Assignment is below at the end

- https://scikit-learn.org/stable/modules/tree.html (https://scikit-learn.org/stable/modules/tree.html)
- https://scikit-learn.org/stable/modules/generated/sklearn.tree.DecisionTreeClassifier.html (https://scikit-learn.org/stable/modules/generated/sklearn.tree.DecisionTreeClassifier.html)
- https://scikit-learn.org/stable/modules/generated/sklearn.tree.plot_tree.html (https://scikit-learn.org/stable/modules/generated/sklearn.tree.plot_tree.html)

In [34]:
```
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline
plt.rcParams['figure.figsize'] = (20, 6)
plt.rcParams['font.size'] = 14
import pandas as pd
```

In [215]:
```
df = pd.read_csv('adult.data', index_col=False)
```

In [5]:
```
golden = pd.read_csv('adult.test', index_col=False)
```

In [6]:
```
golden.head()
```

Out[6]:

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	
0	25	Private	226802	11th	7	Never-married	Machine-op-inspct	Own-child	Black	
1	38	Private	89814	HS-grad	9	Married-civ-spouse	Farming-fishing	Husband	White	
2	28	Local-gov	336951	Assoc-acdm	12	Married-civ-spouse	Protective-serv	Husband	White	
3	44	Private	160323	Some-college	10	Married-civ-spouse	Machine-op-inspct	Husband	Black	
4	18	?	103497	Some-college	10	Never-married	?	Own-child	White	Fe

In [7]:
```
df.head()
```

Out[7]:

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	
0	39	State-gov	77516	Bachelors	13	Never-married	Adm-clerical	Not-in-family	White	
1	50	Self-emp-not-inc	83311	Bachelors	13	Married-civ-spouse	Exec-managerial	Husband	White	
2	38	Private	215646	HS-grad	9	Divorced	Handlers-cleaners	Not-in-family	White	
3	53	Private	234721	11th	7	Married-civ-spouse	Handlers-cleaners	Husband	Black	
4	28	Private	338409	Bachelors	13	Married-civ-spouse	Prof-specialty	Wife	Black	F

In [8]:
```
df.columns
```

Out[8]:
```
Index(['age', 'workclass', 'fnlwgt', 'education', 'education-num',
       'marital-status', 'occupation', 'relationship', 'race', 'sex',
       'capital-gain', 'capital-loss', 'hours-per-week', 'native-coun
try',
       'salary'],
      dtype='object')
```

In [9]:
```
from sklearn import preprocessing
```

In [20]:
```
import sklearn
print(sklearn.__version__)
```

```
1.0.2
```

In [18]:
```
!pip install --upgrade scikit-learn
```

```
Requirement already satisfied: scikit-learn in /opt/anaconda3/lib/pyt
hon3.9/site-packages (1.0.2)
Collecting scikit-learn
  Downloading scikit_learn-1.2.1-cp39-cp39-macosx_10_9_x86_64.whl (9.
1 MB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 9.1/9.1 MB 8.1 MB/s eta
0:00:0000:0100:01
Requirement already satisfied: threadpoolctl>=2.0.0 in /opt/anaconda3
/lib/python3.9/site-packages (from scikit-learn) (2.2.0)
Collecting joblib>=1.1.1
  Downloading joblib-1.2.0-py3-none-any.whl (297 kB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 298.0/298.0 kB 11.3 MB/s
eta 0:00:00
Requirement already satisfied: scipy>=1.3.2 in /opt/anaconda3/lib/pyt
hon3.9/site-packages (from scikit-learn) (1.9.1)
Requirement already satisfied: numpy>=1.17.3 in /opt/anaconda3/lib/py
thon3.9/site-packages (from scikit-learn) (1.21.5)
Installing collected packages: joblib, scikit-learn
  Attempting uninstall: joblib
    Found existing installation: joblib 1.1.0
    Uninstalling joblib-1.1.0:
      Successfully uninstalled joblib-1.1.0
  Attempting uninstall: scikit-learn
    Found existing installation: scikit-learn 1.0.2
    Uninstalling scikit-learn-1.0.2:
      Successfully uninstalled scikit-learn-1.0.2
Successfully installed joblib-1.2.0 scikit-learn-1.2.1
```

In [1]:
```
import sklearn
print(sklearn.__version__)
```

```
1.2.1
```

In [85]:
```
# Columns we want to transform
transform_columns = ['sex']

#Columns we can't use because non-numerical
non_num_columns = ['workclass', 'education', 'marital-status',
                   'occupation', 'relationship', 'race', 'sex',
                   'native-country']
```

In [86]:
```
transform_columns, non_num_columns
```

Out[86]:
```
(['sex'],
 ['workclass',
  'education',
  'marital-status',
  'occupation',
  'relationship',
  'race',
  'sex',
  'native-country'])
```

First let's try using `pandas.get_dummies()` to transform columns

In [87]:
```
dummies = pd.get_dummies(df[transform_columns])
dummies
```

Out[87]:

	sex_ Female	sex_ Male
0	0	1
1	0	1
2	0	1
3	0	1
4	1	0
...	...	...
32556	1	0
32557	0	1
32558	1	0
32559	0	1
32560	1	0

32561 rows × 2 columns

In [88]:
```
dummies.shape
```

Out[88]:
```
(32561, 2)
```

sklearn has a similar process for OneHot Encoding features

In [89]:
```
onehot = preprocessing.OneHotEncoder(handle_unknown="infrequent_if_exi
onehot.fit(df[transform_columns])
```

```
/opt/anaconda3/lib/python3.9/site-packages/sklearn/preprocessing/_enc
oders.py:828: FutureWarning: `sparse` was renamed to `sparse_output`
in version 1.2 and will be removed in 1.4. `sparse_output` is ignored
unless you leave `sparse` to its default value.
  warnings.warn(
```

Out[89]:
```
OneHotEncoder(handle_unknown='infrequent_if_exist', sparse=False,
              sparse_output=False)
```

In a Jupyter environment, please rerun this cell to show the HTML representation or trust the notebook.
On GitHub, the HTML representation is unable to render, please try loading this page with nbviewer.org.

In [90]:
```
onehot.categories_
```

Out[90]:
```
[array([' Female', ' Male'], dtype=object)]
```

In [91]:
```
sex = onehot.transform(df[transform_columns])
sex
```

Out[91]:
```
array([[0., 1.],
       [0., 1.],
       [0., 1.],
       ...,
       [1., 0.],
       [0., 1.],
       [1., 0.]])
```

In [92]:
```
sex.shape
```

Out[92]:
```
(32561, 2)
```

In addition to OneHot encoding there is Ordinal Encoding

In [93]:
```
enc = preprocessing.OrdinalEncoder()
enc.fit(df[["salary"]])
salary = enc.transform(df[["salary"]])
salary
```

Out[93]:
```
array([[0.],
       [0.],
       [0.],
       ...,
       [0.],
       [0.],
       [1.]])
```

In [94]:
```
enc.categories_[0]
```

Out[94]:
```
array([' <=50K', ' >50K'], dtype=object)
```

In [95]:
```
x = df.copy()

# transformed = pd.get_dummies(df[transform_columns])


onehot = preprocessing.OneHotEncoder(handle_unknown="infrequent_if_exi

enc = preprocessing.OrdinalEncoder()

enc.fit(df[["salary"]])


transformed = onehot.transform(df[transform_columns])
new_cols = list(onehot.categories_[0].flatten())
df_trans = pd.DataFrame(transformed, columns=new_cols)


x = pd.concat(
    [
        x.drop(non_num_columns, axis=1),
        df_trans
    ],
    axis=1,)


x["salary"] = enc.transform(df[["salary"]])
```

```
/opt/anaconda3/lib/python3.9/site-packages/sklearn/preprocessing/_enc
oders.py:828: FutureWarning: `sparse` was renamed to `sparse_output`
in version 1.2 and will be removed in 1.4. `sparse_output` is ignored
unless you leave `sparse` to its default value.
  warnings.warn(
```

In [246]:
```
df_trans
```

Out[246]:

	Female	Male
0	0.0	1.0
1	0.0	1.0
2	0.0	1.0
3	0.0	1.0
4	1.0	0.0
...	...	...
16276	1.0	0.0
16277	0.0	1.0
16278	0.0	1.0
16279	0.0	1.0
16280	0.0	1.0

16281 rows × 2 columns

In [256]:
```
enc.fit(df[["salary"]])
```

Out[256]:
```
▾ OrdinalEncoder
OrdinalEncoder()
```

In [240]:
```
onehot.transform(df[transform_columns])
```

Out[240]:
```
array([[0., 1.],
       [0., 1.],
       [0., 1.],
       ...,
       [1., 0.],
       [0., 1.],
       [1., 0.]])
```

In [96]:
```
x.head()
```

Out[96]:

	age	fnlwgt	education-num	capital-gain	capital-loss	hours-per-week	salary	Female	Male
0	39	77516	13	2174	0	40	0.0	0.0	1.0
1	50	83311	13	0	0	13	0.0	0.0	1.0
2	38	215646	9	0	0	40	0.0	0.0	1.0
3	53	234721	7	0	0	40	0.0	0.0	1.0
4	28	338409	13	0	0	40	0.0	1.0	0.0

In [97]:
```
xt = golden.copy()

transformed = onehot.transform(xt[transform_columns])
new_cols = list(onehot.categories_[0].flatten())
df_trans = pd.DataFrame(transformed, columns=new_cols)

xt = pd.concat(
    [
        xt.drop(non_num_columns, axis=1),
        df_trans
    ],
    axis=1,)

xt["salary"] = enc.fit_transform(golden[["salary"]])
```

In [98]:
```
list(xt)
```

Out[98]:
```
['age',
 'fnlwgt',
 'education-num',
 'capital-gain',
 'capital-loss',
 'hours-per-week',
 'salary',
 ' Female',
 ' Male']
```

In [99]:
```
xt.salary.value_counts()
```

Out[99]:
```
0.0    12435
1.0     3846
Name: salary, dtype: int64
```

In [100]:
```
xt.salary, x.salary
```

Out[100]:
```
(0        0.0
 1        0.0
 2        1.0
 3        1.0
 4        0.0
        ...
 16276    0.0
 16277    0.0
 16278    0.0
 16279    0.0
 16280    1.0
 Name: salary, Length: 16281, dtype: float64,
 0        0.0
 1        0.0
 2        0.0
 3        0.0
 4        0.0
        ...
 32556    0.0
 32557    1.0
 32558    0.0
 32559    0.0
 32560    1.0
 Name: salary, Length: 32561, dtype: float64)
```

In [101]:
```
enc.categories_
```

Out[101]:
```
[array([' <=50K.', ' >50K.'], dtype=object)]
```

In [102]:
```
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.ensemble import GradientBoostingClassifier
```

Choose the model of your preference: DecisionTree or RandomForest

In [129]:
```
model = RandomForestClassifier(criterion='entropy')
```

In [137]:
```
model = DecisionTreeClassifier(criterion='entropy', max_depth=None)
```

In [130]:
```
model.fit(x.drop(['fnlwgt','salary'], axis=1), x.salary)
```

Out[130]:
```
RandomForestClassifier(criterion='entropy')
```

In a Jupyter environment, please rerun this cell to show the HTML representation or trust the notebook.
On GitHub, the HTML representation is unable to render, please try loading this page with nbviewer.org.

In [119]:
```
model.tree_.node_count
```

Out[119]:
```
8341
```

In [120]:
```
# Tree
list(zip(x.drop(['fnlwgt','salary'], axis=1).columns, model.feature_im
```

Out[120]:
```
[('age', 0.32391467900665477),
 ('education-num', 0.16048851806738418),
 ('capital-gain', 0.22784598464777944),
 ('capital-loss', 0.07827183570519927),
 ('hours-per-week', 0.15389326908322057),
 (' Female', 0.05439417820662001),
 (' Male', 0.0011915352831417538)]
```

In [131]:
```
# Forest
list(zip(x.drop(['fnlwgt','salary'], axis=1).columns, model.feature_im
```

Out[131]:
```
[('age', 0.3418366383367088),
 ('education-num', 0.16987852836589729),
 ('capital-gain', 0.18299948424191378),
 ('capital-loss', 0.07002533755900361),
 ('hours-per-week', 0.18125529252257955),
 (' Female', 0.0293043435748306),
 (' Male', 0.02470037539906628)]
```

In [121]:
```
x.drop(['fnlwgt','salary'], axis=1).head()
```

Out[121]:

	age	education-num	capital-gain	capital-loss	hours-per-week	Female	Male
0	39	13	2174	0	40	0.0	1.0
1	50	13	0	0	13	0.0	1.0
2	38	9	0	0	40	0.0	1.0
3	53	7	0	0	40	0.0	1.0
4	28	13	0	0	40	1.0	0.0

In [122]:
```
x.columns, xt.columns
```

Out[122]:
```
(Index(['age', 'fnlwgt', 'education-num', 'capital-gain', 'capital-lo
ss',
        'hours-per-week', 'salary', ' Female', ' Male'],
       dtype='object'),
 Index(['age', 'fnlwgt', 'education-num', 'capital-gain', 'capital-lo
ss',
        'hours-per-week', 'salary', ' Female', ' Male'],
       dtype='object'))
```

In [123]:
```
set(x.columns) - set(xt.columns)
```

Out[123]:
```
set()
```

In [124]:
```
list(x.drop('salary', axis=1).columns)
```

Out[124]:
```
['age',
 'fnlwgt',
 'education-num',
 'capital-gain',
 'capital-loss',
 'hours-per-week',
 ' Female',
 ' Male']
```

In [132]:
```
predictions = model.predict(xt.drop(['fnlwgt','salary'], axis=1))
predictionsx = model.predict(x.drop(['fnlwgt','salary'], axis=1))
```

In [133]:
```
predictions, predictionsx
```

Out[133]:
```
(array([0., 0., 0., ..., 1., 1., 0.]), array([0., 0., 0., ..., 0.,
0., 1.]))
```

In [127]:
```
from sklearn.metrics import (
    accuracy_score,
    classification_report,
    confusion_matrix, auc, roc_curve
)
```

In [128]:
```
# tree
accuracy_score(xt.salary, predictions)
```

Out[128]:
```
0.8207112585222038
```

In [134]:
```
# forest
accuracy_score(xt.salary, predictions)
```

Out[134]:
```
0.8263620170751182
```

In [114]:
```
confusion_matrix(xt.salary, predictions)
```

Out[114]:
```
array([[11508,   927],
       [ 1868,  1978]])
```

In [115]:
```
# tree
print(classification_report(xt.salary, predictions))
```

```
              precision    recall  f1-score   support

         0.0       0.86      0.93      0.89     12435
         1.0       0.68      0.51      0.59      3846

    accuracy                           0.83     16281
   macro avg       0.77      0.72      0.74     16281
weighted avg       0.82      0.83      0.82     16281
```

In [135]:
```
# forest
print(classification_report(xt.salary, predictions))
```

```
              precision    recall  f1-score   support

         0.0       0.86      0.92      0.89     12435
         1.0       0.67      0.51      0.58      3846

    accuracy                           0.83     16281
   macro avg       0.77      0.72      0.74     16281
weighted avg       0.82      0.83      0.82     16281
```

In [138]:
```
# tree
accuracy_score(x.salary, predictionsx)
```

Out[138]:
```
0.8955806025613464
```

In [136]:
```
# forest
accuracy_score(x.salary, predictionsx)
```

Out[136]:
```
0.8955806025613464
```

In [49]:
```
confusion_matrix(x.salary, predictionsx)
```

Out[49]:
```
array([[24097,   623],
       [ 2777,  5064]])
```

In [50]:
```
# tree
print(classification_report(x.salary, predictionsx))
```

```
              precision    recall  f1-score   support

         0.0       0.90      0.97      0.93     24720
         1.0       0.89      0.65      0.75      7841

    accuracy                           0.90     32561
   macro avg       0.89      0.81      0.84     32561
weighted avg       0.90      0.90      0.89     32561
```

In [58]:
```
# forest
print(classification_report(x.salary, predictionsx))
```

```
              precision    recall  f1-score   support

         0.0       0.91      0.96      0.93     24720
         1.0       0.85      0.68      0.76      7841

    accuracy                           0.90     32561
   macro avg       0.88      0.82      0.85     32561
weighted avg       0.89      0.90      0.89     32561
```

For the following use the above `adult` dataset.

1. Show the RandomForest outperforms the DecisionTree for a fixed `max_depth` by training using the train set and calculate `precision, recall, f1, confusion matrix` on golden-test set. Start with only numerical features/columns. (age, education-num, capital-gain, capital-loss, hours-per-week)

In [178]:
```
model = DecisionTreeClassifier(criterion='entropy', max_depth=2)
```

In [179]:
```
model.fit(x.drop(['fnlwgt','salary'], axis=1), x.salary)
```

Out[179]:
```
DecisionTreeClassifier(criterion='entropy', max_depth=2)
```
In a Jupyter environment, please rerun this cell to show the HTML representation or trust the notebook.
On GitHub, the HTML representation is unable to render, please try loading this page with nbviewer.org.

In [180]:
```
predictions = model.predict(xt.drop(['fnlwgt','salary'], axis=1))
predictionsx = model.predict(x.drop(['fnlwgt','salary'], axis=1))
```

In [181]:
```
# tree max_depth 2
accuracy_score(xt.salary, predictions)
```

Out[181]:
```
0.8030833486886555
```

In [182]:
```
confusion_matrix(xt.salary, predictions)
```

Out[182]:
```
array([[12428,     7],
       [ 3199,   647]])
```

In [183]:
```
# tree
print(classification_report(x.salary, predictionsx))
```

```
              precision    recall  f1-score   support

         0.0       0.79      1.00      0.88     24720
         1.0       0.99      0.18      0.30      7841

    accuracy                           0.80     32561
   macro avg       0.89      0.59      0.59     32561
weighted avg       0.84      0.80      0.74     32561
```

In [184]:
```
model = DecisionTreeClassifier(criterion='entropy', max_depth=4)
```

In [185]:
```
model.fit(x.drop(['fnlwgt','salary'], axis=1), x.salary)
```

Out[185]:
```
DecisionTreeClassifier(criterion='entropy', max_depth=4)
```
In a Jupyter environment, please rerun this cell to show the HTML representation or trust the notebook.
On GitHub, the HTML representation is unable to render, please try loading this page with nbviewer.org.

In [186]:
```
predictions = model.predict(xt.drop(['fnlwgt','salary'], axis=1))
predictionsx = model.predict(x.drop(['fnlwgt','salary'], axis=1))
```

In [187]:
```
# tree max_depth 4
accuracy_score(xt.salary, predictions)
```

Out[187]:
```
0.8192985688839752
```

In [188]:
```
confusion_matrix(xt.salary, predictions)
```

Out[188]:
```
array([[11467,   968],
       [ 1974,  1872]])
```

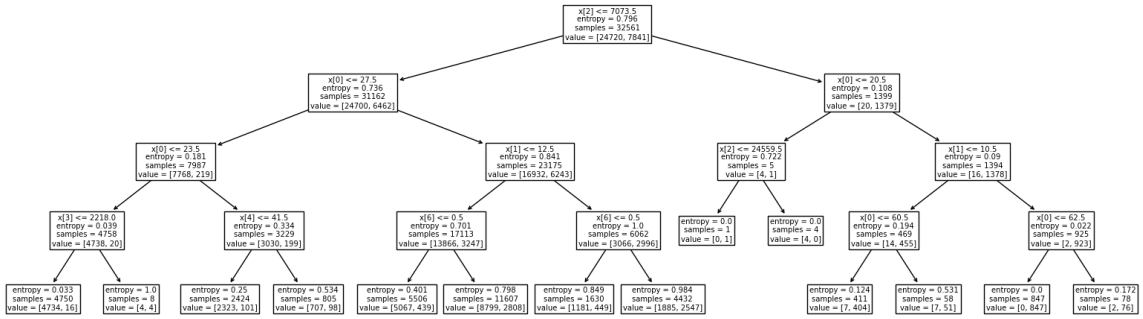
In [189]:
```
# tree
print(classification_report(x.salary, predictionsx))
```

```
              precision    recall  f1-score   support

         0.0       0.85      0.92      0.89     24720
         1.0       0.67      0.50      0.57      7841

    accuracy                           0.82     32561
   macro avg       0.76      0.71      0.73     32561
weighted avg       0.81      0.82      0.81     32561
```

In [190]:
```
from sklearn import tree
tree.plot_tree(model)
```

Out[190]:
```
[Text(0.5288461538461539, 0.9, 'x[2] <= 7073.5\nentropy = 0.796\nsamp
les = 32561\nvalue = [24720, 7841]'),
 Text(0.3076923076923077, 0.7, 'x[0] <= 27.5\nentropy = 0.736\nsample
s = 31162\nvalue = [24700, 6462]'),
 Text(0.15384615384615385, 0.5, 'x[0] <= 23.5\nentropy = 0.181\nsampl
es = 7987\nvalue = [7768, 219]'),
 Text(0.07692307692307693, 0.3, 'x[3] <= 2218.0\nentropy = 0.039\nsam
ples = 4758\nvalue = [4738, 20]'),
 Text(0.038461538461538464, 0.1, 'entropy = 0.033\nsamples = 4750\nva
lue = [4734, 16]'),
 Text(0.11538461538461539, 0.1, 'entropy = 1.0\nsamples = 8\nvalue =
[4, 4]'),
 Text(0.23076923076923078, 0.3, 'x[4] <= 41.5\nentropy = 0.334\nsampl
es = 3229\nvalue = [3030, 199]'),
 Text(0.19230769230769232, 0.1, 'entropy = 0.25\nsamples = 2424\nvalu
e = [2323, 101]'),
 Text(0.2692307692307692, 0.1, 'entropy = 0.534\nsamples = 805\nvalue
= [707, 98]'),
 Text(0.46153846153846156, 0.5, 'x[1] <= 12.5\nentropy = 0.841\nsampl
es = 23175\nvalue = [16932, 6243]'),
 Text(0.38461538461538464, 0.3, 'x[6] <= 0.5\nentropy = 0.701\nsample
s = 17113\nvalue = [13866, 3247]'),
 Text(0.34615384615384615, 0.1, 'entropy = 0.401\nsamples = 5506\nval
ue = [5067, 439]'),
 Text(0.4230769230769231, 0.1, 'entropy = 0.798\nsamples = 11607\nval
ue = [8799, 2808]'),
 Text(0.5384615384615384, 0.3, 'x[6] <= 0.5\nentropy = 1.0\nsamples =
6062\nvalue = [3066, 2996]'),
 Text(0.5, 0.1, 'entropy = 0.849\nsamples = 1630\nvalue = [1181, 44
9]'),
 Text(0.5769230769230769, 0.1, 'entropy = 0.984\nsamples = 4432\nvalu
e = [1885, 2547]'),
 Text(0.75, 0.7, 'x[0] <= 20.5\nentropy = 0.108\nsamples = 1399\nvalu
e = [20, 1379]'),
 Text(0.6538461538461539, 0.5, 'x[2] <= 24559.5\nentropy = 0.722\nsam
ples = 5\nvalue = [4, 1]'),
 Text(0.6153846153846154, 0.3, 'entropy = 0.0\nsamples = 1\nvalue =
[0, 1]'),
 Text(0.6923076923076923, 0.3, 'entropy = 0.0\nsamples = 4\nvalue =
[4, 0]'),
 Text(0.8461538461538461, 0.5, 'x[1] <= 10.5\nentropy = 0.09\nsamples
= 1394\nvalue = [16, 1378]'),
 Text(0.7692307692307693, 0.3, 'x[0] <= 60.5\nentropy = 0.194\nsample
s = 469\nvalue = [14, 455]'),
 Text(0.7307692307692307, 0.1, 'entropy = 0.124\nsamples = 411\nvalue
= [7, 404]'),
 Text(0.8076923076923077, 0.1, 'entropy = 0.531\nsamples = 58\nvalue
= [7, 51]'),
 Text(0.9230769230769231, 0.3, 'x[0] <= 62.5\nentropy = 0.022\nsample
s = 925\nvalue = [2, 923]'),
 Text(0.8846153846153846, 0.1, 'entropy = 0.0\nsamples = 847\nvalue =
[0, 847]'),
 Text(0.9615384615384616, 0.1, 'entropy = 0.172\nsamples = 78\nvalue
```

```
= [2, 76]')]
```



In [191]:
```
model = RandomForestClassifier(criterion='entropy')
```

In [192]:
```
model.fit(x.drop(['fnlwgt','salary'], axis=1), x.salary)
```

Out[192]:
```
RandomForestClassifier(criterion='entropy')
```
In a Jupyter environment, please rerun this cell to show the HTML representation or trust the notebook.
On GitHub, the HTML representation is unable to render, please try loading this page with nbviewer.org.

In [193]:
```
predictions = model.predict(xt.drop(['fnlwgt','salary'], axis=1))
predictionsx = model.predict(x.drop(['fnlwgt','salary'], axis=1))
```

In [194]:
```
# random forest
accuracy_score(xt.salary, predictions)
```

Out[194]:
```
0.8282046557336773
```

In [195]:
```
confusion_matrix(xt.salary, predictions)
```

Out[195]:
```
array([[11499,   936],
       [ 1861,  1985]])
```

In [196]:
```
# random forest
print(classification_report(x.salary, predictionsx))
```

```
              precision    recall  f1-score   support

         0.0       0.90      0.97      0.93     24720
         1.0       0.86      0.67      0.76      7841

    accuracy                           0.90     32561
   macro avg       0.88      0.82      0.85     32561
weighted avg       0.89      0.90      0.89     32561
```

With a max depth of 4 for decision tree, the random forest has a higher precision, recall and f1-score.

2. Use a RandomForest or DecisionTree and the `adult` dataset, systematically add new columns, one by one, that are non-numerical but converted using the feature-extraction techniques we learned. Using the golden-test set show `[precision, recall, f1, confusion matrix]` for each additional feature added.

In [351]:
```
df.head()
```

Out[351]:

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	
0	39	State-gov	77516	Bachelors	13	Never-married	Adm-clerical	Not-in-family	White	
1	50	Self-emp-not-inc	83311	Bachelors	13	Married-civ-spouse	Exec-managerial	Husband	White	
2	38	Private	215646	HS-grad	9	Divorced	Handlers-cleaners	Not-in-family	White	
3	53	Private	234721	11th	7	Married-civ-spouse	Handlers-cleaners	Husband	Black	
4	28	Private	338409	Bachelors	13	Married-civ-spouse	Prof-specialty	Wife	Black	F

In [352]:
```
#breakout education parameters
dummy = pd.get_dummies(df['education'])
dummy.shape
```

Out[352]:
```
(32561, 16)
```

In [353]:
```
enc = preprocessing.OrdinalEncoder()
enc.fit(df[["education"]])
```

Out[353]:
```
▾ OrdinalEncoder
OrdinalEncoder()
```

In [354]:
```
enc.categories_
```

Out[354]:
```
[array([' 10th', ' 11th', ' 12th', ' 1st-4th', ' 5th-6th', ' 7th-8th
',
        ' 9th', ' Assoc-acdm', ' Assoc-voc', ' Bachelors', ' Doctorat
e',
        ' HS-grad', ' Masters', ' Preschool', ' Prof-school',
        ' Some-college'], dtype=object)]
```

In [355]:
```
x2 = df.copy()

x2 = pd.concat([x2.drop(non_num_columns, axis=1)], axis=1)
#                pd.get_dummies(df['education'])], axis=1,)

x2["education"] = enc.fit_transform(df[["education"]])
x2.head()
```

Out[355]:

	age	fnlwgt	education-num	capital-gain	capital-loss	hours-per-week	salary	education
0	39	77516	13	2174	0	40	<=50K	9.0
1	50	83311	13	0	0	13	<=50K	9.0
2	38	215646	9	0	0	40	<=50K	11.0
3	53	234721	7	0	0	40	<=50K	1.0
4	28	338409	13	0	0	40	<=50K	9.0

In [356]:
```
enc.fit(df[["salary"]])
enc.categories_
```

Out[356]:
```
[array([' <=50K', ' >50K'], dtype=object)]
```

In [357]:
```
x2["salary"] = enc.fit_transform(df[["salary"]])
```

In [358]:
```
x2 = x2.dropna()
x2.head()
```

Out[358]:

	age	fnlwgt	education-num	capital-gain	capital-loss	hours-per-week	salary	education
0	39	77516	13	2174	0	40	0.0	9.0
1	50	83311	13	0	0	13	0.0	9.0
2	38	215646	9	0	0	40	0.0	11.0
3	53	234721	7	0	0	40	0.0	1.0
4	28	338409	13	0	0	40	0.0	9.0

In [359]:
```
enc.fit(golden[["education"]])
enc.categories_
```

Out[359]:
```
[array([' 10th', ' 11th', ' 12th', ' 1st-4th', ' 5th-6th', ' 7th-8th
',
        ' 9th', ' Assoc-acdm', ' Assoc-voc', ' Bachelors', ' Doctorat
e',
        ' HS-grad', ' Masters', ' Preschool', ' Prof-school',
        ' Some-college'], dtype=object)]
```

In [360]:
```
xt2 = golden.copy()

xt2 = pd.concat([xt2.drop(non_num_columns, axis=1)], axis=1,)

xt2["education"] = enc.transform(golden[["education"]])
xt2.head()
```

Out[360]:

	age	fnlwgt	education-num	capital-gain	capital-loss	hours-per-week	salary	education
0	25	226802	7	0	0	40	<=50K.	1.0
1	38	89814	9	0	0	50	<=50K.	11.0
2	28	336951	12	0	0	40	>50K.	7.0
3	44	160323	10	7688	0	40	>50K.	15.0
4	18	103497	10	0	0	30	<=50K.	15.0

In [361]:
```
enc.fit(golden[["salary"]])

xt2["salary"] = enc.transform(golden[["salary"]])

xt2 = xt2.dropna()
```

In [362]:
```
xt2.head()
```

Out[362]:

	age	fnlwgt	education-num	capital-gain	capital-loss	hours-per-week	salary	education
0	25	226802	7	0	0	40	0.0	1.0
1	38	89814	9	0	0	50	0.0	11.0
2	28	336951	12	0	0	40	1.0	7.0
3	44	160323	10	7688	0	40	1.0	15.0
4	18	103497	10	0	0	30	0.0	15.0

In [363]:
```
model = RandomForestClassifier(criterion='entropy')
```

In [364]:
```
model.fit(x2.drop(['fnlwgt','salary'], axis=1), x.salary)
```

Out[364]:
```
RandomForestClassifier
RandomForestClassifier(criterion='entropy')
```

In [365]:
```
x2.drop(['fnlwgt','salary'], axis=1)
```

Out[365]:

	age	education-num	capital-gain	capital-loss	hours-per-week	education
0	39	13	2174	0	40	9.0
1	50	13	0	0	13	9.0
2	38	9	0	0	40	11.0
3	53	7	0	0	40	1.0
4	28	13	0	0	40	9.0
...	...	...	...	...	...	...
32556	27	12	0	0	38	7.0
32557	40	9	0	0	40	11.0
32558	58	9	0	0	40	11.0
32559	22	9	0	0	20	11.0
32560	52	9	15024	0	40	11.0

32561 rows × 6 columns

In [366]:
```
predictions2 = model.predict(xt2.drop(['fnlwgt','salary'], axis=1))
predictionsx2 = model.predict(x2.drop(['fnlwgt','salary'], axis=1))
```

In [367]:
```
# random forest w/ education
accuracy_score(xt2.salary, predictions2)
```

Out[367]:
```
0.8221853694490511
```

In [368]:
```
confusion_matrix(xt2.salary, predictions2)
```

Out[368]:
```
array([[11550,   885],
       [ 2010,  1836]])
```

In [369]:
```
# random forest w/ education
print(classification_report(x2.salary, predictionsx2))
```

```
              precision    recall  f1-score   support

         0.0       0.89      0.97      0.93     24720
         1.0       0.86      0.62      0.72      7841

    accuracy                           0.88     32561
   macro avg       0.88      0.79      0.82     32561
weighted avg       0.88      0.88      0.88     32561
```

In [370]:
```
#breakout occupation parameters
dummy = pd.get_dummies(df['occupation'])
dummy.shape
```

Out[370]:
```
(32561, 15)
```

In [371]:
```
enc.fit(df[["occupation"]])
enc.categories_
```

Out[371]:
```
[array([' ?', ' Adm-clerical', ' Armed-Forces', ' Craft-repair',
        ' Exec-managerial', ' Farming-fishing', ' Handlers-cleaners',
        ' Machine-op-inspct', ' Other-service', ' Priv-house-serv',
        ' Prof-specialty', ' Protective-serv', ' Sales', ' Tech-suppo
rt',
        ' Transport-moving'], dtype=object)]
```

In [372]:
```
x2 = df.copy()

x2 = pd.concat([x2.drop(non_num_columns, axis=1)], axis=1)
x2["occupation"] = enc.fit_transform(df[["occupation"]])
x2["education"] = enc.fit_transform(df[["education"]])
x2["salary"] = enc.fit_transform(df[["salary"]])
x2.head()
```

Out[372]:

	age	fnlwgt	education-num	capital-gain	capital-loss	hours-per-week	salary	occupation	education
0	39	77516	13	2174	0	40	0.0	1.0	9.0
1	50	83311	13	0	0	13	0.0	4.0	9.0
2	38	215646	9	0	0	40	0.0	6.0	11.0
3	53	234721	7	0	0	40	0.0	6.0	1.0
4	28	338409	13	0	0	40	0.0	10.0	9.0

In [373]:
```
enc.fit(golden[["occupation"]])
enc.categories_
```

Out[373]:
```
[array([' ?', ' Adm-clerical', ' Armed-Forces', ' Craft-repair',
        ' Exec-managerial', ' Farming-fishing', ' Handlers-cleaners',
        ' Machine-op-inspct', ' Other-service', ' Priv-house-serv',
        ' Prof-specialty', ' Protective-serv', ' Sales', ' Tech-suppo
rt',
        ' Transport-moving'], dtype=object)]
```

In [375]:
```
xt2 = golden.copy()

xt2 = pd.concat([xt2.drop(non_num_columns, axis=1)], axis=1)
xt2["occupation"] = enc.transform(golden[["occupation"]])
enc.fit(golden[["education"]])
xt2["education"] = enc.transform(golden[["education"]])
enc.fit(golden[["salary"]])
xt2["salary"] = enc.transform(golden[["salary"]])
xt2.head()
```

Out[375]:

	age	fnlwgt	education-num	capital-gain	capital-loss	hours-per-week	salary	occupation	education
0	25	226802	7	0	0	40	0.0	7.0	1.0
1	38	89814	9	0	0	50	0.0	5.0	11.0
2	28	336951	12	0	0	40	1.0	11.0	7.0
3	44	160323	10	7688	0	40	1.0	7.0	15.0
4	18	103497	10	0	0	30	0.0	0.0	15.0

In [376]:
```
xt2 = xt2.dropna()
```

In [377]:
```
model = RandomForestClassifier(criterion='entropy')
model.fit(x2.drop(['fnlwgt','salary'], axis=1), x.salary)
```

Out[377]:
```
▾          RandomForestClassifier

RandomForestClassifier(criterion='entropy')
```

In [378]:
```
predictions2 = model.predict(xt2.drop(['fnlwgt','salary'], axis=1))
predictionsx2 = model.predict(x2.drop(['fnlwgt','salary'], axis=1))
```

In [379]:
```
# random forest w/ education & occupation
accuracy_score(xt2.salary, predictions2)
```

Out[379]:
```
0.8141391806400098
```

In [380]:
```
confusion_matrix(xt2.salary, predictions2)
```

Out[380]:
```
array([[11298,  1137],
       [ 1889,  1957]])
```

In [381]:
```
# random forest w/ education & occupation
print(classification_report(x2.salary, predictionsx2))
```

```
              precision    recall  f1-score   support

         0.0       0.93      0.98      0.95     24720
         1.0       0.91      0.76      0.83      7841

    accuracy                           0.92     32561
   macro avg       0.92      0.87      0.89     32561
weighted avg       0.92      0.92      0.92     32561
```

Compared the above report to the previous outputs: Just salary:

```
              precision    recall  f1-score   support

         0.0       0.90      0.97      0.93     24720
         1.0       0.86      0.67      0.76      7841
```

Addition of education ordinal:

```
              precision    recall  f1-score   support

         0.0       0.89      0.97      0.93     24720
         1.0       0.86      0.62      0.72      7841
```

In [ ]: