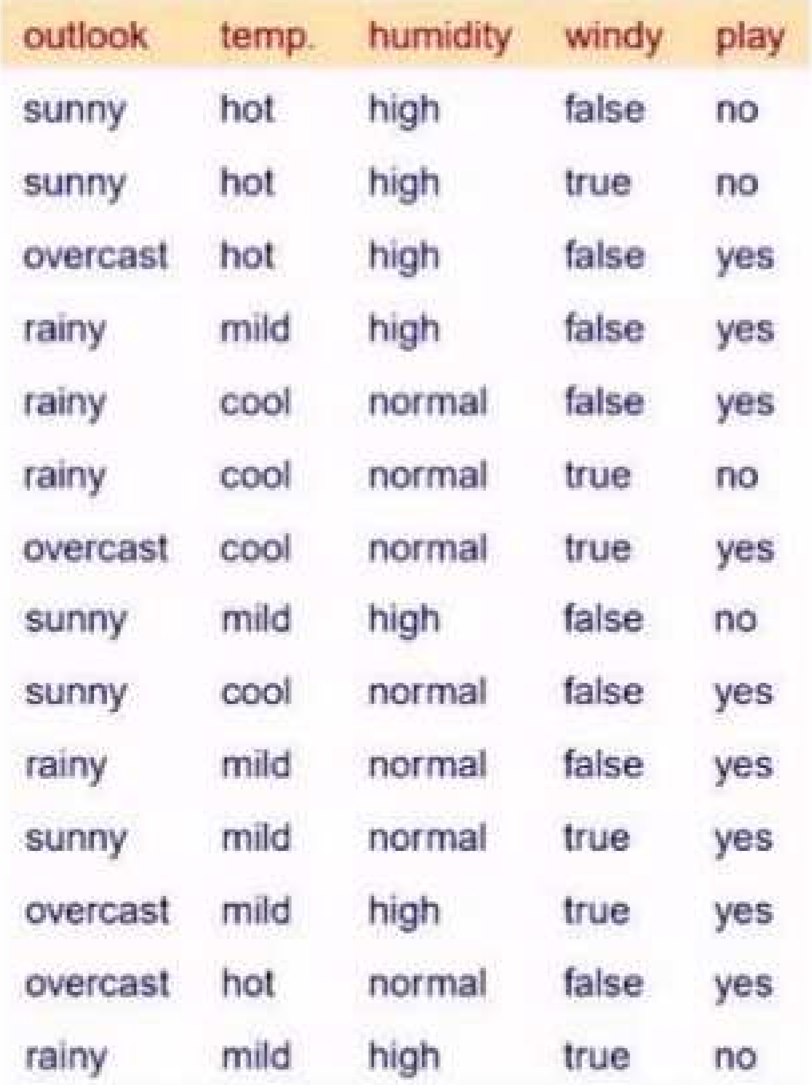
Which Question to ask and When?

Let's First Visualize the Decision Tree



Learn about Decision Tree

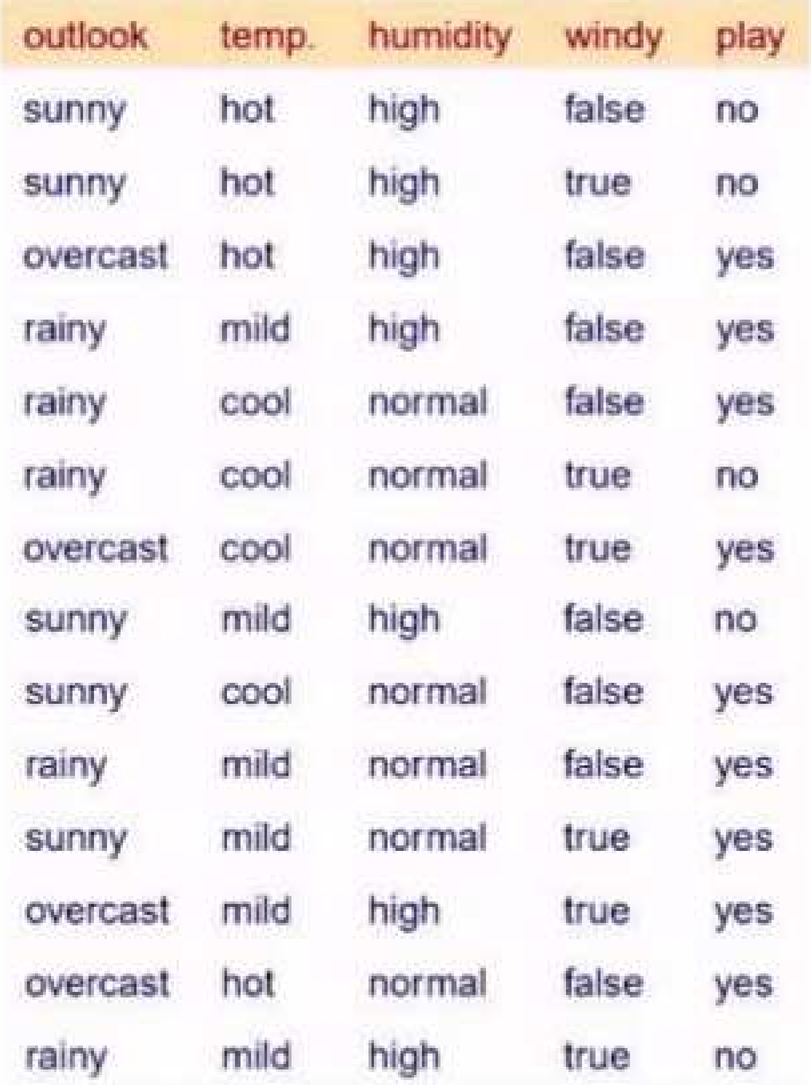
Which one among them should you pick first?



outlook	temp.	humidity	windy	play
sunny	hot	high	false	no
sunny	hot	high	true	no
overcast	hot	high	false	yes
rainy	mild	high	false	yes
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high	true	yes
overcast	hot	normal	false	yes
rainy	mild	high	true	no

Learn about Decision Tree

Answer: Determine the attribute that best classifies the training data



outlook	temp.	humidity	windy	play
sunny	hot	high	false	no
sunny	hot	high	true	no
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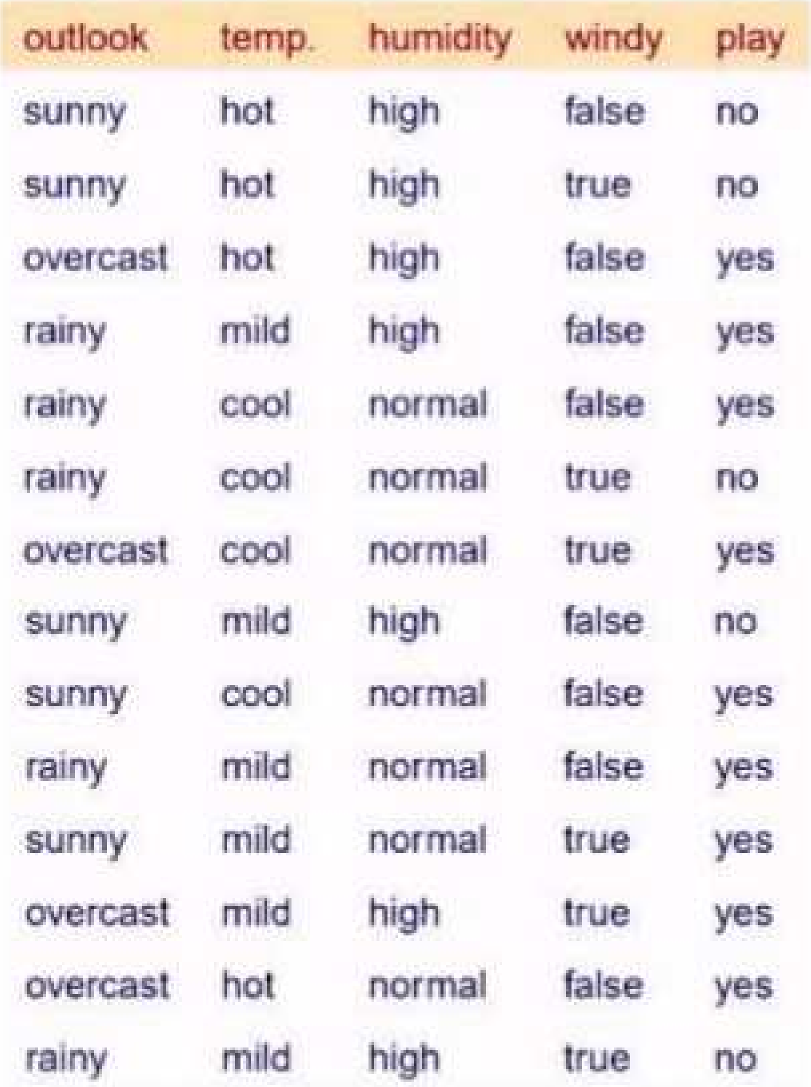
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high	true	yes
overcast	hot	normal	false	yes
rainy	mild	high	true	no

Learn about Decision Tree

But How do we choose the best attribute?

Or

How does a tree decide where to split?



outlook	temp.	humidity	windy	play
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sunny	hot	high	true	no
overcast	hot	high	false	yes
rainy	mild	high	false	yes
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high	true	yes
overcast	hot	normal	false	yes
rainy	mild	high	true	no

How Does A Tree Decide Where To Split?

Gini Index

The measure of impurity (or purity) used in building decision tree in CART is Gini Index

Information Gain

The information gain is the decrease in entropy after a dataset is split on the basis of an attribute. Constructing a decision tree is all about finding attribute that returns the highest information gain

Chi Square

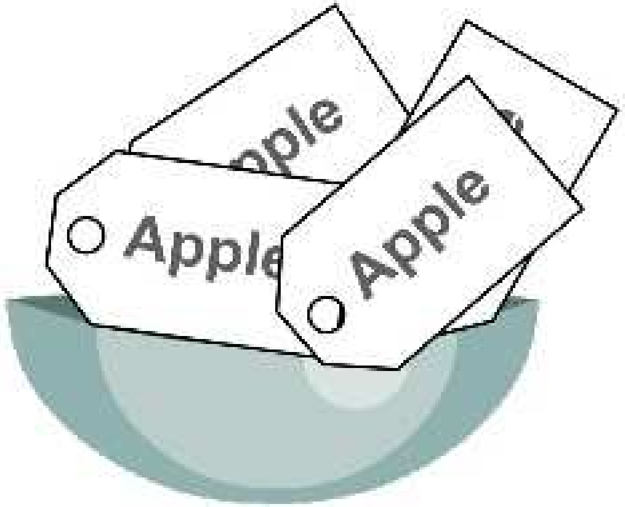
It is an algorithm to find out the statistical significance between the differences between sub-nodes and parent node

Reduction in Variance

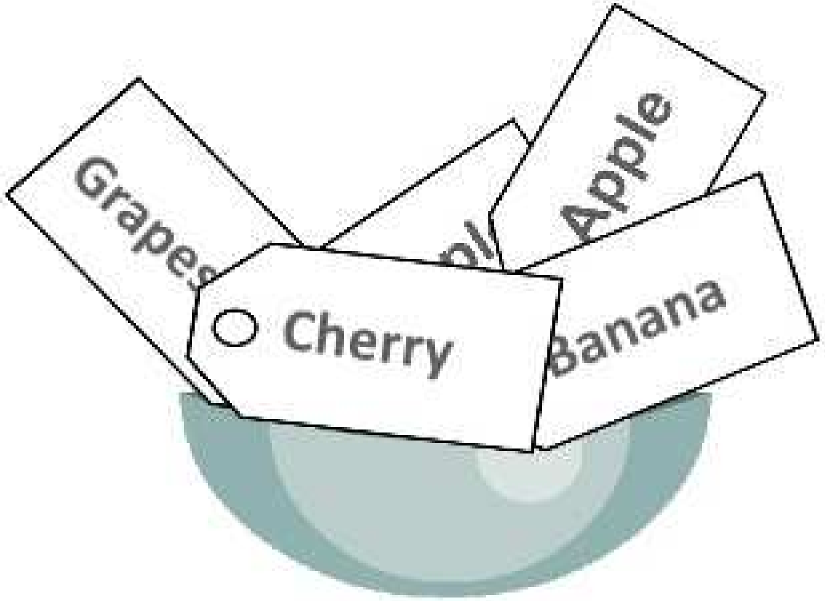
Reduction in variance is an algorithm used for continuous target variables (regression problems). The split with lower variance is selected as the criteria to split the population

Let's First Understand What is Impurity

Impurity = 0



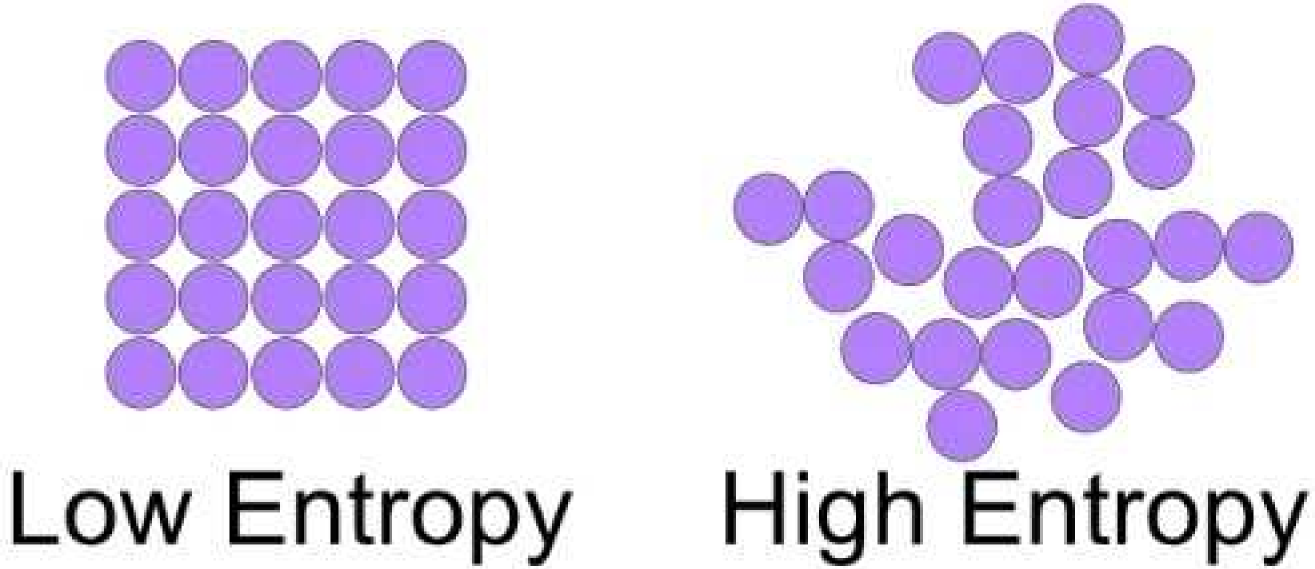
Let’s First Understand What is Impurity



Impurity $\neq$ 0

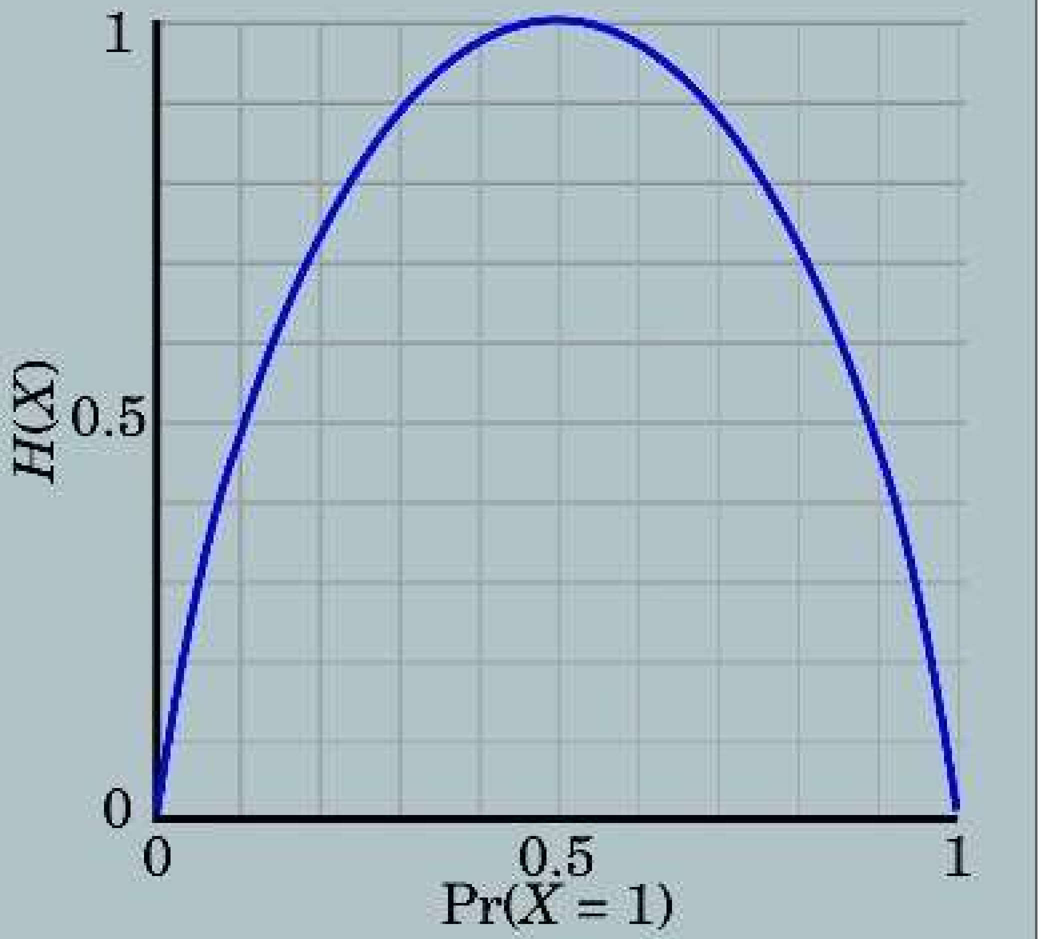
What is Entropy?

- Defines randomness in the data
- **Entropy** is just a metric which measures the impurity or
- The first step to solve the problem of a decision tree



edureka!

What is Entropy?



Entropy(s) =- P(yes) $\log_2 P(yes)$ – P(no) $\log_2 P(no)$

Where,

- S is the total sample space,
- P(yes) is probability of yes

If number of *yes* = number of *no ie P(S) = 0.5*

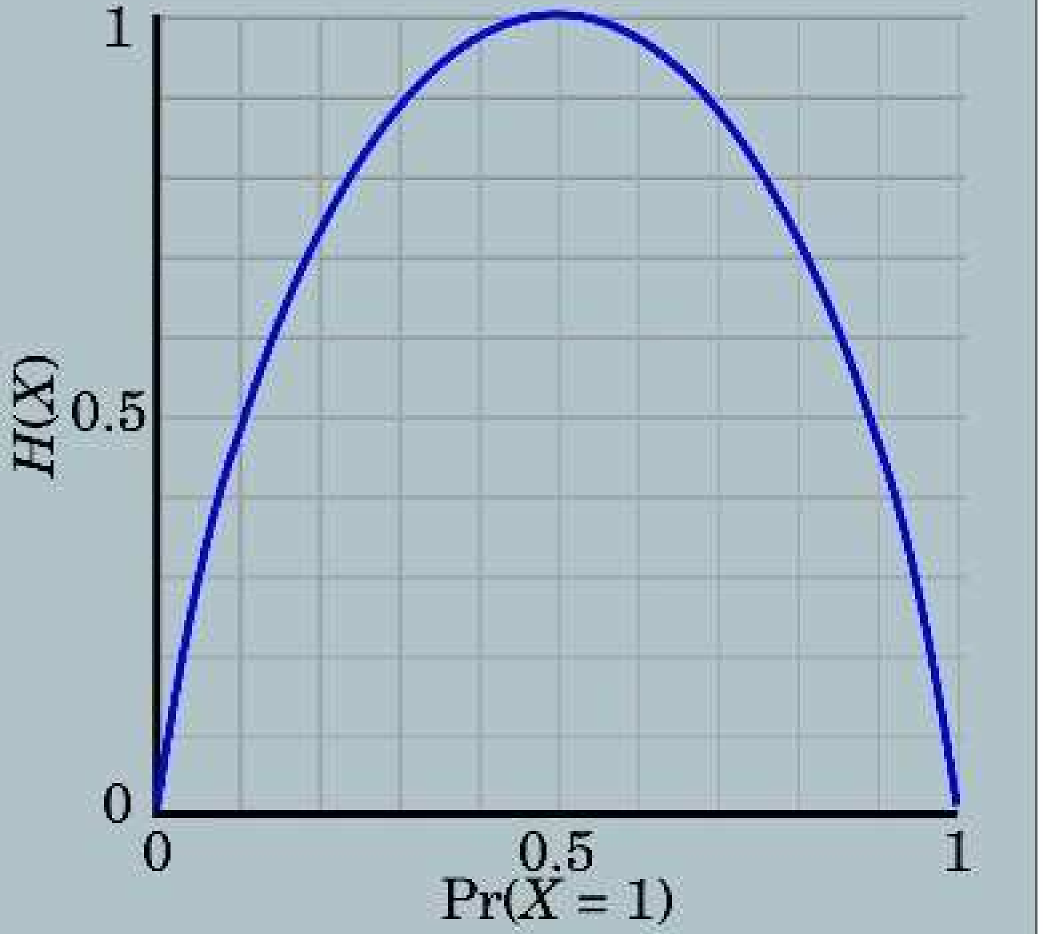
⇒ *Entropy(s) = 1*

If it contains all yes or all no ie P(S) = 1 or 0

⇒ *Entropy(s) = 0*

edureka!

What is Entropy?



$E(S) = -P(Yes)\log_2 P(Yes)$

When P(Yes) =P(No) = 0.5 ie YES + NO = Total Sample(S)

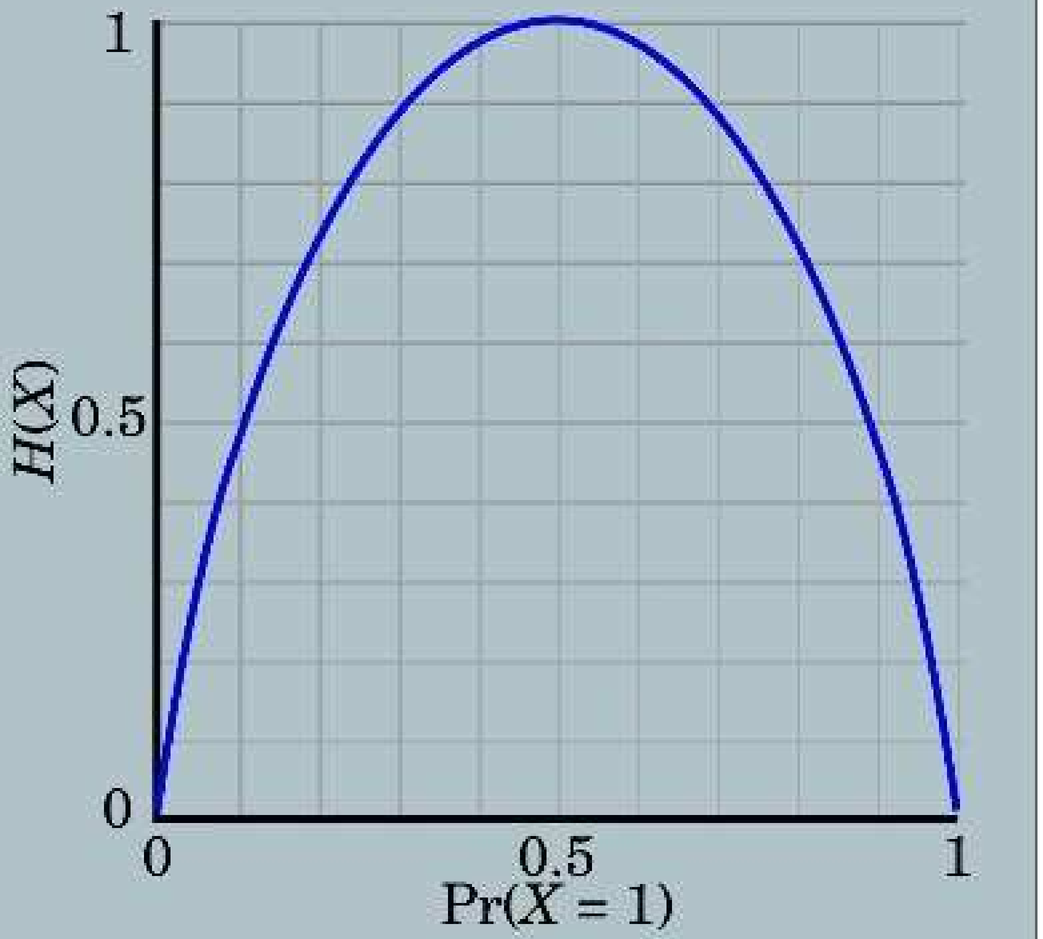
$E(S) = 0.5\ \log_2 0.5 - 0.5\ \log_2 0.5$

$E(S) = 0.5(\log_2 0.5 - \log_2 0.5)$

$E(S) = 1$

edureka!

What is Entropy?



$E(S) = -P(Yes)\log_2 P(Yes)$

When P(Yes) = 1 ie YES = Total Sample(S)

$E(S) = 1\ \log_2 1$

$E(S) = 0$

$E(S) = -P(No)\log_2 P(No)$

When P(No) = 1 ie No = Total Sample(S)

$E(S) = 1\ \log_2 1$

$E(S) = 0$

What is Information Gain?

- Measures the reduction in entropy
- Decides which attribute should be selected as the decision node

If S is our total collection,

Information Gain = Entropy(S) – [(Weighted Avg) x Entropy(each feature)]

Let’s Build Our Decision Tree

Step 1: Compute the entropy for the Data set

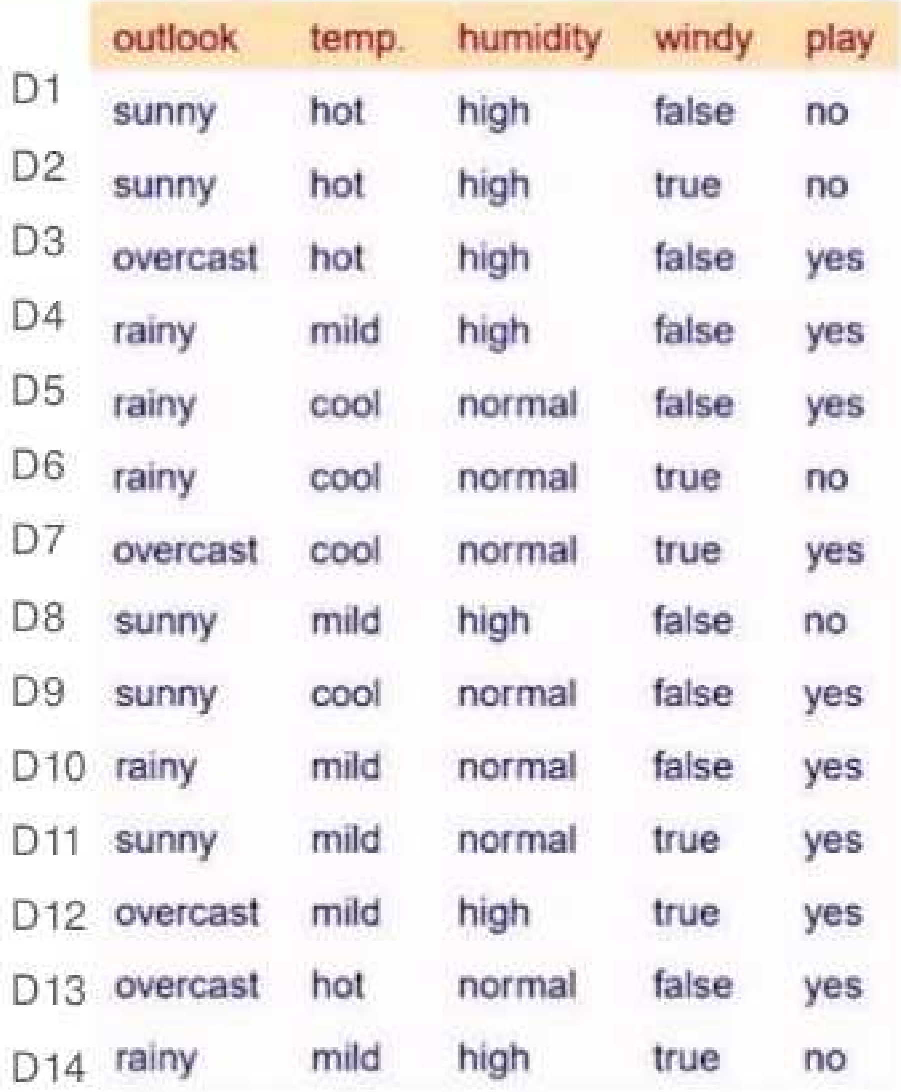
Out of 14 instances we have 9 YES and 5 NO

So we have the formula,

$E(S) = -P(Yes) \log_2 P(Yes) - P(No) \log_2 P(No)$

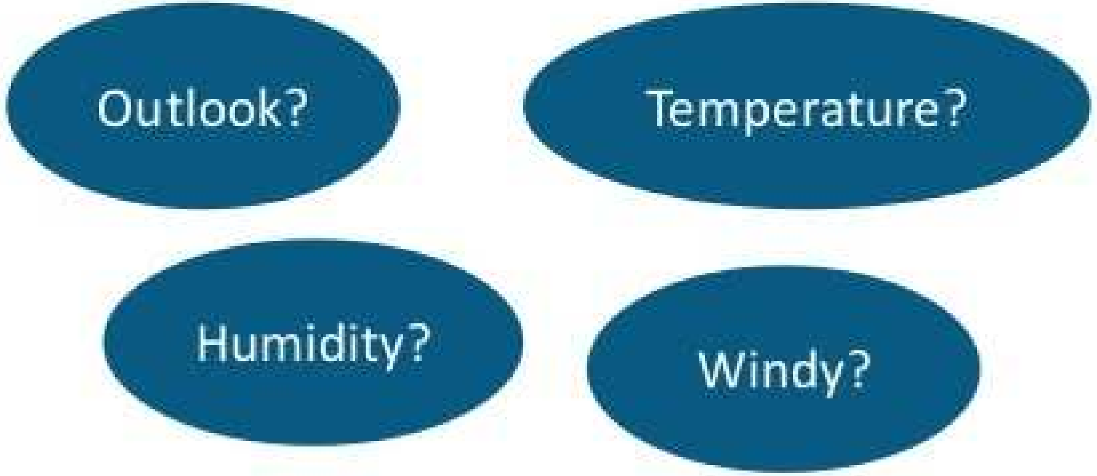
$E(S) = - (9/14)^* \log_2 9/14 - (5/14)^* \log_2 5/14$

$E(S) = 0.41+0.53 = 0.94$



	outlook	temp.	humidity	windy	play
D1	sunny	hot	high	false	no
D2	sunny	hot	high	true	no
D3	overcast	hot	high	false	yes
D4	rainy	mild	high	false	yes
D5	rainy	cool	normal	false	yes
D6	rainy	cool	normal	true	no
D7	overcast	cool	normal	true	yes
D8	sunny	mild	high	false	no
D9	sunny	cool	normal	false	yes
D10	rainy	mild	normal	false	yes
D11	sunny	mild	normal	true	yes
D12	overcast	mild	high	true	yes
D13	overcast	hot	normal	false	yes
D14	rainy	mild	high	true	no

Which Node To Select As Root Node?

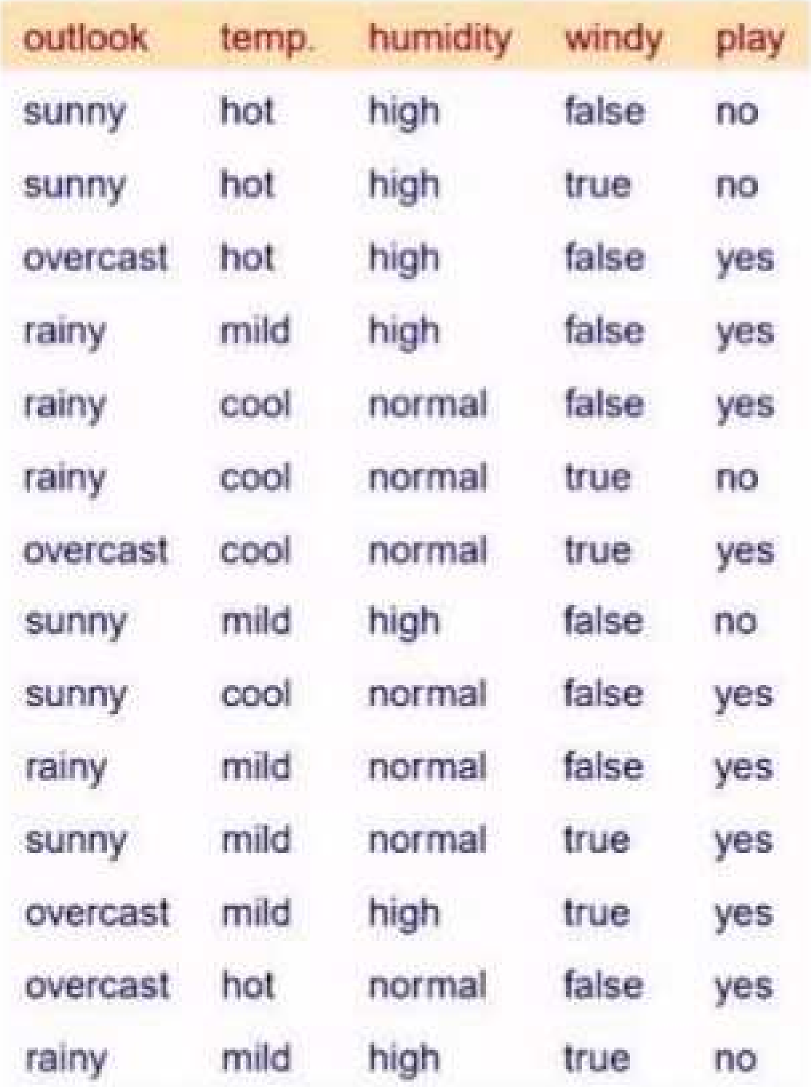


Outlook?

Temperature?

Humidity?

Windy?



outlook	temp.	humidity	windy	play
sunny	hot	high	false	no
sunny	hot	high	true	no
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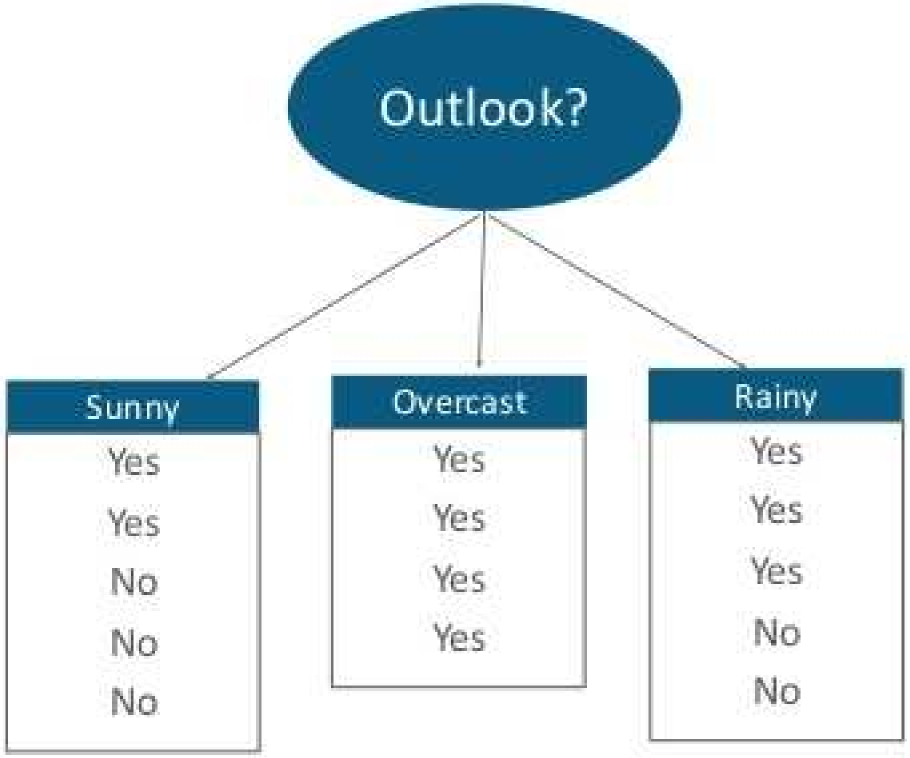
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high	true	yes
overcast	hot	normal	false	yes
rainy	mild	high	true	no

Which Node To Select As Root Node: Outlook



Outlook?

Sunny	Overcast	Rainy
Yes	Yes	Yes
Yes	Yes	Yes
No	Yes	Yes
No	Yes	No
No		No

outlook	temp.	humidity	windy	play
sunny	hot	high	false	no
sunny	hot	high	true	no
overcast	hot	high	false	yes
rainy	mild	high	false	yes
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high	true	yes
overcast	hot	normal	false	yes
rainy	mild	high	true	no

Which Node To Select As Root Node: Outlook

$E(Outlook = Sunny) = -2/5 \log_2 2/5 - 3/5 \log_2 3/5 = 0.971$

$E(Outlook = Overcast) = -1 \log_2 1 - 0 \log_2 0 = 0$

$E(Outlook = Sunny) = -3/5 \log_2 3/5 - 2/5 \log_2 2/5 = 0.971$

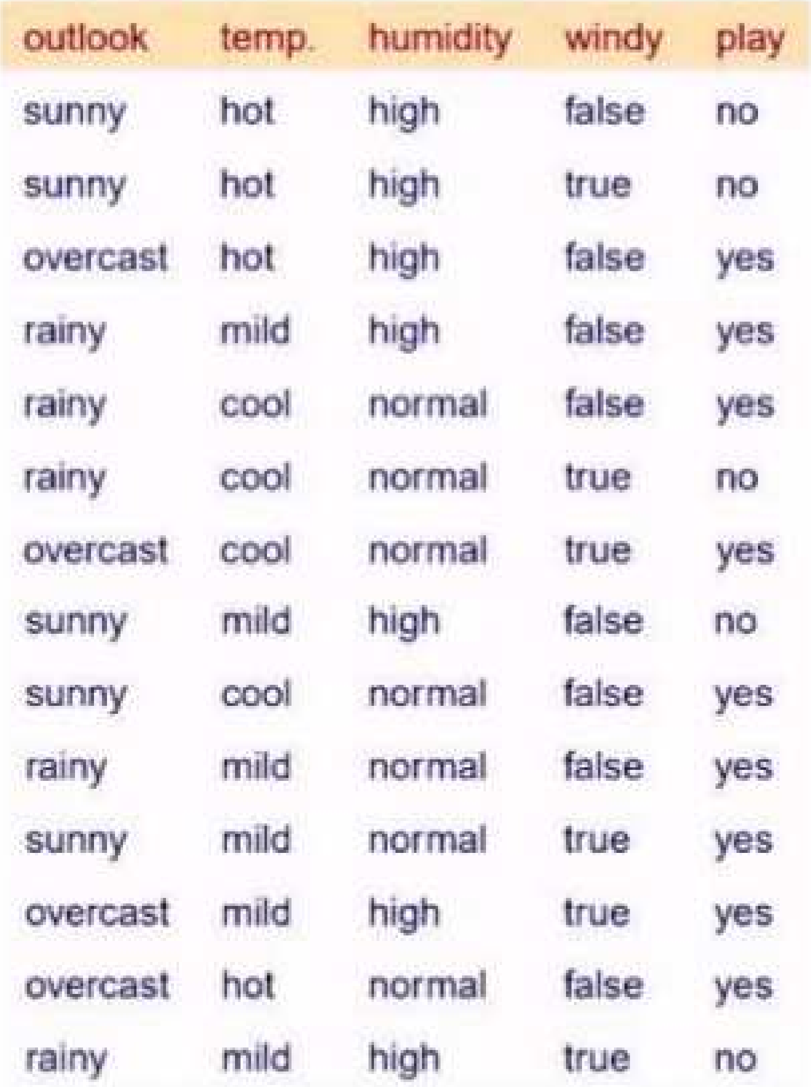
Information from outlook,

$I(Outlook) = 5/14 \times 0.971 + 4/14 \times 0 + 5/14 \times 0.971 = 0.693$

Information gained from outlook,

$Gain(Outlook) = E(S) - I(Outlook)$

$\mathbf{0.94 - 0.693 = 0.247}$



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sunny	hot	high	true	no
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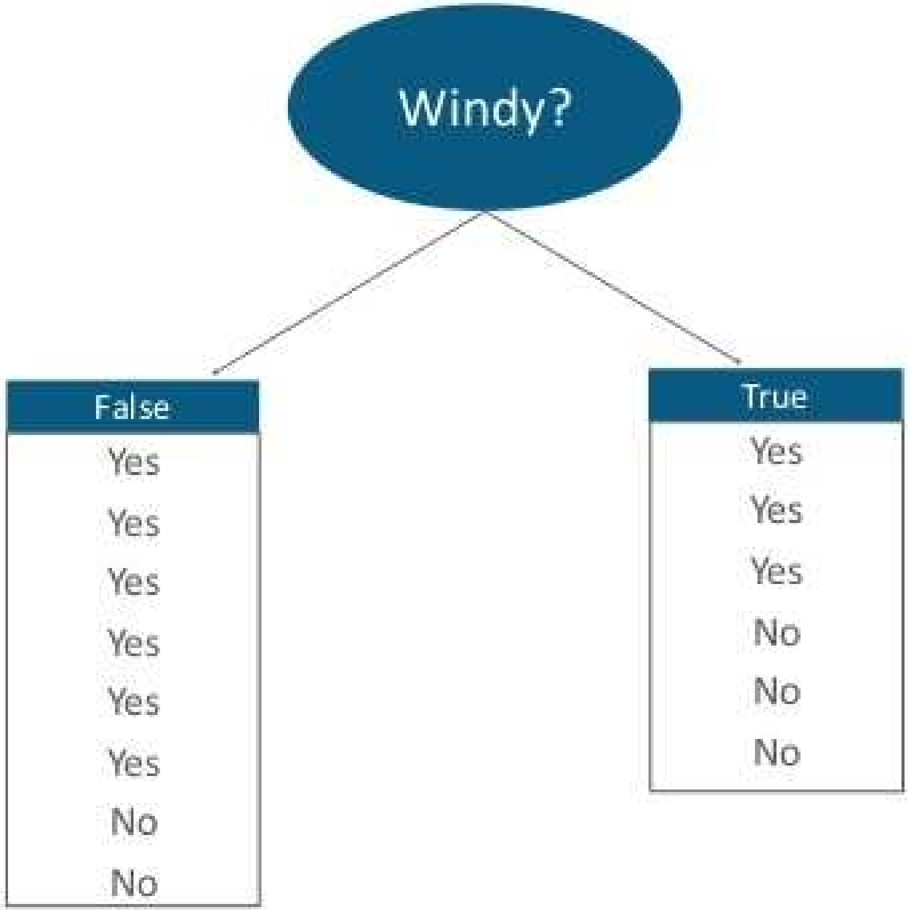
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high	true	yes
overcast	hot	normal	false	yes
rainy	mild	high	true	no

Which Node To Select As Root Node: Outlook



outlook	temp.	humidity	windy	play
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sunny	hot	high	true	no
overcast	hot	high	false	yes
rainy	mild	high	false	yes
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high	true	yes
overcast	hot	normal	false	yes
rainy	mild	high	true	no

Which Node To Select As Root Node: Windy

E(Windy = True) = 1

E(Windy = False) = 0.811

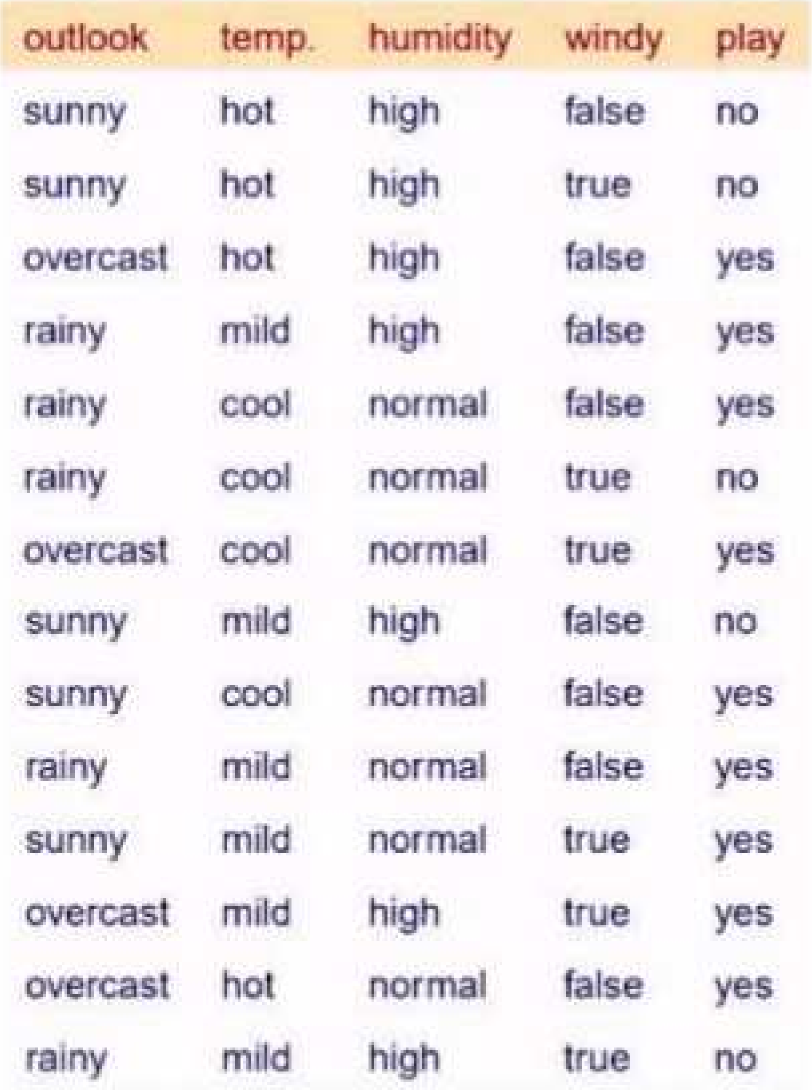
Information from windy,

I(Windy) = 8/14 x 0.811+ 6/14 x 1 = 0.892

Information gained from outlook,

Gain(Windy) = E(S) – I(Windy)

0.94 – 0.892 = 0.048



outlook	temp.	humidity	windy	play
sunny	hot	high	false	no
sunny	hot	high	true	no
overcast	hot	high	false	yes
rainy	mild	high	false	yes
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high	true	yes
overcast	hot	normal	false	yes
rainy	mild	high	true	no

Similarly We Calculated For Rest Two

Which Node To Select As Root Node

Outlook:
Info 0.693
Gain: 0.940-0.693 $\boxed{0.247}$

Temperature:
Info 0.911
Gain: 0.940-0.911 0.029

Humidity:
Info 0.788
Gain: 0.940-0.788 0.152

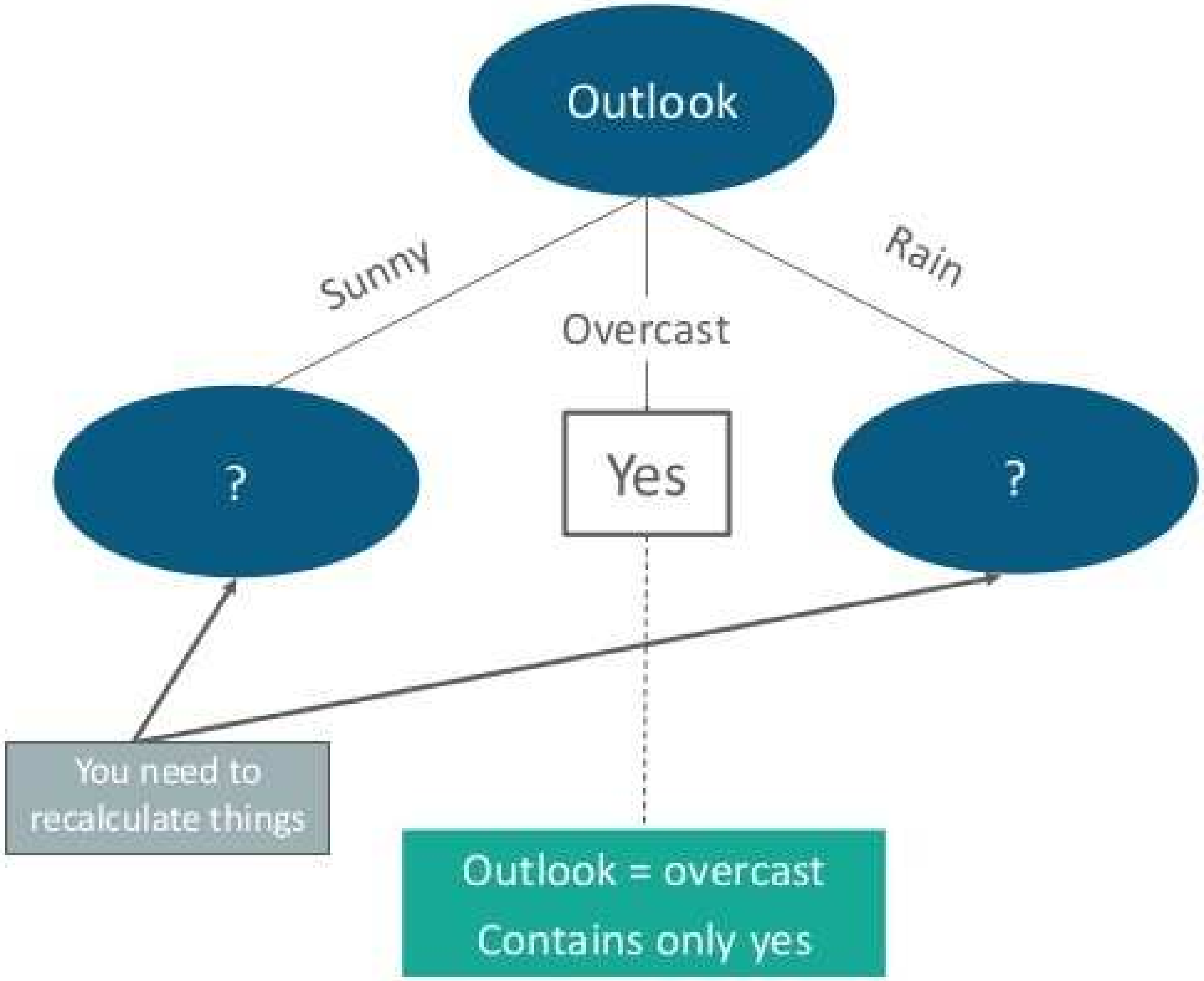
Windy:
Info 0.892
Gain: 0.940-0.982 0.048

Since Max gain = 0.247,

Outlook is our ROOT Node

outlook	temp.	humidity	windy	play
sunny	hot	high	false	no
sunny	hot	high	true	no
overcast	hot	high	false	yes
rainy	mild	high	false	yes
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high	true	yes
overcast	hot	normal	false	yes
rainy	mild	high	true	no

Which Node To Select Further?

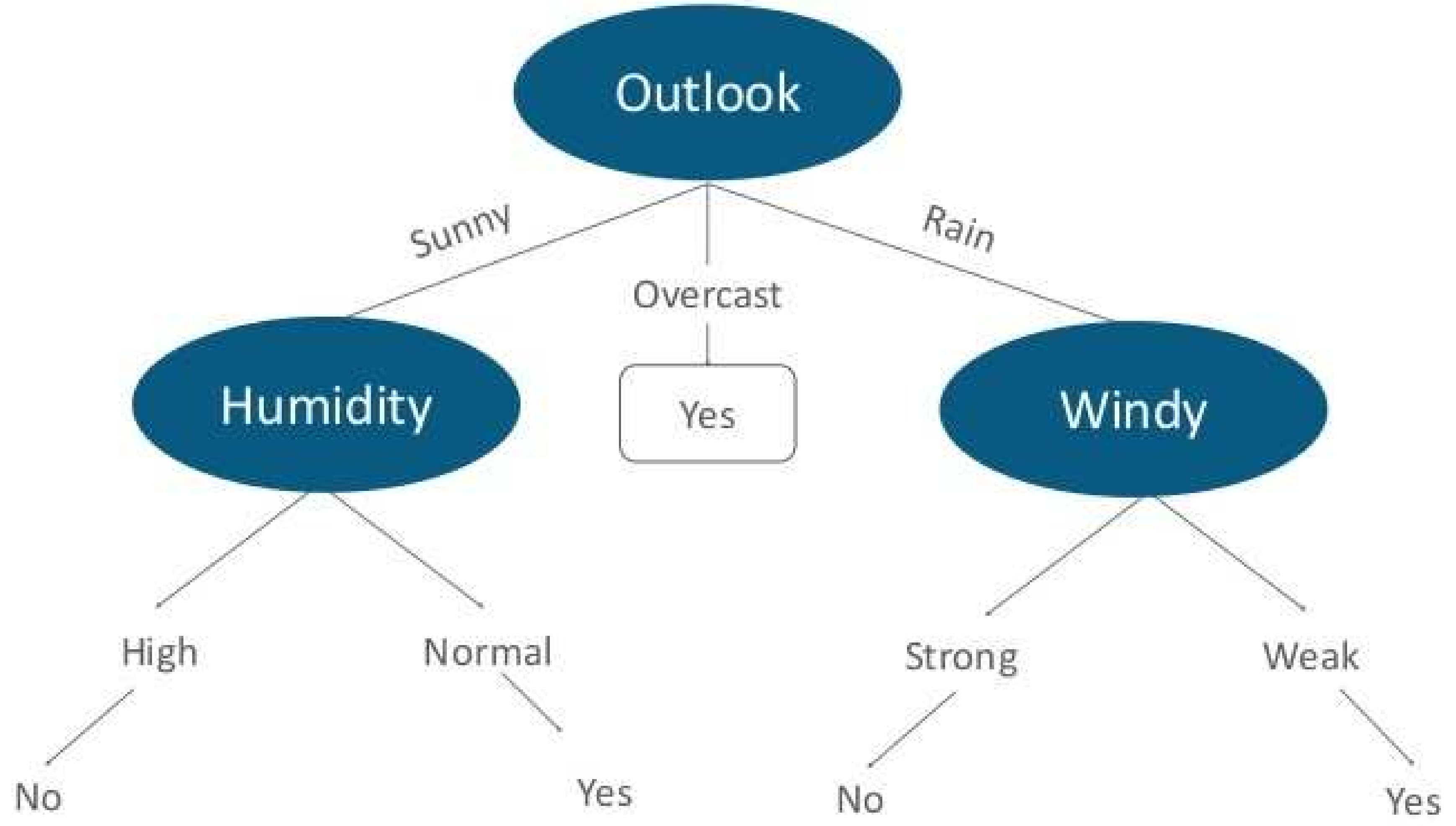


You need to recalculate things

Outlook = overcast
Contains only yes

outlook	temp.	humidity	windy	play
sunny	hot	high	false	no
sunny	hot	high	true	no
overcast	hot	high	false	yes
rainy	mild	high	false	yes
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high	true	yes
overcast	hot	normal	false	yes
rainy	mild	high	true	no

This Is How Your Complete Tree Will Look Like



Machine Leaning
Training Using
Python

What Should I Do To Play - Pruning

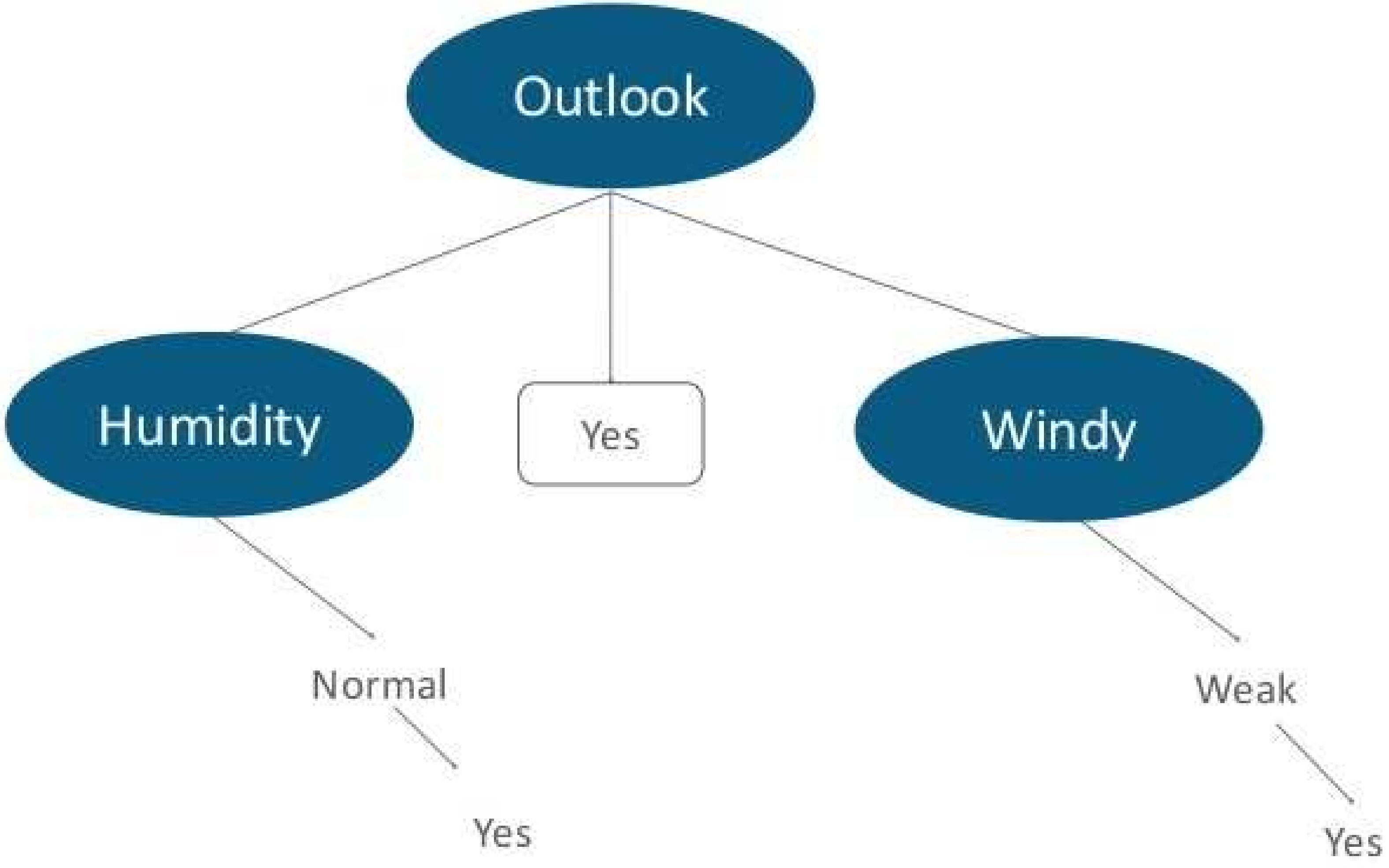
edureka!

edureka!

What is Pruning?

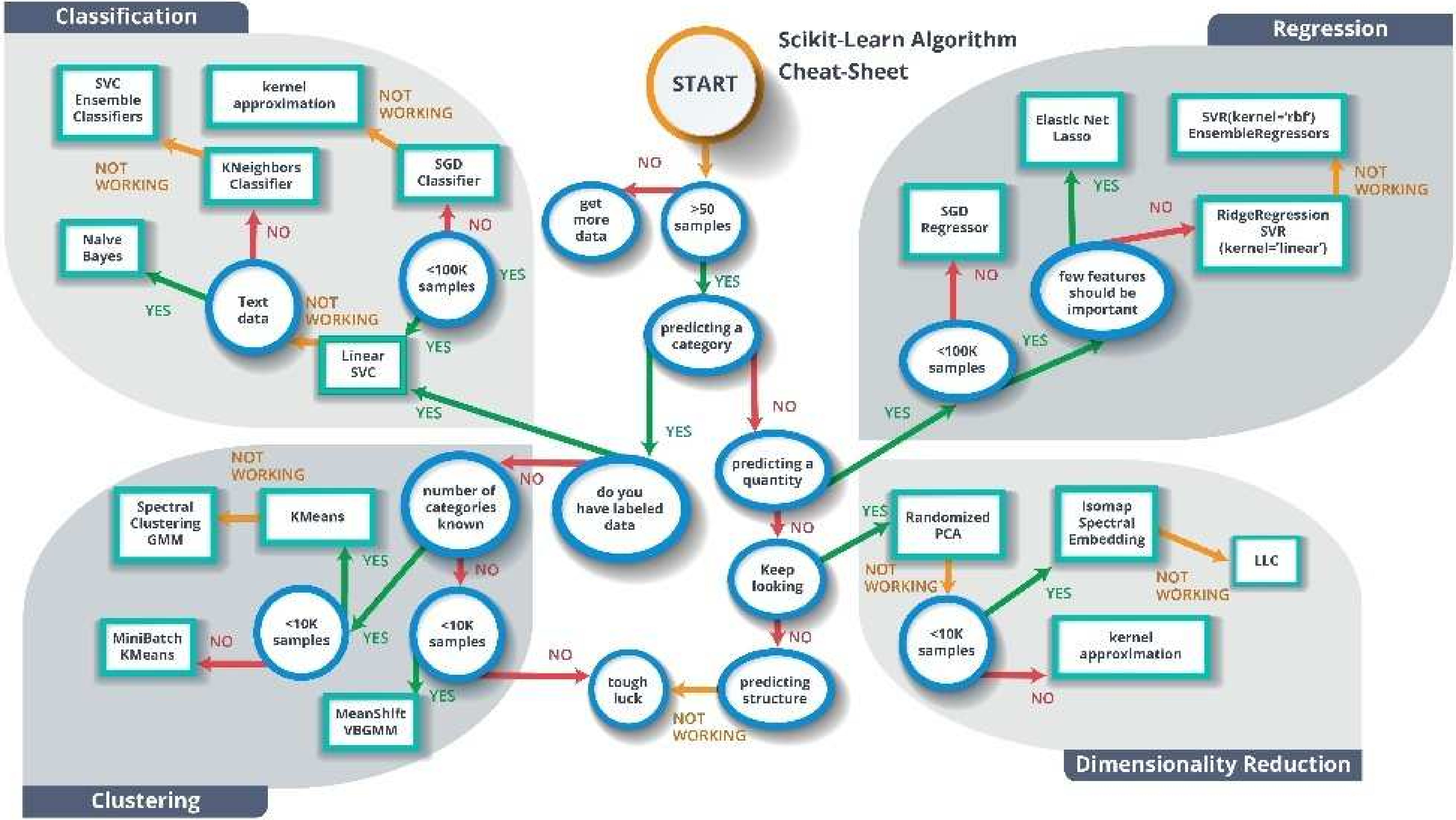
"A decision tree is a graphical representation of all the possible solutions to a decision based on certain conditions"

Pruning: Reducing The Complexity



Are tree based models better than linear models?

Scikit-Learn Algorithm Cheat-Sheet



START

>50 samples

NO

get more data

YES

predicting a category

YES

do you have labeled data

YES

NO

Classification

<100K samples

YES

Linear SVC

NOT WORKING

Text data

YES

Naive Bayes

NO

KNeighbors Classifier

NOT WORKING

SVC Ensemble Classifiers

NO

SGD Classifier

NOT WORKING

kernel approximation

Clustering

number of categories known

YES

<10K samples

YES

KMeans

NOT WORKING

Spectral Clustering GMM

NO

MiniBatch KMeans

NO

<10K samples

YES

MeanShift VBGMM

NO

tough luck

NO

predicting a quantity

YES

Regression

<100K samples

NO

SGD Regressor

YES

few features should be important

YES

Elastic Net Lasso

NO

RidgeRegression SVR (kernel='linear')

NOT WORKING

SVR(kernel='rbf') EnsembleRegressors

NO

Keep looking

YES

Dimensionality Reduction

Randomized PCA

NOT WORKING

<10K samples

YES

Isomap Spectral Embedding

NOT WORKING

LLC

NO

kernel approximation

NO

predicting structure

NOT WORKING

tough luck

edureka!