HW 1

Please start working on this assignment as soon as possible. If you are a beginner in Python this might take a long time. The **objective** of this assignment is to help you familiarize w python packages related to machine learning, namely scikit-learn package.

DO NOT ERASE MARKDOWN CELLS AND INSTRUCTIONS IN YOUR HW submission

Instructions

This assignment covers several aspects of KNN Classifier and performence evaluation we have covered in introML module. eep the following in mind:

- Structure your notebook cells as sugested
- **Q** - QUESTION posted in a markdown cell
  - it explains the task in details
  - it is marked with **Q1**, ... **Q10** ...

- **A** - Marks the location where you need to enter your answer below
  - it can be `python code` (more often) or markdown cell (less often)
  - it is marked with **A1**, ... **A10** ... and you enter your answers **below**
  - make sure the cell is running and produces no errors
- Before you submit the HW:
  - Make sure your notebook can always be rerun from top to bottom.
- Follow instructions given in canvas for homework submission.

Tutorials

- KNN with sklearn
- Confusion Matrix
- Plot Confursion Matrix with Sklearn

1. CLASSIFICATION USING KNN ALGORITHM

Data is in the ../data/ folder, and datafile name is heart.dat **Keep** the relative path from **HW** folder to **data** folder in your submission e.g. you will access the file as ../data/heart.dat

Q1 use pandas to read ../data/heart.dat

- NOTE : use separator as space while reading this data
- Use column names from metadata in given order
- NOTE : YOU WON'T SEE 'PRESENCE' in metadata (in attribute information)

A1 Replace the ? mark with your answer

```
import pandas as pd

columns = [ 'age', 'sex', 'cp', 'restbp', 'chol', 'fastbs', 'restecg',
'maxhr', 'exang', 'oldpeak', 'slope', 'vcflour', 'thal', 'presence' ]

df = pd.read_csv( '../data/heart.dat', sep='\s', names=columns )

df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 270 entries, 0 to 269
Data columns (total 14 columns):
 #   Column    Non-Null Count  Dtype
---  ------    --------------  -----
 0   age       270 non-null    float64
 1   sex       270 non-null    float64
 2   cp        270 non-null    float64
 3   restbp    270 non-null    float64
 4   chol      270 non-null    float64
 5   fastbs    270 non-null    float64
 6   restecg   270 non-null    float64
 7   maxhr     270 non-null    float64
 8   exang     270 non-null    float64
 9   oldpeak   270 non-null    float64
 10  slope     270 non-null    float64
 11  vcflour   270 non-null    float64
 12  thal      270 non-null    float64
 13  presence  270 non-null    int64
dtypes: float64(13), int64(1)
memory usage: 29.7 KB

C:\Users\Isaac\AppData\Local\Temp\ipykernel_10716\197060135.py:5:
ParserWarning: Falling back to the 'python' engine because the 'c'
engine does not support regex separators (separators > 1 char and
different from '\s+' are interpreted as regex); you can avoid this
warning by specifying engine='python'.
  df = pd.read_csv( '../data/heart.dat', sep='\s', names=columns )
```

Q2

1. Have a look at head and tail of your data
- N.B: You can use .tail and .head methods
- N.B: Print both of them, if you just run `without printing` only output from last command will be printed

1. Let us view the size of dataset as well
- print data shape

1. Now let us see if there is some missing value
2. If there is any na values drop it

N.B You can add more cells as per your need.

A2 Replace ??? with code in the code cell below

```
# Code goes below
df.head()

df.tail()

df.shape

df.isna()

df.dropna()
```

```
      age  sex   cp  restbp   chol  fastbs  restecg  maxhr  exang
oldpeak  \
0    70.0  1.0  4.0   130.0  322.0     0.0      2.0  109.0    0.0
2.4
1    67.0  0.0  3.0   115.0  564.0     0.0      2.0  160.0    0.0
1.6
2    57.0  1.0  2.0   124.0  261.0     0.0      0.0  141.0    0.0
0.3
3    64.0  1.0  4.0   128.0  263.0     0.0      0.0  105.0    1.0
0.2
4    74.0  0.0  2.0   120.0  269.0     0.0      2.0  121.0    1.0
0.2
..    ...  ...  ...     ...    ...     ...      ...    ...    ...
...
265  52.0  1.0  3.0   172.0  199.0     1.0      0.0  162.0    0.0
0.5
266  44.0  1.0  2.0   120.0  263.0     0.0      0.0  173.0    0.0
0.0
267  56.0  0.0  2.0   140.0  294.0     0.0      2.0  153.0    0.0
1.3
268  57.0  1.0  4.0   140.0  192.0     0.0      0.0  148.0    0.0
0.4
269  67.0  1.0  4.0   160.0  286.0     0.0      2.0  108.0    1.0
1.5

     slope  vcflour  thal  presence
0      2.0      3.0   3.0         2
1      2.0      0.0   7.0         1
2      1.0      0.0   7.0         2
3      2.0      1.0   7.0         1
4      1.0      1.0   3.0         1
..     ...      ...   ...       ...
265    1.0      0.0   7.0         1
266    1.0      0.0   7.0         1
267    2.0      0.0   3.0         1
268    2.0      0.0   6.0         1
269    2.0      3.0   3.0         2
```

```
[270 rows x 14 columns]
```

Q3 Now we will look deeper into the dataset

- Use pairplot from sns to plot this data frame
- See the statistics of the data by describing dataframe

A3 Replace ??? with code in the code cell below

```
import seaborn as sns

sns.set(style='dark', color_codes=True)
g = sns.pairplot( df, corner=True )

import matplotlib.pyplot as plt
plt.show( g )

#describe dataframe
df.describe()
```

```
c:\Users\Isaac\anaconda3\Lib\site-packages\seaborn\axisgrid.py:118:
UserWarning: The figure layout has changed to tight
  self._figure.tight_layout(*args, **kwargs)
```

	age	sex	cp	restbp	chol	fastbs	\
count	270.000000	270.000000	270.000000	270.000000	270.000000	270.000000	
mean	54.433333	0.677778	3.174074	131.344444	249.659259	0.148148	
std	9.109067	0.468195	0.950090	17.861608	51.686237	0.355906	
min	29.000000	0.000000	1.000000	94.000000	126.000000	0.000000	
25%	48.000000	0.000000	3.000000	120.000000	213.000000	0.000000	

```
50%     55.000000    1.000000    3.000000  130.000000  245.000000
0.000000
75%     61.000000    1.000000    4.000000  140.000000  280.000000
0.000000
max     77.000000    1.000000    4.000000  200.000000  564.000000
1.000000

          restecg       maxhr       exang    oldpeak       slope
vcflour  \
count  270.000000  270.000000  270.000000  270.00000  270.000000
270.000000
mean     1.022222  149.677778    0.329630    1.05000    1.585185
0.670370
std      0.997891   23.165717    0.470952    1.14521    0.614390
0.943896
min      0.000000   71.000000    0.000000    0.00000    1.000000
0.000000
25%      0.000000  133.000000    0.000000    0.00000    1.000000
0.000000
50%      2.000000  153.500000    0.000000    0.80000    2.000000
0.000000
75%      2.000000  166.000000    1.000000    1.60000    2.000000
1.000000
max      2.000000  202.000000    1.000000    6.20000    3.000000
3.000000

             thal    presence
count  270.000000  270.000000
mean     4.696296    1.444444
std      1.940659    0.497827
min      3.000000    1.000000
25%      3.000000    1.000000
50%      3.000000    1.000000
75%      7.000000    2.000000
max      7.000000    2.000000
```

Q4

1. From the above pairplot what kind of relationship we can derive between age and heartrate?

A4 Write your answer here.....The relationship appears to be vaguely inverse, as the cluster of scatter points gradually decrease as age increases.

Q5 If you go through metadata (heart.doc) (Attribute Information:) you will see that all data in our dataframe are not of same types.

- So we should deal them accordingly.

- We don't have to do anything to 'real' data. However we have to deal with ordered data and nominal data

- We only need to convert all nominal and ordered data to dummy variables

A5 Replace ??? with code in the code cell below

```
dummy_list = [ 'cp', 'restecg', 'slope', 'thal' ]
df = pd.get_dummies( df, columns=dummy_list, prefix=dummy_list,
prefix_sep='-')
df.head()
```

```
    age  sex  restbp   chol  fastbs  maxhr  exang  oldpeak  vcflour
presence  \
0  70.0  1.0   130.0  322.0     0.0  109.0    0.0      2.4      3.0
2
1  67.0  0.0   115.0  564.0     0.0  160.0    0.0      1.6      0.0
1
2  57.0  1.0   124.0  261.0     0.0  141.0    0.0      0.3      0.0
2
3  64.0  1.0   128.0  263.0     0.0  105.0    1.0      0.2      1.0
1
4  74.0  0.0   120.0  269.0     0.0  121.0    1.0      0.2      1.0
1

   ...  cp-4.0  restecg-0.0  restecg-1.0  restecg-2.0  slope-1.0
slope-2.0  \
0  ...    True        False        False         True      False
True
1  ...   False        False        False         True      False
True
2  ...   False         True        False        False       True
False
3  ...    True         True        False        False      False
True
4  ...   False        False        False         True       True
False

   slope-3.0  thal-3.0  thal-6.0  thal-7.0
0      False      True     False     False
1      False     False     False      True
2      False     False     False      True
3      False     False     False      True
4      False      True     False     False

[5 rows x 23 columns]
```

KNN Model from sklearn

Q6 Get training data from the dataframe

1. Assign values of `presence` column to y, note you have to use .values method
2. Drop 'presence' column from data frame,
3. Assign df values to x

Split dataset into train and test data use train_test_split

1. Use stratify = y and test_size = 0.25 and random_state = 123
2. Create a KNN model using sklearn library, `Initialize n_neighbors = 4`, `(See the documenttaion for details)`
3. Fit the model with the train data

A6 Replace ??? with code in the code cell below

```
import numpy as np
from sklearn.model_selection import train_test_split
from sklearn.neighbors import KNeighborsClassifier
# Assign values of ```presence``` column to y, note you have to
use .values method
y = df['presence'].values
# Drop 'presence' column from data frame,
df.drop('presence', axis=1)
# Assign df values to x
x = df.values
# View shape of x and y
x.shape, y.shape

# Use stratify = y and test_size = 0.25 and random_state = 123

xtrain, xtest, ytrain, ytest = train_test_split( x, y, stratify=y,
test_size=0.25, random_state=123 )

# Create a KNN model using sklearn library, k=4
knn = KNeighborsClassifier( n_neighbors=4 )

# Fit the model with the train data
knn.fit( xtrain, ytrain )

KNeighborsClassifier(n_neighbors=4)
```

Q7 *Analysis*

- Predict xtest and view first 20 predicitons
- Compare prediction with real ytest 20 predictions
- Print the score with test data

The way we fit the dataset is not good
Normalization

- rescale only real value columns
- For each column normalize `df[col] as (x - mean) / standard_deviation`

A7 Replace ??? with code in the code cell below

```
#  Predict xtest and view first 25 predicitons
print( knn.predict( xtest )[0:25] )

# Compare prediction with real ytest 25 predictions
print( ytest[0:25] )

# Print the score with test data
print( knn.score( xtest, ytest ) )

#rescale only real value columns
realcols = [ 'age', 'restbp', 'chol', 'maxhr', 'oldpeak', 'vcflour' ]

# For each column normalize ```df[col] as (x - mean) /
standard_deviation```
for col in realcols:
  mean = df[col].mean()
  std = df[col].std()
  df[col] = ( df[col] - mean ) / std
```

```
[1 1 1 1 2 2 2 1 1 1 2 1 2 2 2 1 1 1 1 1 1 2 1 1 1]
[1 2 2 2 2 1 1 1 1 2 2 1 2 1 1 1 1 1 1 1 2 2 2 1 1]
0.6617647058823529
```

Q8 Write the code to train new model using KNN classifier, k=4 (same as above)

A8 Replace ??? with code in the code cell below

```
# update x
x = df.values

# Train test Split
xtrain, xtest, ytrain, ytest = train_test_split( x, y, stratify=y,
test_size=0.25, random_state=123 )

# Model Initialization
knn = KNeighborsClassifier( n_neighbors=4 )

# Model fitting with training data
knn.fit( xtrain, ytrain )

# Now print score on test data
knn.score( xtest, ytest )
```

```
0.8382352941176471
```

Q9 Lets analyze the difference between two modeling strategies (data normalization) Compare score with and without data normalization process and explain

A9
Normalization scores closer to 1 than non-normalized data.

Q10 Now we will write a function that will initialize, fit and return score on test data for given values of k and Plot result

1. Use values from 1 to 25(inclusive) and get score and plot as a line graph
- Hint : For advance method you can use map (recall functional programming from last exercise) or you can use simple loops
1. Finally you can print the best value of k by getting the index

- N.B: Note index starts with 0 but values of k starts with 1 so actual value of k will be 1 more

- You can use `np.argmax()` function
1. Now define your best model as bestknn and print score

A10 Write the code below (replace??)

```
import matplotlib.pyplot as plt
from sklearn.metrics import confusion_matrix

def returnScore(k, xtrain, xtest, ytrain, ytest):
  knn = KNeighborsClassifier(n_neighbors=k)
  knn.fit( xtrain, ytrain )
  return knn.score( xtest, ytest )


result = [*map(lambda i:returnScore( i,xtrain, xtest, ytrain, ytest ),
range( 1,25 ))]
print(result)
plt.plot(result)


print('BESt VALUE OF K',np.argmax(result) + 1 )


bestknn = KNeighborsClassifier( n_neighbors=np.argmax(result) + 1 )

bestknn.fit( xtrain, ytrain )
bestknn.score( xtest, ytest )


ypred = bestknn.predict( xtest )
matrix = confusion_matrix( ytest, ypred )
print(matrix)
```

```
[0.8382352941176471, 0.8088235294117647, 0.8676470588235294,
0.8382352941176471, 0.8676470588235294, 0.8676470588235294,
0.8676470588235294, 0.8529411764705882, 0.8823529411764706,
```

```
0.8676470588235294, 0.8970588235294118, 0.8529411764705882,
0.8823529411764706, 0.8676470588235294, 0.8676470588235294,
0.8529411764705882, 0.8676470588235294, 0.8529411764705882,
0.8676470588235294, 0.8529411764705882, 0.8676470588235294,
0.8529411764705882, 0.8676470588235294, 0.8529411764705882]
BESt VALUE OF K 11
[[35  3]
 [ 4 26]]
```

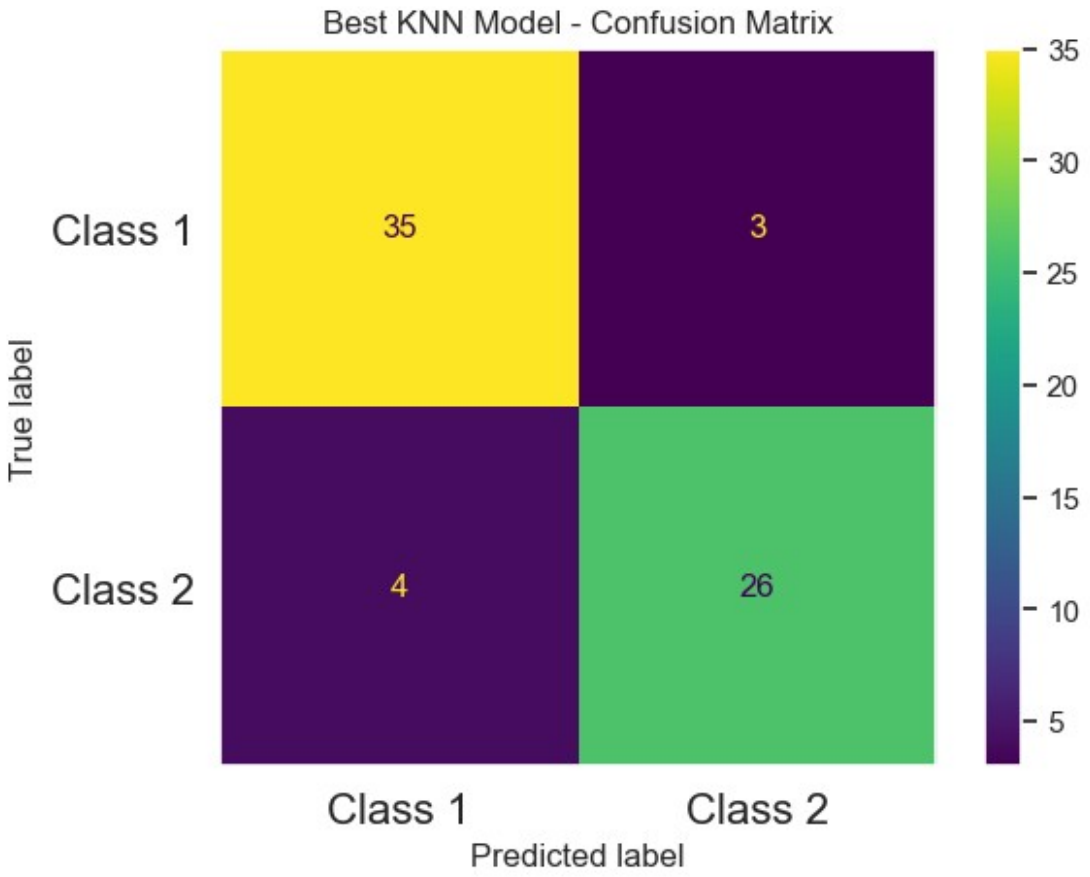
Q11 Now plot confusion matrix using ConfusionMatrixDisplay, for xtest data. Use the Best KNN model from the above question as the estimator. See Visualization with Display Objects example.

A11 Replace ??? with code in the code cell below

```
from sklearn.metrics import ConfusionMatrixDisplay
import matplotlib.pyplot as plt

cm = ConfusionMatrixDisplay.from_estimator( bestknn, xtest, ytest )

plt.title("Best KNN Model - Confusion Matrix")
plt.xticks(range(2), ["Class 1","Class 2"], fontsize=16)
plt.yticks(range(2), ["Class 1","Class 2"], fontsize=16)
plt.show()
```



Q12:

1. Calculate the test MSE
2. Get the score from the model using test data
3. Plot Precision-Recall Curve from the true & predicted test data (Use sklearn PrecisionRecallDisplay)

A12 Replace ??? with code in the code cell below

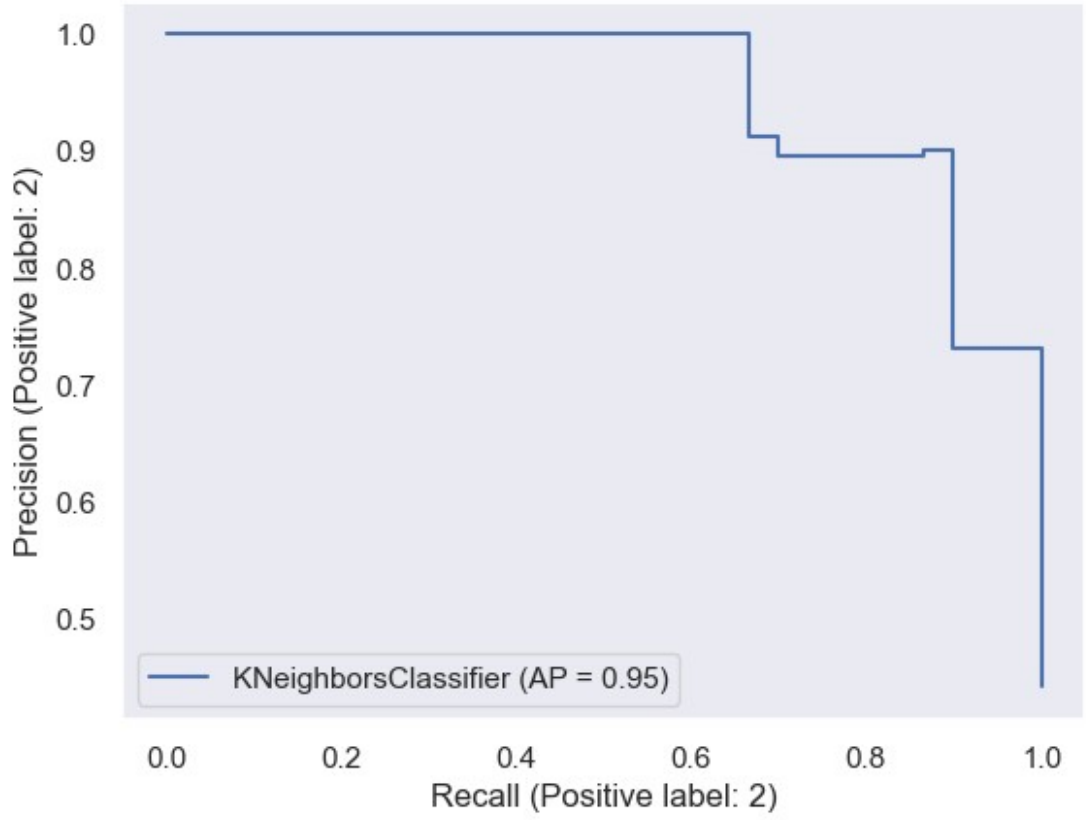
```
from sklearn.metrics import mean_squared_error
from sklearn.metrics import PrecisionRecallDisplay
import matplotlib.pyplot as plt

mse = mean_squared_error( ytest, ypred )          # Calculate the test
MSE
print("Test mean squared error (MSE): {:.2f}".format(mse))

print(bestknn.score( xtest, ytest ))


PrecisionRecallDisplay.from_estimator( bestknn, xtest, ytest )
plt.show()
```

```
Test mean squared error (MSE): 0.10
0.8970588235294118
```



Further reading

- KNN model creation
- Example of KNN

Submission Instructions

1. Run all cells in `HW1.ipynb` and make sure there are no errors
2. Print `HW1.ipynb` to pdf file
3. Create a Folder HW0 and Upload `HW1.ipynb` and `HW1.pdf` files to your git repo allocated for this course e.g: https://git.txstate.edu/NetID/netid before the deadline. Make Sure Instructor and TA has access for the repo.