San Francisco Bay University

CS483 - Fundamentals of Artificial Intelligence
Homework Assignment #4

Instruction: **Due day: 7/21/2022**

A. Push the source code to Github
B. Overdue homework submission could not be accepted.
C. Take academic honesty and integrity seriously (Zero Tolerance of Cheating & Plagiarism)

1. Re-calculate the entropy for the feature selection in the example of file "*Gini Impurity Cal in Decision Tree*" rather than Gini impurity method. And then, compare the results from two different criteria

   Hint: taking the reference at the following link for your calculation

   https://towardsdatascience.com/entropy-how-decision-trees-make-decisions-2946b9c18c8

Solution:

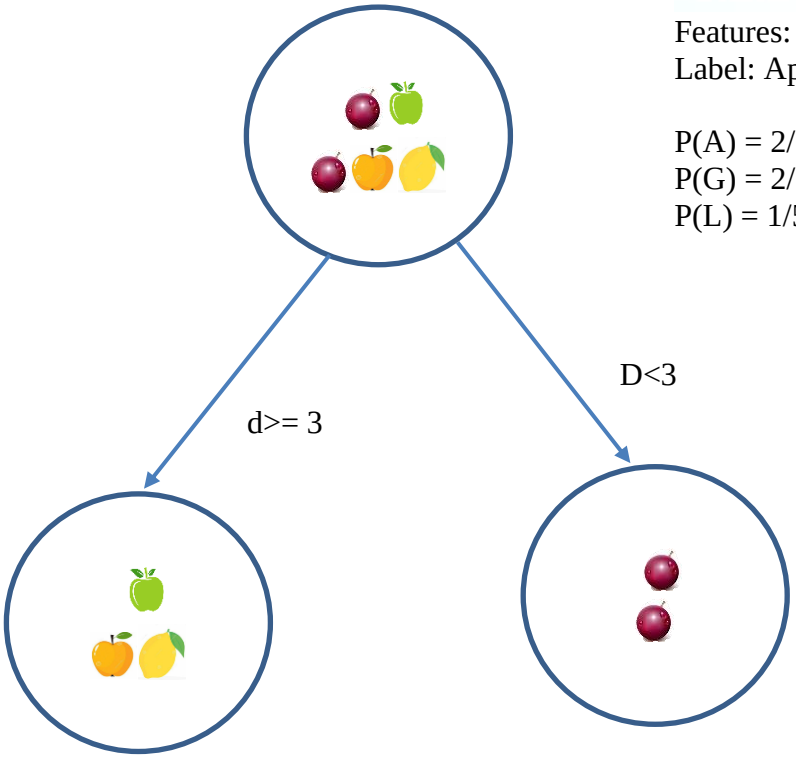
Color	Diameter	Label
Green	3	Apple
Yellow	3	Apple
Red	1	Grape
Red	1	Grape
Yellow	3	Lemon

Feature 1: Diameter

Total pop = 5
Apple: 2
Grape: 2
Lemon: 1

Features: Color, Diameter
Label: Apple, Grape, Lemon

P(A) = 2/5 = 0.4
P(G) = 2/5 = 0.4
P(L) = 1/5 = 0.2



For diameter >=3

P(A) = 2/3 = 0.67
P(L) = 1/3 = 0.33

For diameter < 3

P(A) = 0/2 = 0
P(G) = 2/2 = 1

Diameter Entropy (Ed) Calculation:

E (Parent) = $-P(A)\log_2 P(A) - P(G)\log_2 P(G) - P(L)\log_2 P(L)$

$= -\frac{2}{5}\log_2\left(\frac{2}{5}\right) - \frac{2}{5}\log_2\left(\frac{2}{5}\right) - \frac{1}{5}\log_2\left(\frac{1}{5}\right) = 1.52$

E (d>= 3) = $-\frac{2}{3}\log_2\left(\frac{2}{3}\right) - 0 - \frac{1}{3}\log_2\left(\frac{1}{3}\right) = 0.98$

E (d< 3) = $0 - \frac{2}{2}\log_2\left(\frac{2}{2}\right) - 0 = 0$

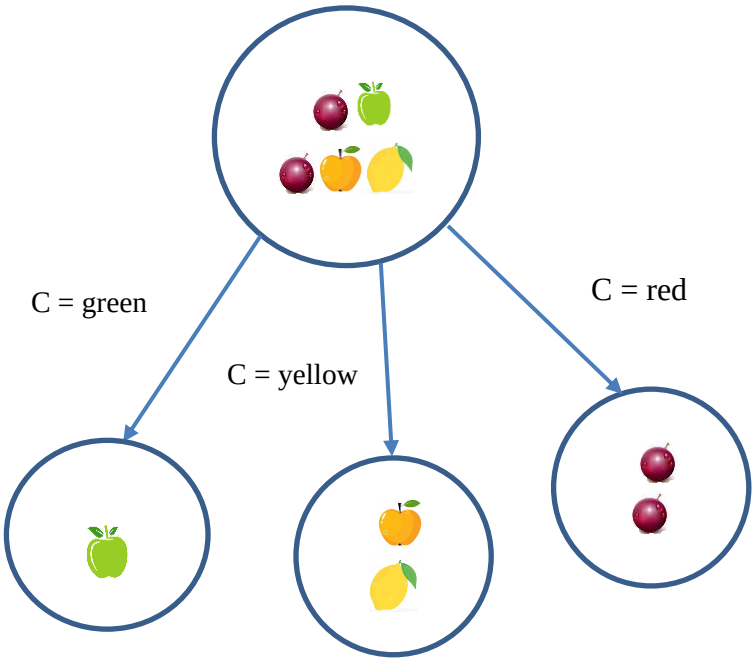
Weighted average of entropies

E(diameter) = $\frac{3}{5} * 0.98 + \frac{2}{5} * 0 = 0.588$

Information Gain = E(Parent) - E(diameter) = 1.52-0.588 = 0.932

Feature 2: color

Color	Diameter	Label
Green	3	Apple
Yellow	3	Apple
Red	1	Grape
Red	1	Grape
Yellow	3	Lemon



For color=green

P(A) = 1/1
P(L) = 0
P(G) = 0

For color=yellow

P(A) = 1/2
P(L) = 1/2
P(G) = 0

For color=red

P(A) = 0
P(L) = 0
P(G) = 2/2

Color Entropy (Ed) Calculation:

E (C = green) = $-P(A)\log_2 P(A) - P(G)\log_2 P(G) - P(L)\log_2 P(L)$
$= 0$

E (C = yellow) = $-\frac{1}{2}\log_2\left(\frac{1}{2}\right) - \frac{1}{2}\log_2\left(\frac{1}{2}\right) - 0 = 1$

E (C = red) = 0

Weighted average of entropies

$$E(Color) = \frac{1}{5} * 0 + \frac{2}{5} * 1 + \frac{2}{5} * 0 = 0.4$$

Information Gain = E(Parent) - E(color) = 1.52-0.4 = 1.12

Conclusion:

The information gain from color feature is higher than the one from diameter, hence the first choice for classification is **color.** Comparing the Gini index and Entropy, Gini index requires less mathematical computation compared to entropy, but entropy is more accurate as shown in this example (Entropy achieved the same classification accuracy as Gini impurity in the first level)

2. Given a dataset as follows, please buildup a decision tree with max information gain comparing the different condition checking features by hand calculation **Gini impurity and information gain.** And predict "Profit" in the new data. After that, write Python program to verify your design through calling existing functions from the library

Age	Competition	Type	Profit
Old	Yes	Software	Down
Old	No	Software	Down
Old	No	Hardware	Down
Mid	Yes	Software	Down
Mid	Yes	Hardware	Down
Mid	No	Hardware	Up
Mid	No	Software	Up
New	Yes	Software	Up
New	No	Hardware	Up
New	No	Software	Up
Mid	No	Hardware	?

Solution:

Level 1: Impurity of root

imp = P(Down)*(1-P(Down)) + P(up)*(1-P(up))
= 5/10*(1-5/10) + 5/10*(1-5/10)
= 0.5

Ave. Imp = 10/10 * 0.5 = **0.5**

Level 2; Impurity of Age

Old	Down	Up
3	3	0

Mid	down	up
4	2	2

New	down	up
3	0	3

Imp = P(Down)*(1-P(Down)) + P(up)*(1-P(up))

Imp= 3/3*(1-3/3) + 0/3*(1-0/3)
= 0

Imp = 2/4*(1-2/4) + 2/4*(1-2/4)
= 0.5

Imp = 0/3*(1-0/3) + 3/3*(1-3/3)
= 0

Ave. Imp = 3/10*0
= 0

Ave.Imp = 4/10*0.5
= 0.2

Ave. Imp = 3/10*0
= 0

Tot. Ave. Imp. = 0 + 0.2 + 0 = **0.2**

Info. Gain = 0.5 (from Ave.Imp of level 1) - 0.2(from Tot. Ave. Imp) = **0.3**

Impurity of Competition:

Yes	Down	Up
4	3	1

No	down	up
6	2	4

Imp = P(Down)*(1-P(Down)) + P(up)*(1-P(up))

Imp= 3/4*(1-3/4) + 1/4*(1-1/4)
= 0.375

Imp = 2/6*(1-2/6) + 4/6*(1-4/6)
= 0.44

Ave. Imp = 4/10*0.375
= 0.15

Ave. Imp = 6/10*0.44
= 0.264

Tot. Ave. Imp. = 0.15 + 0.264 = **0.414**

Info. Gain = 0.5 (from Ave.Imp of level 1) - 0.414(from Tot. Ave. Imp) = **0.086**

Impurity of Type:

Software	Down	Up
6	3	3

hardware	down	up
4	2	2

Imp = P(Down)*(1-P(Down)) + P(up)*(1-P(up))

Imp = 3/6*(1-3/6) + 3/6*(1-3/6)
= 0.5

Imp = 2/4*(1-2/4) + 2/4*(1-2/4)
= 0.5

Ave. Imp = 6/10*0.5
= 0.3

Ave. Imp = 4/10*0.5
= 0.2

Tot. Ave. Imp. = 0.3 + 0.2 = **0.5**

Info. Gain = 0.5 (from Ave.Imp of level 1) - 0.5(from Tot. Ave. Imp) = **0**

Comparing Info Gains

Age	Competition	Type
0.3	**0.086**	**0.0**

→ **Taking "Age" will get highest info gain**

Level 3:

Age	Competition	Type	Profit
Old	Yes	Software	Down
Old	No	Software	Down
Old	No	Hardware	Down

Age	Competition	Type	Profit
Mid	Yes	Software	Down
Mid	Yes	Hardware	Down
Mid	No	Hardware	Up
Mid	No	Software	Up

Impurity of **Competition** in **old**

Avg.imp = **0**
Information gain = **0.3-0** = **0.3**

Impurity of **type** in **old**

Avg.imp = **0**
Information gain = **0.3-0** = **0.3**

Comparing Info Gains in old

Competition	Type
0.3	**0.3**

Both get the same info gain

Impurity of **Competition** in **Mid**

Yes	Down	Up
2	2	0

No	down	up
2	0	2

Impurity of **yes** in **Competition**

Imp = P(Down)*(1-P(Down)) + P(up)*(1-P(up))
Imp = 2/2*(1-2/2) + 0/2*(1-0/2) = 0

Impurity of **No** in **Competition**

Imp = P(Down)*(1-P(Down)) + P(up)*(1-P(up))
Imp = 0/2*(1-0/2) + 2/2*(1-2/2) = 0
Tot. Ave. Imp. = 0 + 0 = **0**
Information gain = **0.3-0** = **0.3**

Impurity of **Type** in **Mid**

Software	Down	Up
2	1	1

Hardware	down	up
2	1	1

Impurity of **software** in **type**

Imp = P(Down)*(1-P(Down)) + P(up)*(1-P(up))

Imp = 1/2*(1-1/2) + 1/2*(1-1/2) = 0.5

Impurity of **hardware** in **type**

Imp = P(Down)*(1-P(Down)) + P(up)*(1-P(up))

Imp = 1/2*(1-1/2) + 1/2*(1-1/2) = 0.5

Tot. Ave. Imp. = 0.5 + 0.5 = **1**

Information gain = 0.3-1 = -0.7

Comparing Info Gains in mid	
Competition	**Type**
0.3	**-0.7**

Competition has higher info gain

Impurity of **New**

Age	Competition	Type	Profit
New	Yes	Software	Up
New	No	Hardware	Up
New	No	Software	Up

Impurity of **Competition** in **new**

Avg.imp = 0

Information gain = 0.3-0 = 0.3

Impurity of **type** in **new**

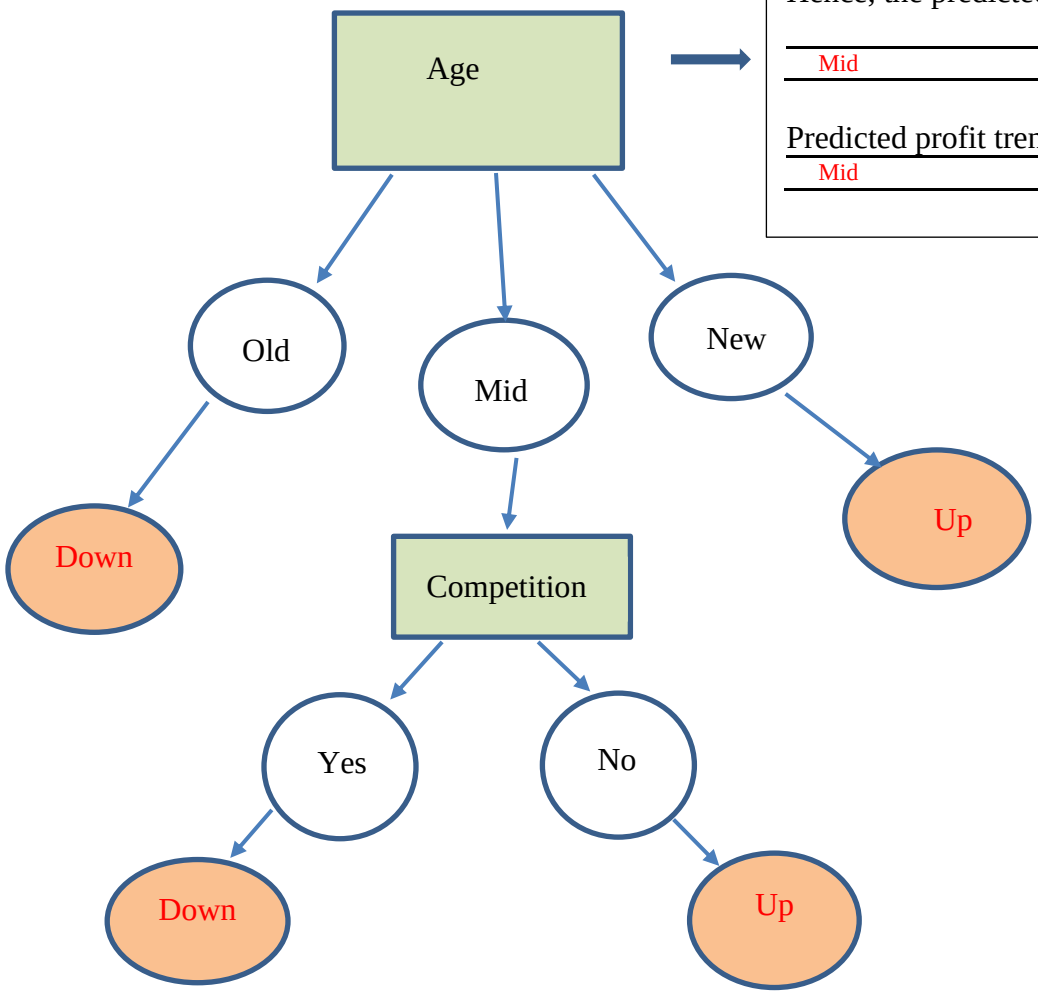
Avg.imp = 0

Information gain = 0.3-0 = 0.3

Comparing Info Gains in mid	
Competition	**Type**
0.3	**0.3**

Both features have the same info gain

Final Decision Tree:



Hence, the predicted profit for:

Mid	No	Hardware	?

Predicted profit trend is Up

Mid	No	Hardware	up

Python Code Verification:

```
#!/usr/bin/env python
# coding: utf-8

import pandas as pd
import numpy as np
from sklearn.tree import DecisionTreeClassifier
from sklearn import tree


"""
    Loading Data
"""
col_names = ['Age', 'Competition',  'Type', 'Profit']
# load dataset
df = pd.read_csv("/content/fruits.csv")
df.head()

df=df.split('\n')
dat=[]
for data in df:
    word=data.split(' ')
    dat.append(word)
ndf=pd.DataFrame(dat,columns=['Age','Competition','Type','profit'])


x_train=ndf.iloc[:,0:3]
y_train=ndf.iloc[:,3]
print(x_train)

clf_tree=DecisionTreeClassifier(random_state=0,max_depth=3)
clf_fit=clf_tree.fit(x_train,y_train)

x_test=np.array([1,1,1])
x_test=x_test.reshape(1,-1)
predicted=clf_fit.predict(x_test)
```