# Decision Trees

October 27, 2019

[1]:
```
import pandas as pd

columns = ["Day", "Outlook", "Temp", "Humidity", "Wind", "Play?"]
day_data = ["D1", "D2", "D3", "D4", "D5", "D6", "D7", "D8", "D9", "D10", "D11",␣
 ↪"D12", "D13", "D14", "D15", "D16"]
outlook_data = ["Sunny", "Sunny", "Overcast", "Rain", "Rain", "Rain",␣
 ↪"Overcast", "Sunny", "Sunny", "Rain", "Sunny", "Overcast", "Overcast",␣
 ↪"Rain", "Overcast", "Sunny"]
temp_data = ["Hot", "Hot", "Hot", "Mild", "Cool", "Cool", "Cool", "Mild",␣
 ↪"Cool", "Mild", "Mild", "Mild", "Hot", "Mild", "Mild", "Hot"]
humidity_data = ["High", "High", "High", "High", "Normal", "Normal", "Normal",␣
 ↪"High", "Normal", "Normal", "Normal", "High", "Normal", "High", "Normal",␣
 ↪"Normal"]
wind_data = ["Weak", "Strong", "Weak", "Weak", "Weak", "Strong", "Strong",␣
 ↪"Weak", "Weak", "Weak", "Strong", "Strong", "Weak", "Strong", "Weak",␣
 ↪"Strong"]
play_data = ["No", "No", "No", "Yes", "Yes", "No", "Yes", "No", "Yes", "Yes",␣
 ↪"Yes", "Yes", "No", "No", "", ""]
df = pd.DataFrame(columns = columns)
df['Day'] = day_data
df['Outlook'] = outlook_data
df['Temp'] = temp_data
df['Humidity'] = humidity_data
df['Wind'] = wind_data
df['Play?'] = play_data
df
```

[1]:
```
    Day   Outlook  Temp Humidity    Wind Play?
0    D1     Sunny   Hot     High    Weak    No
1    D2     Sunny   Hot     High  Strong    No
2    D3  Overcast   Hot     High    Weak    No
3    D4      Rain  Mild     High    Weak   Yes
4    D5      Rain  Cool   Normal    Weak   Yes
5    D6      Rain  Cool   Normal  Strong    No
6    D7  Overcast  Cool   Normal  Strong   Yes
7    D8     Sunny  Mild     High    Weak    No
8    D9     Sunny  Cool   Normal    Weak   Yes
```

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9   D10      Rain  Mild   Normal    Weak   Yes
10  D11     Sunny  Mild   Normal  Strong   Yes
11  D12  Overcast  Mild     High  Strong   Yes
12  D13  Overcast   Hot   Normal    Weak    No
13  D14      Rain  Mild     High  Strong    No
14  D15  Overcast  Mild   Normal    Weak
15  D16     Sunny   Hot   Normal  Strong
```

[2]:
```
from math import log2
# First step of ID3, done manually

#First define the entropy of a decision
numNo = 7
numYes = 7
numTotal = 14
entropyDecision = -(numYes/numTotal * log2(numYes/numTotal)) - (numNo/numTotal␣
 ↪* log2(numNo/numTotal))
print("Decision Entropy:",entropyDecision)

# Starting with wind
numWeak = 8 # Not counting D15 and D16
numWeakYes = 4 # Number of times wind was weak and golf was played
numWeakNo = 4 # Number of times wind was not weak (was strong) and golf was␣
 ↪played
entropyWindWeak = -(numWeakNo/numWeak * log2(numWeakNo/numWeak)) - (numWeakYes/
 ↪numWeak * log2(numWeakYes/numWeak))
print("Entropy for weak wind:",entropyWindWeak)

numStrong = 6
numStrongYes = 3
numStrongNo = 3
entropyStrongWind = -(numStrongNo/numStrong * log2(numStrongNo/numStrong)) -␣
 ↪(numStrongYes/numStrong * log2(numStrongYes/numStrong))
print("Entropy for strong wind:",entropyStrongWind)

gainWind = entropyDecision - (numWeak/numTotal * entropyWindWeak) - (numStrong/
 ↪numTotal * entropyStrongWind)
print("Gain for Wind:",gainWind)

# Now for humidity
numHigh = 7
numNormal = 7
numHighYes = 2
numHighNo = 5
numNormalYes = 5
numNormalNo = 2
```

```
entropyHigh = -(numHighNo/numHigh * log2(numHighNo/numHigh)) - (numHighYes/numHigh * log2(numHighYes/numHigh))
entropyNormal = -(numNormalNo/numNormal * log2(numNormalNo/numNormal)) - (numNormalYes/numNormal * log2(numNormalYes/numNormal))
print("\nEntropy for high humidity:",entropyHigh)
print("Entropy for normal humidity:",entropyNormal)
gainHumidity = entropyDecision - (numHigh/numTotal * entropyHigh) - (numNormal/numTotal * entropyNormal)
print("Gain for Humidity:",gainHumidity)

# Next, Temperature
numHot = 4
numMild = 6
numCool = 4
numHotYes = 0
numHotNo = 4
numMildYes = 4
numMildNo = 2
numCoolYes = 3
numCoolNo = 1
# entropyHot = -(numHotNo/numHot * log2(numHotNo/numHot)) - (numHotYes/numHot * log2(numHotYes/numHot))
# Just kidding! The entropy for high temperatures is 0, because the value is always No so there is no variation
entropyHot = 0
entropyMild = -(numMildNo/numMild * log2(numMildNo/numMild)) - (numMildYes/numMild * log2(numMildYes/numMild))
entropyCool = -(numCoolNo/numCool * log2(numCoolNo/numCool)) - (numCoolYes/numCool * log2(numCoolYes/numCool))
gainTemp = entropyDecision - (numHot/numTotal * entropyHot) - (numMild/numTotal * entropyMild) - (numCool/numTotal * entropyCool)
print("\nEntropy for hot temp:",entropyHot)
print("Entropy for mild temp:",entropyMild)
print("Entropy for cool temp:",entropyCool)
print("Gain for Temperature:",gainTemp)

# Finally, outlook
numSunny = 5
numOver = 4
numRain = 5
numSunnyYes = 2
numSunnyNo = 3
numOverYes = 2
numOverNo = 2
numRainYes = 3
numRainNo = 2
```

```
entropySunny = -(numSunnyNo/numSunny * log2(numSunnyNo/numSunny)) -␣
 ↪(numSunnyYes/numSunny * log2(numSunnyYes/numSunny))
entropyOver = -(numOverNo/numOver * log2(numOverNo/numOver)) - (numOverYes/
 ↪numOver * log2(numOverYes/numOver))
entropyRain = -(numRainNo/numRain * log2(numRainNo/numRain)) - (numRainYes/
 ↪numRain * log2(numRainYes/numRain))
gainOutlook = entropyDecision - (numSunny/numTotal * entropySunny) - (numOver/
 ↪numTotal * entropyOver) - (numRain/numTotal * entropyRain)
print("\nEntropy for sunny:",entropySunny)
print("Entropy for overcast:",entropyOver)
print("Entropy for rainy:",entropyRain)
print("Gain for Outlook:",gainOutlook)

print("\nAs we can see above, the highest gain is temperature, so temperature␣
 ↪is the first divider in the decision tree. This marks the end of the first␣
 ↪step.")
```

```
Decision Entropy: 1.0
Entropy for weak wind: 1.0
Entropy for strong wind: 1.0
Gain for Wind: 5.551115123125783e-17

Entropy for high humidity: 0.863120568566631
Entropy for normal humidity: 0.863120568566631
Gain for Humidity: 0.136879431433369

Entropy for hot temp: 0
Entropy for mild temp: 0.9182958340544896
Entropy for cool temp: 0.8112781244591328
Gain for Temperature: 0.37465089270260943

Entropy for sunny: 0.9709505944546686
Entropy for overcast: 1.0
Entropy for rainy: 0.9709505944546686
Gain for Outlook: 0.020749575389522249

As we can see above, the highest gain is temperature, so temperature is the
first divider in the decision tree. This marks the end of the first step.
```

[3]:
```
from sklearn.preprocessing import LabelEncoder

def one_hot(df):
    rows_to_encode = ['Outlook', 'Temp', 'Humidity', 'Wind', 'Play?']
    for i in rows_to_encode:
        encoder = LabelEncoder()
        df[i] = encoder.fit_transform(df[i])
```

```
one_hot(df)
df
```

[3]:

```
     Day  Outlook  Temp  Humidity  Wind  Play?
0     D1        2     1         0     1      1
1     D2        2     1         0     0      1
2     D3        0     1         0     1      1
3     D4        1     2         0     1      2
4     D5        1     0         1     1      2
5     D6        1     0         1     0      1
6     D7        0     0         1     0      2
7     D8        2     2         0     1      1
8     D9        2     0         1     1      2
9    D10        1     2         1     1      2
10   D11        2     2         1     0      2
11   D12        0     2         0     0      2
12   D13        0     1         1     1      1
13   D14        1     2         0     0      1
14   D15        0     2         1     1      0
15   D16        2     1         1     0      0
```

[4]:

```
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import cross_val_score
from sklearn import tree

data = df.iloc[:14,1:-1]
target = df.iloc[:14, -1:]

clf = DecisionTreeClassifier(criterion='entropy', random_state=0)
model = clf.fit(data, target)
```

[5]:

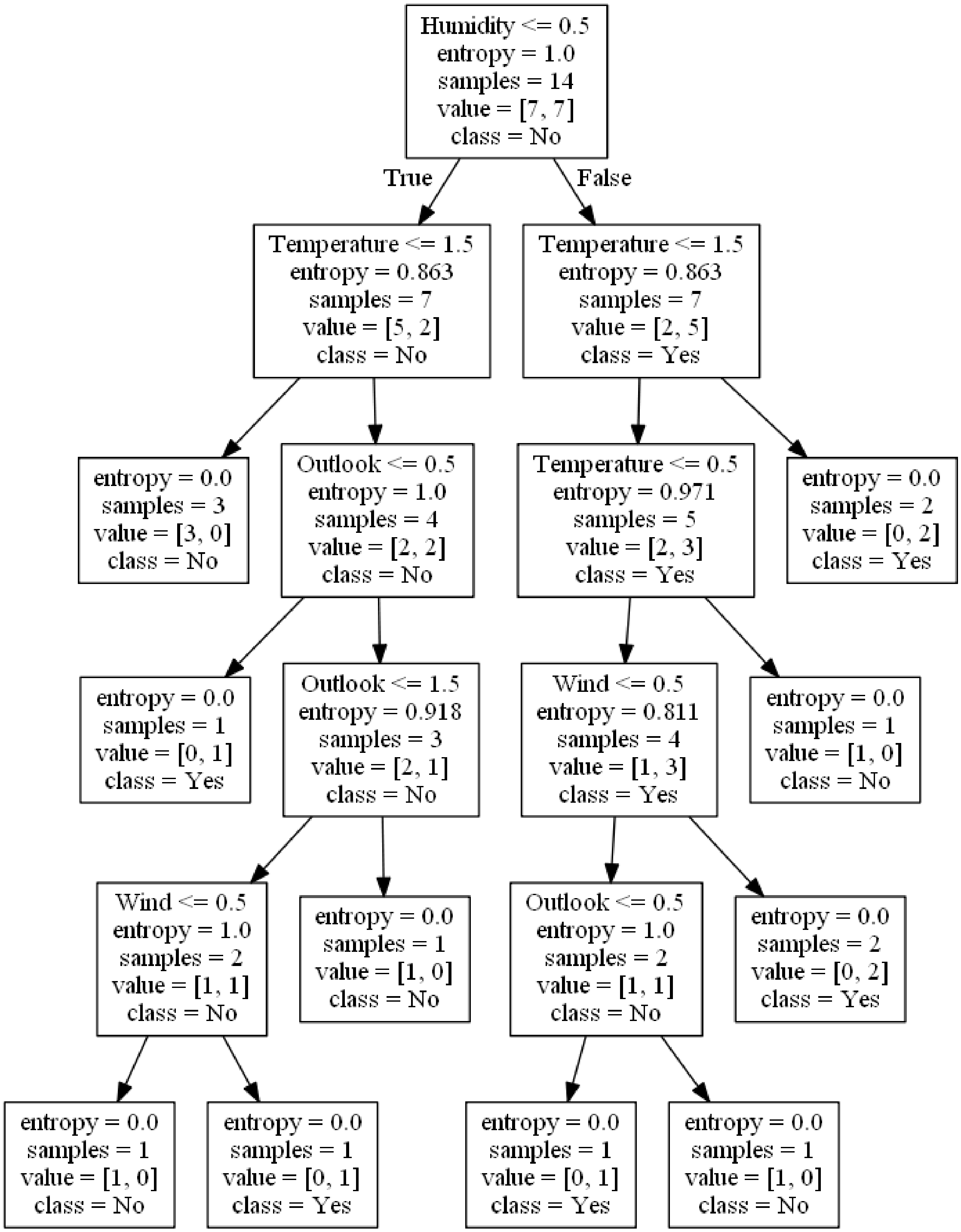
```
d15_data = df.iloc[14:15,1:-1]
d15_prob = model.predict_proba(d15_data)
print("Probabilities for Day 15:",d15_prob,"which corresponds to a 100%␣
 ↪probability on 'Yes'")
d16_data = df.iloc[15:16,1:-1]
d16_prob = clf.predict_proba(d16_data)
print("Probabilities for Day 16:",d16_prob,"which corresponds to a 100%␣
 ↪probability on 'No'")
```

```
Probabilities for Day 15: [[0. 1.]] which corresponds to a 100% probability on
'Yes'
Probabilities for Day 16: [[1. 0.]] which corresponds to a 100% probability on
'No'
```

[6]:

```
import pydotplus
from IPython.display import Image
dot_data = tree.export_graphviz(clf,
                                out_file=None,
                                                ␣
 ↪feature_names=["Outlook","Temperature","Humidity","Wind"],
                                                 class_names=["No","Yes"])
graph = pydotplus.graph_from_dot_data(dot_data)
Image(graph.create_png())
```

[6]:


Humidity <= 0.5
entropy = 1.0
samples = 14
value = [7, 7]
class = No
True
False
Temperature <= 1.5
entropy = 0.863
samples = 7
value = [5, 2]
class = No
Temperature <= 1.5
entropy = 0.863
samples = 7
value = [2, 5]
class = Yes
entropy = 0.0
samples = 3
value = [3, 0]
class = No
Outlook <= 0.5
entropy = 1.0
samples = 4
value = [2, 2]
class = No
Temperature <= 0.5
entropy = 0.971
samples = 5
value = [2, 3]
class = Yes
entropy = 0.0
samples = 2
value = [0, 2]
class = Yes
entropy = 0.0
samples = 1
value = [0, 1]
class = Yes
Outlook <= 1.5
entropy = 0.918
samples = 3
value = [2, 1]
class = No
Wind <= 0.5
entropy = 0.811
samples = 4
value = [1, 3]
class = Yes
entropy = 0.0
samples = 1
value = [1, 0]
class = No
Wind <= 0.5
entropy = 1.0
samples = 2
value = [1, 1]
class = No
entropy = 0.0
samples = 1
value = [1, 0]
class = No
Outlook <= 0.5
entropy = 1.0
samples = 2
value = [1, 1]
class = No
entropy = 0.0
samples = 2
value = [0, 2]
class = Yes
entropy = 0.0
samples = 1
value = [1, 0]
class = No
entropy = 0.0
samples = 1
value = [0, 1]
class = Yes
entropy = 0.0
samples = 1
value = [0, 1]
class = Yes
entropy = 0.0
samples = 1
value = [1, 0]
class = No