1. Exploratory Data Analysis

November 21, 2018

```
In [1]: import numpy as np
        import pandas as pd
        import matplotlib.pyplot as plt
        import seaborn as sns
        %matplotlib inline
```

0.1 Load Data

```
In [2]: !ls ../data/raw
```

```
TBSC2-20181112T130549Z-001.zip tubes2_HeartDisease_train.csv
description.xlsx               ~$description.xlsx
tubes2_HeartDisease_test.csv
```

0.1.1 Initialize Path Constants

```
In [3]: RAW_DATA_PATH = '../data/raw'
```

0.1.2 Load CSV File

```
In [4]: train_df = pd.read_csv('{}/tubes2_HeartDisease_train.csv'.format(RAW_DATA_PATH))
        test_df = pd.read_csv('{}/tubes2_HeartDisease_test.csv'.format(RAW_DATA_PATH))
```

```
In [5]: train_df.head()
```

Out[5]:

	Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8	Column9	\
0	54	1	4	125	216	0	0	140	0	
1	55	1	4	158	217	0	0	110	1	
2	54	0	3	135	304	1	0	170	0	
3	48	0	3	120	195	0	0	125	0	
4	50	1	4	120	0	0	1	156	1	

	Column10	Column11	Column12	Column13	Column14
0	0	?	?	?	1
1	2.5	2	?	?	1
2	0	1	0	3	0
3	0	?	?	?	0
4	0	1	?	6	3

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

```
Out[6]:    Column1  Column2  Column3 Column4 Column5 Column6  Column7 Column8 Column9  \
        0       60        1        2     160     267       1        1     157       0
        1       61        1        4     148     203       0        0     161       0
        2       54        1        4     130     242       0        0      91       1
        3       48        1        4     120     260       0        0     115       0
        4       57        0        1     130     308       0        0      98       0

          Column10 Column11 Column12 Column13
        0      0.5        2        ?        ?
        1        0        1        1        7
        2        1        2        ?        ?
        3        2        2        ?        ?
        4        1        2        ?        ?
```

0.2 Rename Column Names

So it's easier to read..

```
In [7]: from copy import deepcopy

        test_columns_replacement = {
            'Column1': 'age',
            'Column2': 'sex',
            'Column3': 'chest_pain_type',
            'Column4': 'resting_blood_pressure',
            'Column5': 'serum_cholestrol',
            'Column6': 'fasting_blood_sugar',
            'Column7': 'resting_ECG',
            'Column8': 'max_heart_rate_achieved',
            'Column9': 'excercise_induced_angina',
            'Column10': 'ST_depression',
            'Column11': 'peak_exercise_ST_segment',
            'Column12': 'num_of_major_vessels',
            'Column13': 'thal',
        }

        train_columns_replacement = test_columns_replacement.copy()
        train_columns_replacement['Column14'] = 'heart_disease_diagnosis'

        train_df = train_df.rename(columns=train_columns_replacement)

        test_df = test_df.rename(columns=test_columns_replacement)

In [8]: train_df.head()
```

```
Out[8]:    age  sex  chest_pain_type resting_blood_pressure serum_cholestrol  \
        0   54    1                4                    125              216
```

```
1   55    1               4                   158              217
2   54    0               3                   135              304
3   48    0               3                   120              195
4   50    1               4                   120                0

  fasting_blood_sugar resting_ECG max_heart_rate_achieved  \
0                   0           0                     140
1                   0           0                     110
2                   1           0                     170
3                   0           0                     125
4                   0           1                     156

  excercise_induced_angina ST_depression peak_exercise_ST_segment  \
0                        0             0                        ?
1                        1           2.5                        2
2                        0             0                        1
3                        0             0                        ?
4                        1             0                        1

  num_of_major_vessels thal  heart_disease_diagnosis
0                    ?    ?                        1
1                    ?    ?                        1
2                    0    3                        0
3                    ?    ?                        0
4                    ?    6                        3
```

In [9]:
```
test_df.head()
```

Out[9]:
```
   age  sex  chest_pain_type resting_blood_pressure serum_cholestrol  \
0   60    1                2                   160              267
1   61    1                4                   148              203
2   54    1                4                   130              242
3   48    1                4                   120              260
4   57    0                1                   130              308

  fasting_blood_sugar  resting_ECG max_heart_rate_achieved  \
0                   1           1                     157
1                   0           0                     161
2                   0           0                      91
3                   0           0                     115
4                   0           0                      98

  excercise_induced_angina ST_depression peak_exercise_ST_segment  \
0                        0           0.5                        2
1                        0             0                        1
2                        1             1                        2
3                        0             2                        2
4                        0             1                        2
```

```
  num_of_major_vessels thal
0                    ?    ?
1                    1    7
2                    ?    ?
3                    ?    ?
4                    ?    ?
```

0.3 Exploratory Data Analysis

0.3.1 Check For Null Values

Nan values null

```
In [10]: train_df.isnull().sum()
```

```
Out[10]: age                         0
         sex                         0
         chest_pain_type             0
         resting_blood_pressure      0
         serum_cholestrol            0
         fasting_blood_sugar         0
         resting_ECG                 1
         max_heart_rate_achieved     0
         excercise_induced_angina    0
         ST_depression               0
         peak_exercise_ST_segment    0
         num_of_major_vessels        0
         thal                        0
         heart_disease_diagnosis     0
         dtype: int64
```

```
In [11]: test_df.isnull().sum()
```

```
Out[11]: age                         0
         sex                         0
         chest_pain_type             0
         resting_blood_pressure      0
         serum_cholestrol            0
         fasting_blood_sugar         0
         resting_ECG                 0
         max_heart_rate_achieved     0
         excercise_induced_angina    0
         ST_depression               0
         peak_exercise_ST_segment    0
         num_of_major_vessels        0
         thal                        0
         dtype: int64
```

Dataset specific null type Column with values '?' in the dataset is null values a well

```
In [12]: def pad_text(text, target_length):
             assert(len(text) <= target_length)
             return text + (' ' * (target_length - len(text)))

         def print_data_null_encoded(data):
             for column in data.columns:
                 null_values = data[column].apply(lambda x: x == '?')
                 print('{}: {} ({} %)'.format(pad_text(column, 25),
                                              sum(null_values),
                                              sum(null_values) * 100 / data.shape[0]))
```

```
In [13]: print('==== Train Data ====')
         print_data_null_encoded(train_df)

         print('\n\n')

         print('==== Test Data ====')
         print_data_null_encoded(test_df)
```

```
==== Train Data ====
age                       : 0 (0.0 %)
sex                       : 0 (0.0 %)
chest_pain_type           : 0 (0.0 %)
resting_blood_pressure    : 47 (6.033376123234916 %)
serum_cholestrol          : 24 (3.0808729139922977 %)
fasting_blood_sugar       : 78 (10.012836970474968 %)
resting_ECG               : 1 (0.12836970474967907 %)
max_heart_rate_achieved   : 44 (5.648267008985879 %)
excercise_induced_angina  : 44 (5.648267008985879 %)
ST_depression             : 49 (6.290115532734275 %)
peak_exercise_ST_segment  : 262 (33.632862644415916 %)
num_of_major_vessels      : 514 (65.98202824133504 %)
thal                      : 408 (52.374839537869065 %)
heart_disease_diagnosis   : 0 (0.0 %)



==== Test Data ====
age                       : 0 (0.0 %)
sex                       : 0 (0.0 %)
chest_pain_type           : 0 (0.0 %)
resting_blood_pressure    : 12 (8.51063829787234 %)
serum_cholestrol          : 6 (4.25531914893617 %)
fasting_blood_sugar       : 12 (8.51063829787234 %)
resting_ECG               : 0 (0.0 %)
max_heart_rate_achieved   : 11 (7.801418439716312 %)
```

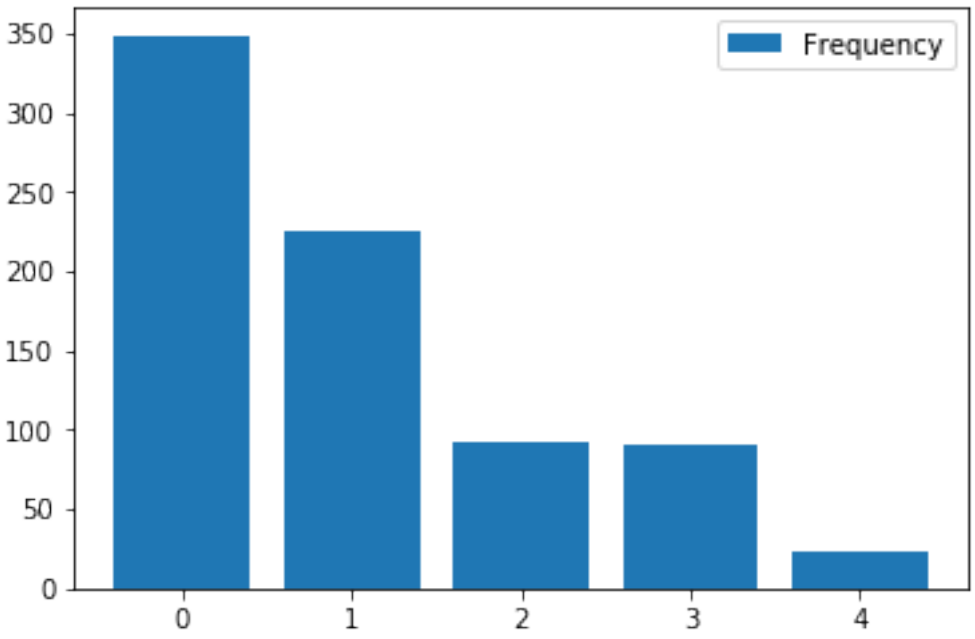
```
excercise_induced_angina : 11 (7.801418439716312 %)
ST_depression            : 13 (9.21985815602837 %)
peak_exercise_ST_segment : 47 (33.333333333333336 %)
num_of_major_vessels     : 97 (68.79432624113475 %)
thal                     : 78 (55.319148936170215 %)
```

The above data shows that some of the columns (*num_of_major_vessels*,*thal*) majority values are null. Null values cannot be used in the model and need to be solved. There are several methods to solve this null value problem. One of the methods is imputing null values to some value that could represent the data well.

0.3.2 Attribute Analysis

Heart Disease Diagnosis

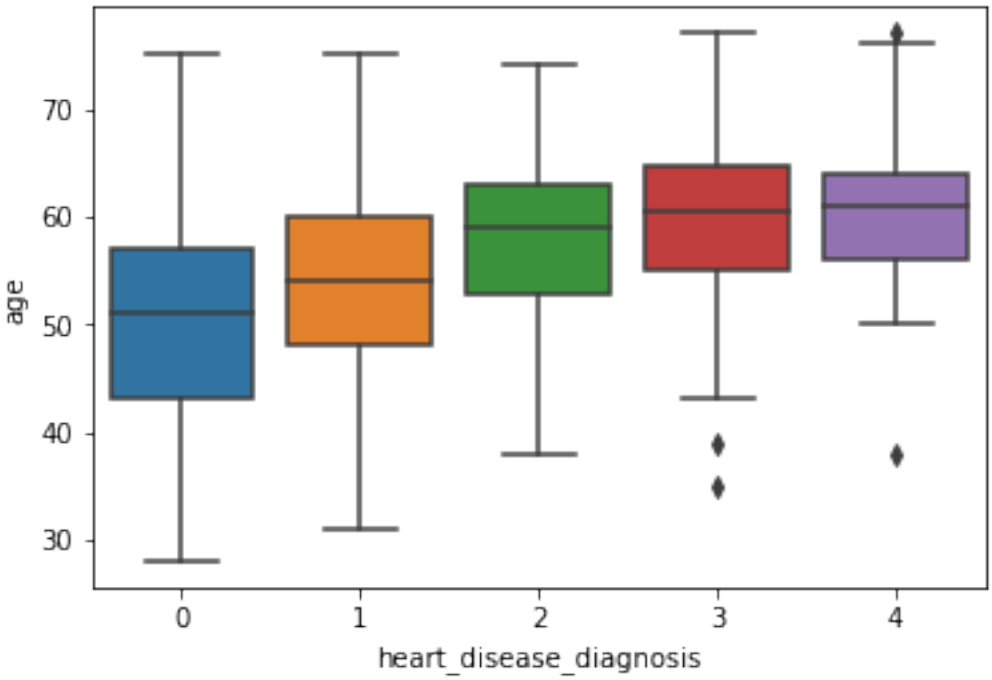
```
In [14]: label_count = {}
         label = train_df['heart_disease_diagnosis']

         for i in range(5):
             label_count[str(i)] = label.loc[label ==i].count()

         plt.bar(label_count.keys(), [label_count[str(i)] for i in range(5)], label="Frequency"
         leg = plt.legend()
         plt.show()
```



The figure above shows the distribution of the labels of the data. We can see that it declines as the label values increases. This implies that the worse the diagnosis is, the occurence of the diagnosis is much rarer.

Age

```
In [15]: sns.boxplot(x="heart_disease_diagnosis", y="age", data=train_df)
         plt.show()
```

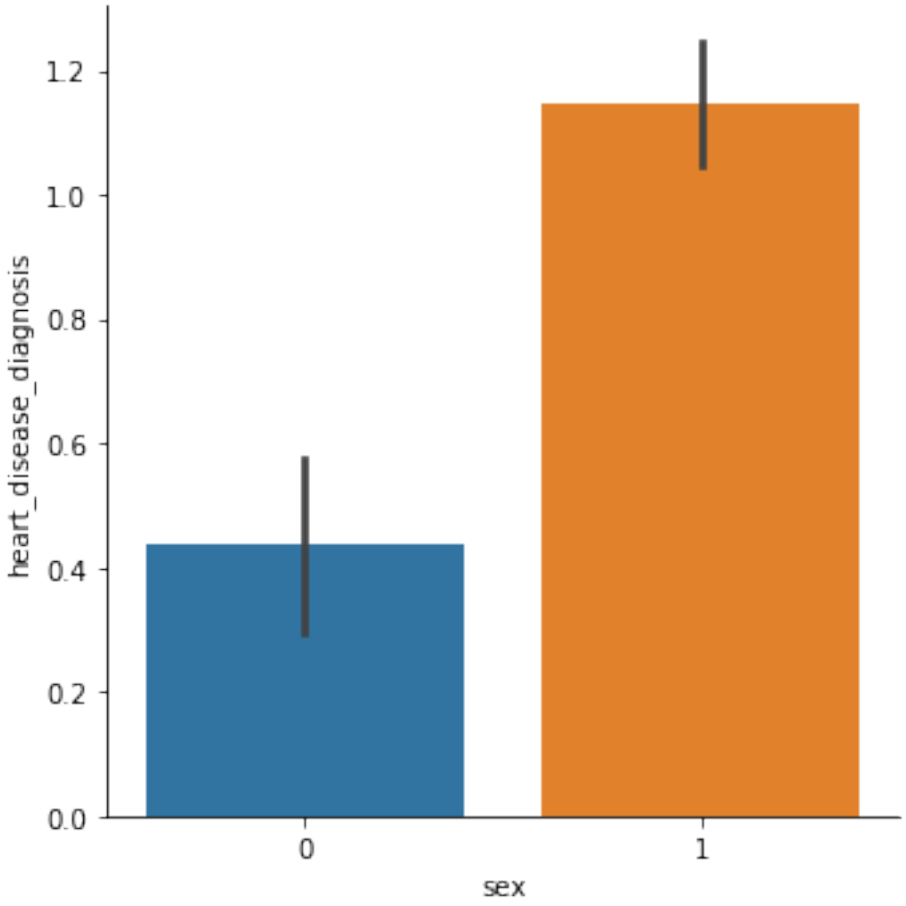


The figure above shows the boxplot of the age of the diagnosed people. We can see that the median value of each group of heart diagnosis increases as the diagnosis goes worse. This implies that the older the person is, there is much more chance to be diagnosed a worse heart disease diagnosis.

0.3.3 Sex

```
In [16]: sns.catplot(x="sex", y="heart_disease_diagnosis", data=train_df, kind='bar')
         plt.show()
```

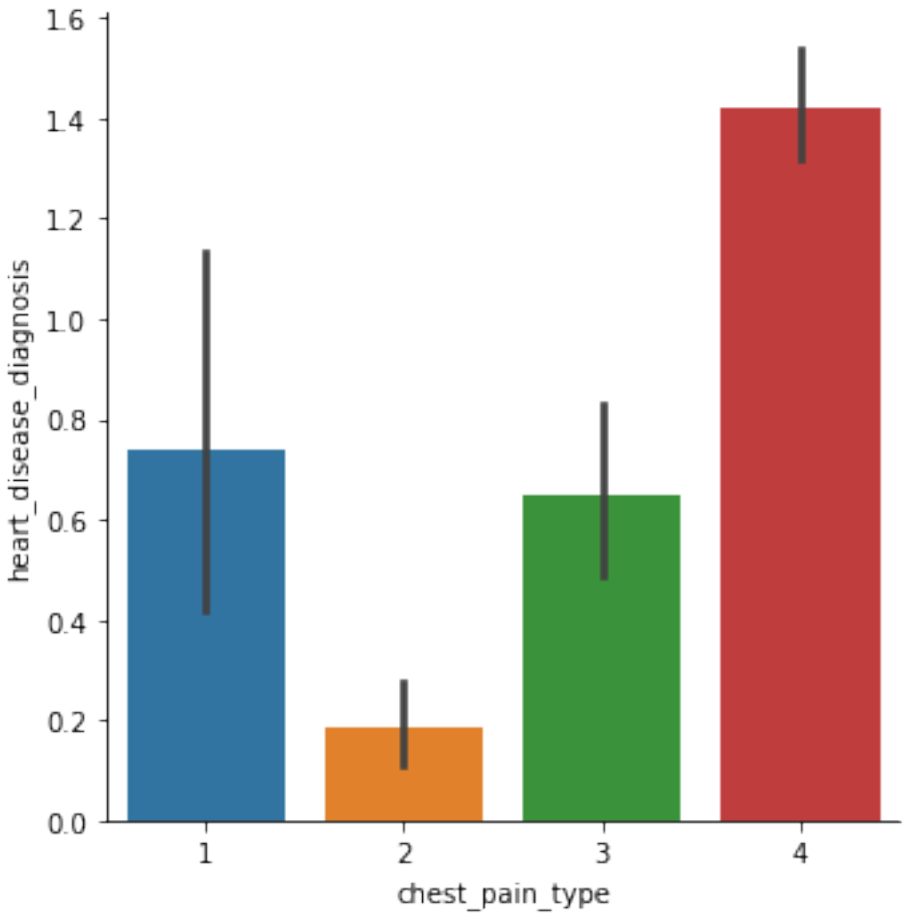
```
/usr/local/lib/python3.7/site-packages/scipy/stats/stats.py:1713: FutureWarning: Using a non-tu
  return np.add.reduce(sorted[indexer] * weights, axis=axis) / sumval
```



The figure above shows the catplot of the sex of the diagnosed people. Sex number 1 (male) is much more prone to the worse heart disease diagnosis.

Chest Pain Type

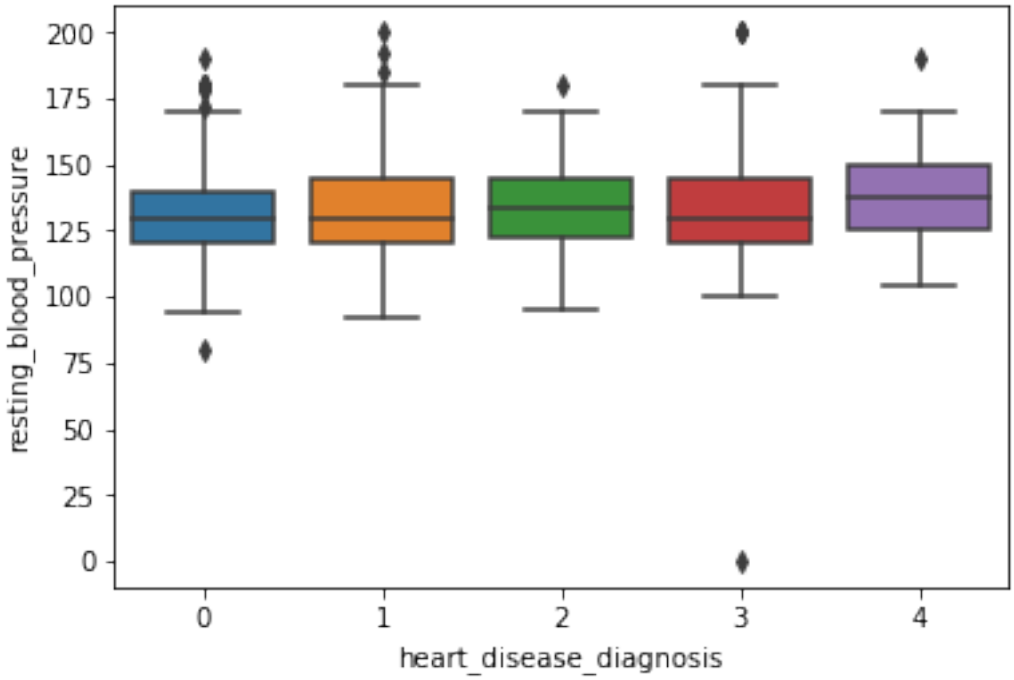
```
In [17]: sns.catplot(x="chest_pain_type", y="heart_disease_diagnosis",
                     data=train_df.loc[train_df['chest_pain_type'].astype(str) != '?'], kind='
         plt.show()
```



The figure above shows the cat plot of the chest pain type for each heart disease diagnosis. For the worst heart disease diagnosis, chest pain type 4 is dominant.

0.3.4 Resting Blood Pressure

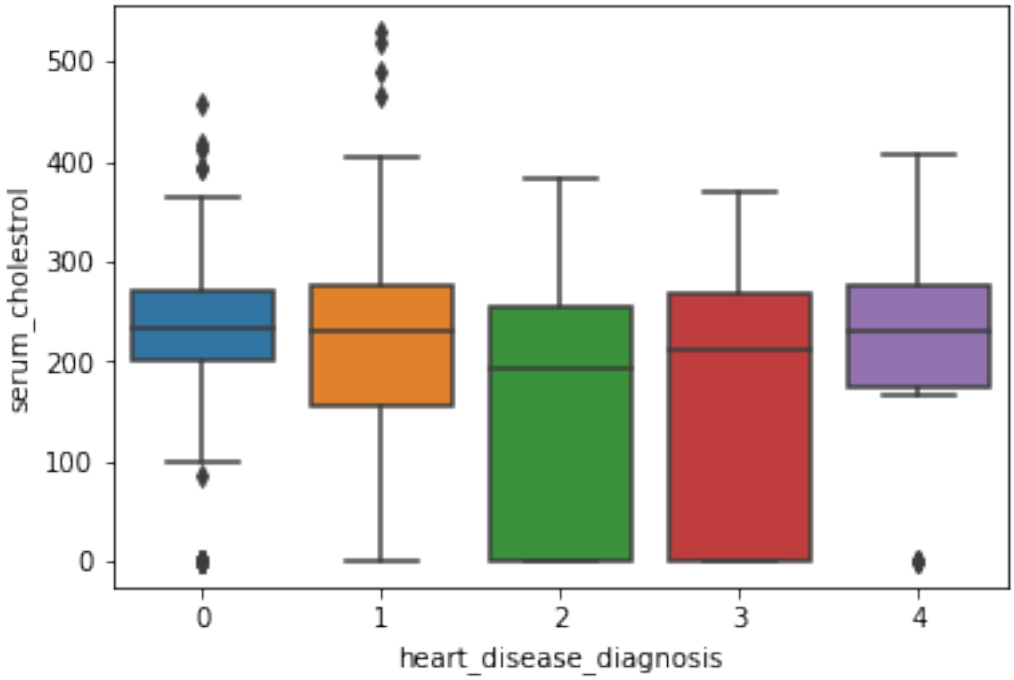
```
In [18]: clean_data = train_df.loc[train_df['resting_blood_pressure'].astype(str) != '?' ]
         clean_data = clean_data[['resting_blood_pressure', 'heart_disease_diagnosis']].astype
         sns.boxplot(x="heart_disease_diagnosis", y="resting_blood_pressure",
                     data=clean_data)
         plt.show()
```



The figure above shows the box plot of the resting blood pressure for each diagnosed person. There is no apparent difference between the five heart disease category. This shows a low variance of data.

0.3.5 Serum Cholestrol

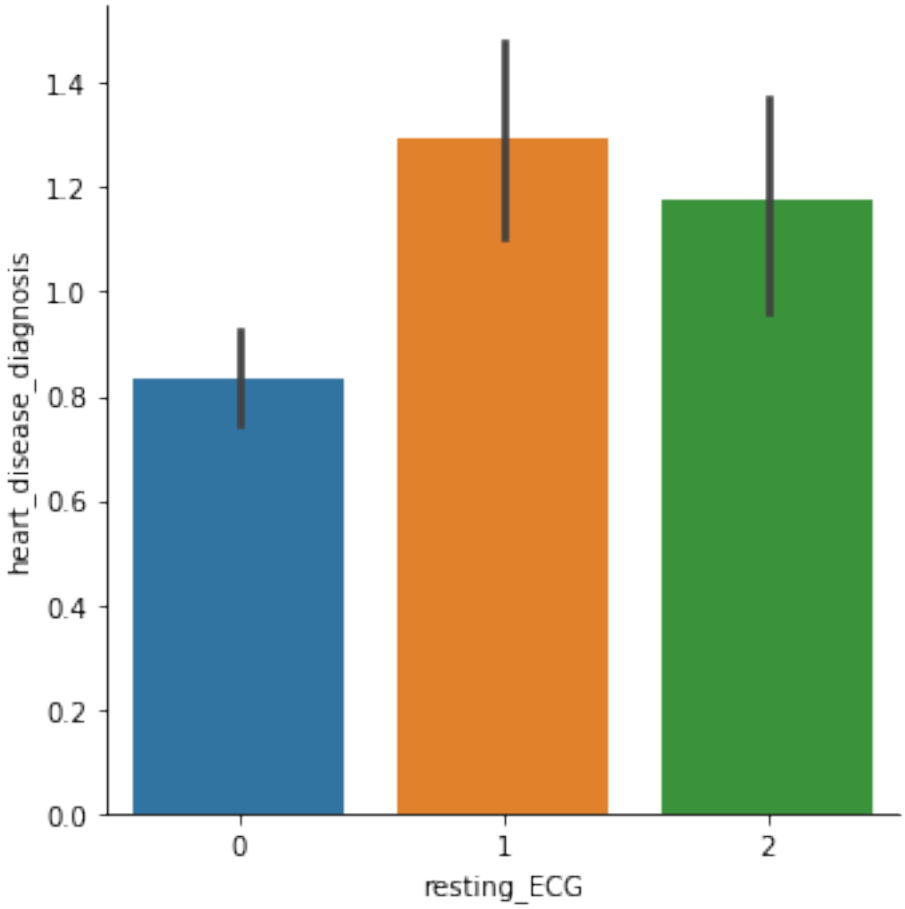
```
In [19]: clean_data = train_df.loc[train_df['serum_cholestrol'].astype(str) != '?' ]
         clean_data = clean_data[['serum_cholestrol', 'heart_disease_diagnosis']].astype(int)
         sns.boxplot(x="heart_disease_diagnosis", y="serum_cholestrol",
                     data=clean_data)
         plt.show()
```



The figure above shows the box plot of the serum cholestrol for each diagnosed person. There are a lot of zero values in the data, making the heart disease diagnosis 2 and 3 have a really wide boxplot.

0.3.6 Resting ECG

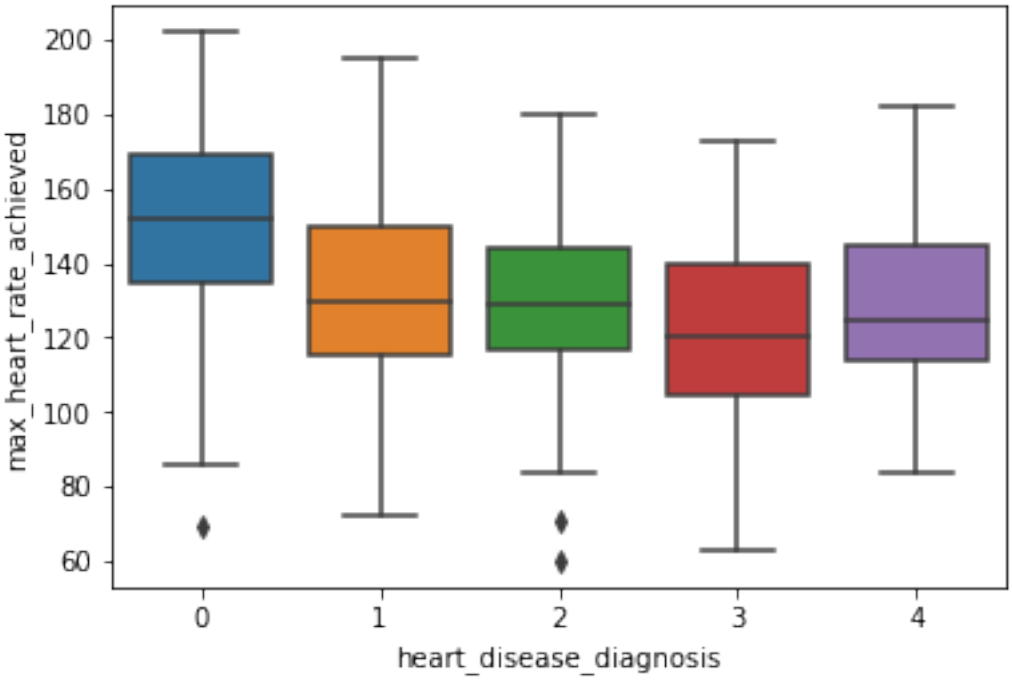
```
In [20]: clean_data = train_df.loc[train_df['resting_ECG'].astype(str) != '?']
         clean_data = clean_data.loc[~clean_data['resting_ECG'].isna()]
         clean_data = clean_data[['resting_ECG', 'heart_disease_diagnosis']].astype(int)
         sns.catplot(x="resting_ECG", y="heart_disease_diagnosis",
                     data=clean_data, kind='bar')
         plt.show()
```



The figure above shows the catplot of the resting ECG for each diagnosed person. There is no apparent difference between the 3 type of resting ECG, looking at the frequency of each heart disease category

0.3.7 Max Heart Rate Achieved

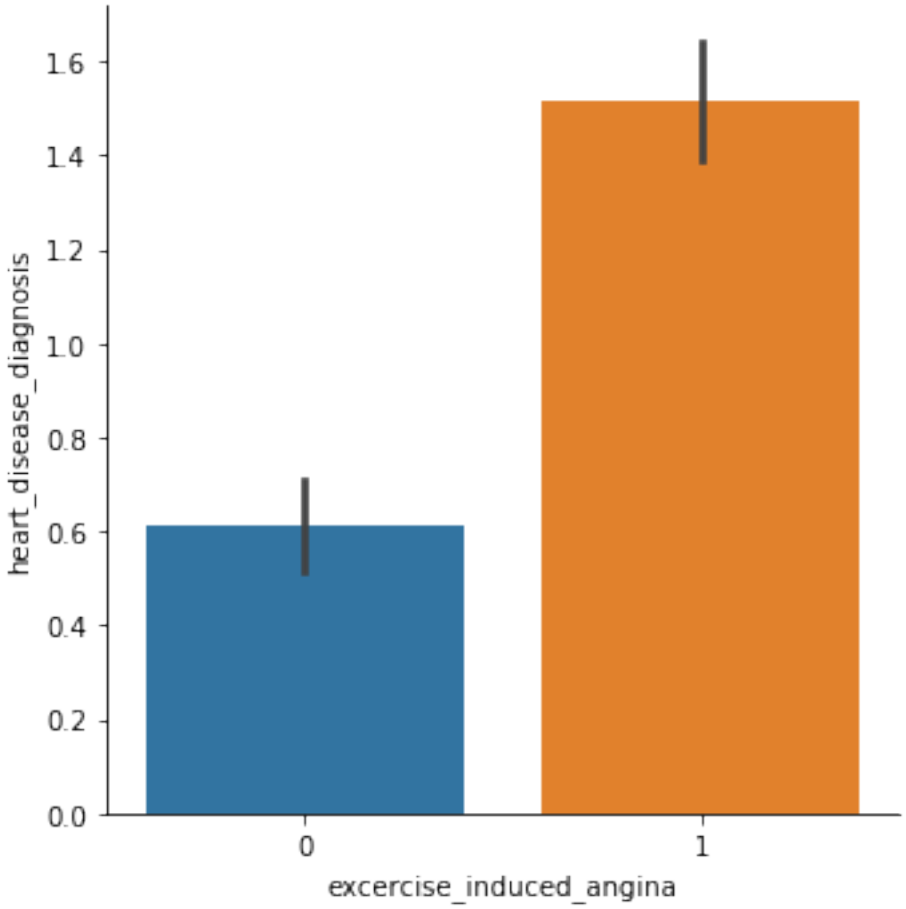
```
In [21]: clean_data = train_df.loc[train_df['max_heart_rate_achieved'].astype(str) != '?' ]
         clean_data = clean_data[['max_heart_rate_achieved', 'heart_disease_diagnosis']].astyp
         sns.boxplot(x="heart_disease_diagnosis", y="max_heart_rate_achieved",
                     data=clean_data)
         plt.show()
```



The figure above shows the box plot of the max heart rate achieved for each person. The max heart rate is higher when the person is not diagnosed with a heart disease.

0.3.8 Exercise Induced Angina

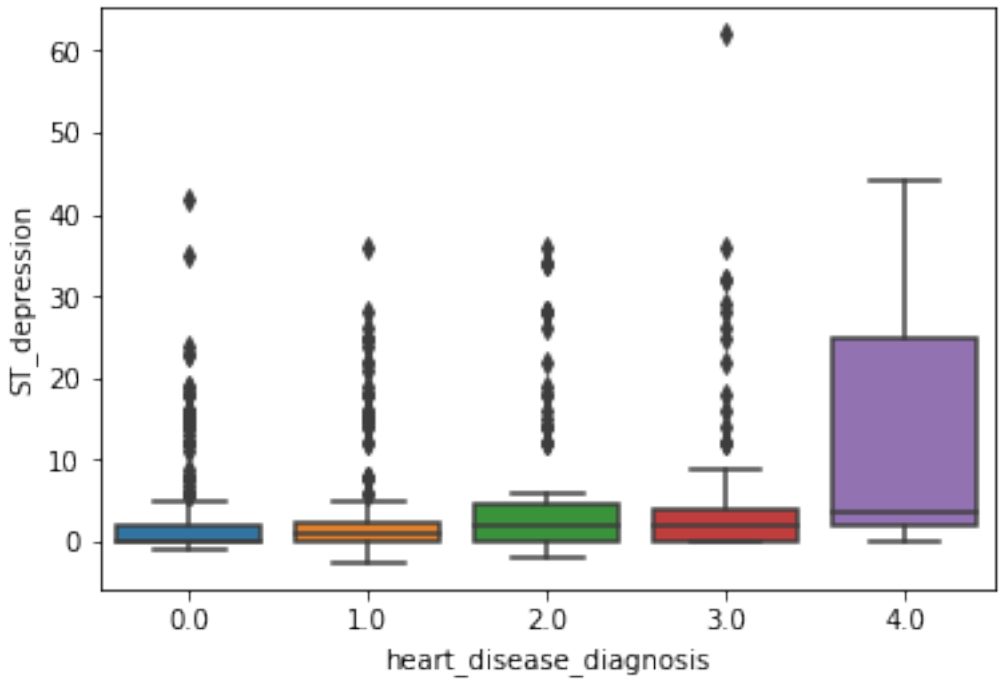
```
In [22]: clean_data = train_df.loc[train_df['excercise_induced_angina'].astype(str) != '?']
         clean_data = clean_data.loc[~clean_data['excercise_induced_angina'].isna()]
         clean_data = clean_data[['excercise_induced_angina', 'heart_disease_diagnosis']].asty
         sns.catplot(x="excercise_induced_angina", y="heart_disease_diagnosis",
                     data=clean_data, kind='bar')
         plt.show()
```



The figure above shows the catplot of the exercise induced angina for each diagnosed person. There is no apparent difference between the 2 type of exercise induced angina, looking at the frequency of each heart disease category

0.3.9 ST Depression

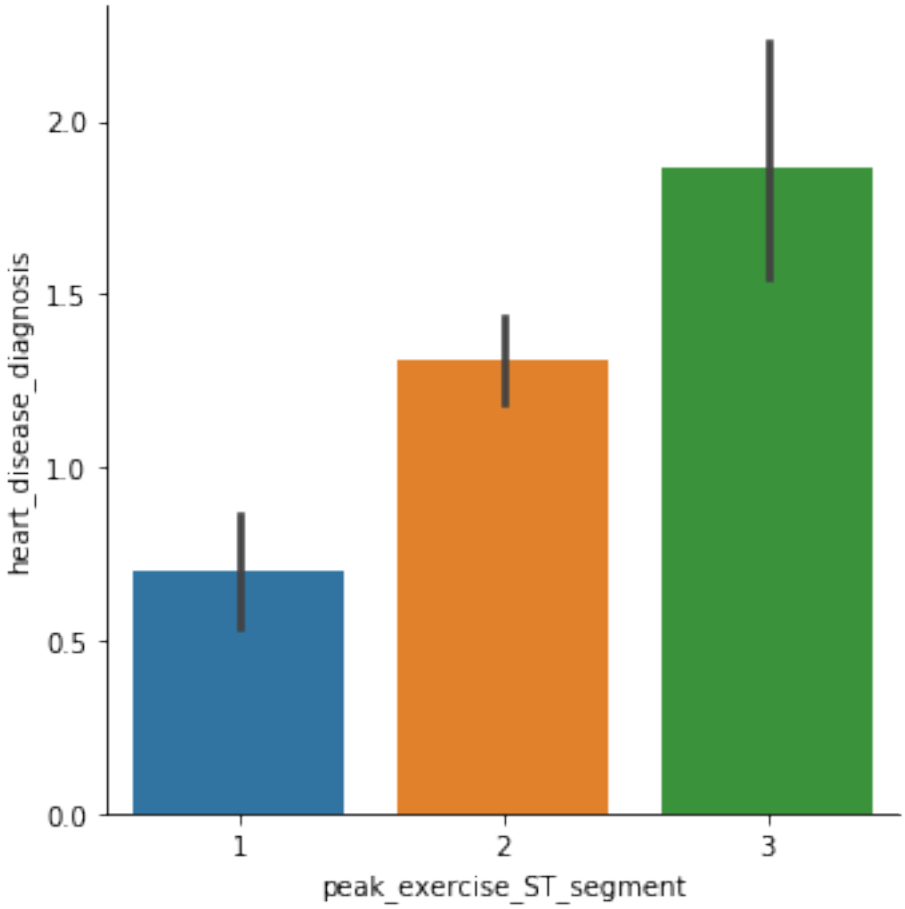
```
In [23]: clean_data = train_df.loc[train_df['ST_depression'].astype(str) != '?' ]
         clean_data = clean_data[['ST_depression', 'heart_disease_diagnosis']].astype(float)
         sns.boxplot(x="heart_disease_diagnosis", y="ST_depression",
                     data=clean_data)
         plt.show()
```



The figure above shows the box plot of the ST Depression for each person. There is a very low variance for the ST depression for each of the heart diagnosis.

0.3.10 Peak Exercise ST Segment

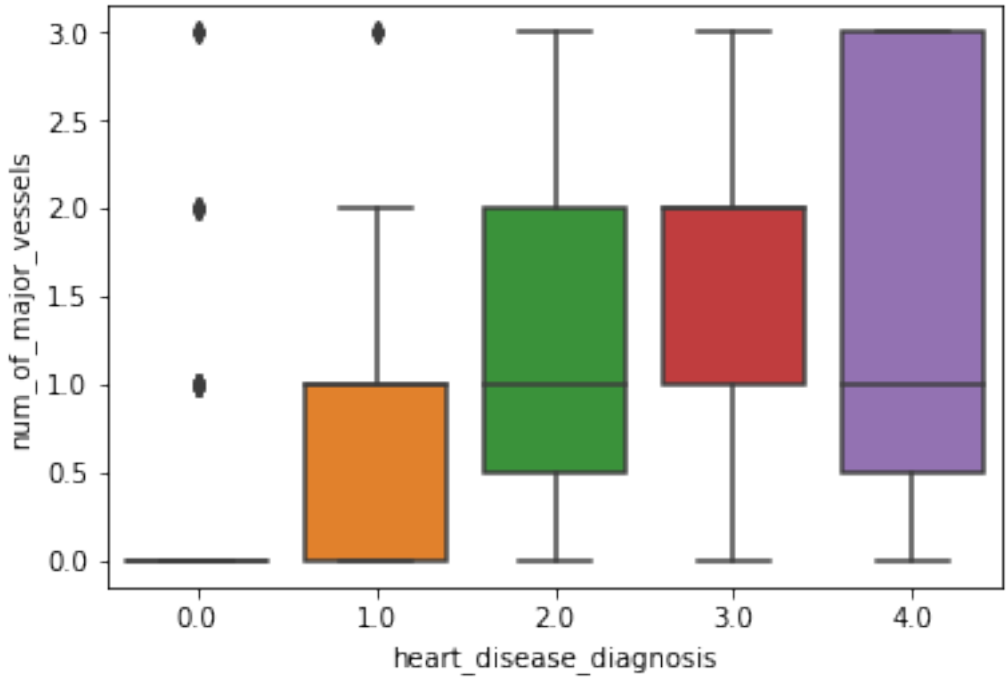
```
In [24]: clean_data = train_df.loc[train_df['peak_exercise_ST_segment'].astype(str) != '?']
         clean_data = clean_data.loc[~clean_data['peak_exercise_ST_segment'].isna()]
         clean_data = clean_data[['peak_exercise_ST_segment', 'heart_disease_diagnosis']].asty
         sns.catplot(x="peak_exercise_ST_segment", y="heart_disease_diagnosis",
                     data=clean_data, kind='bar')
         plt.show()
```



The figure above shows the catplot of the peak exercise ST segment for each diagnosed person. There is no apparent difference between the 2 type of exercise induced angina, looking at the frequency of each heart disease category

0.3.11 Number of Major Vessels

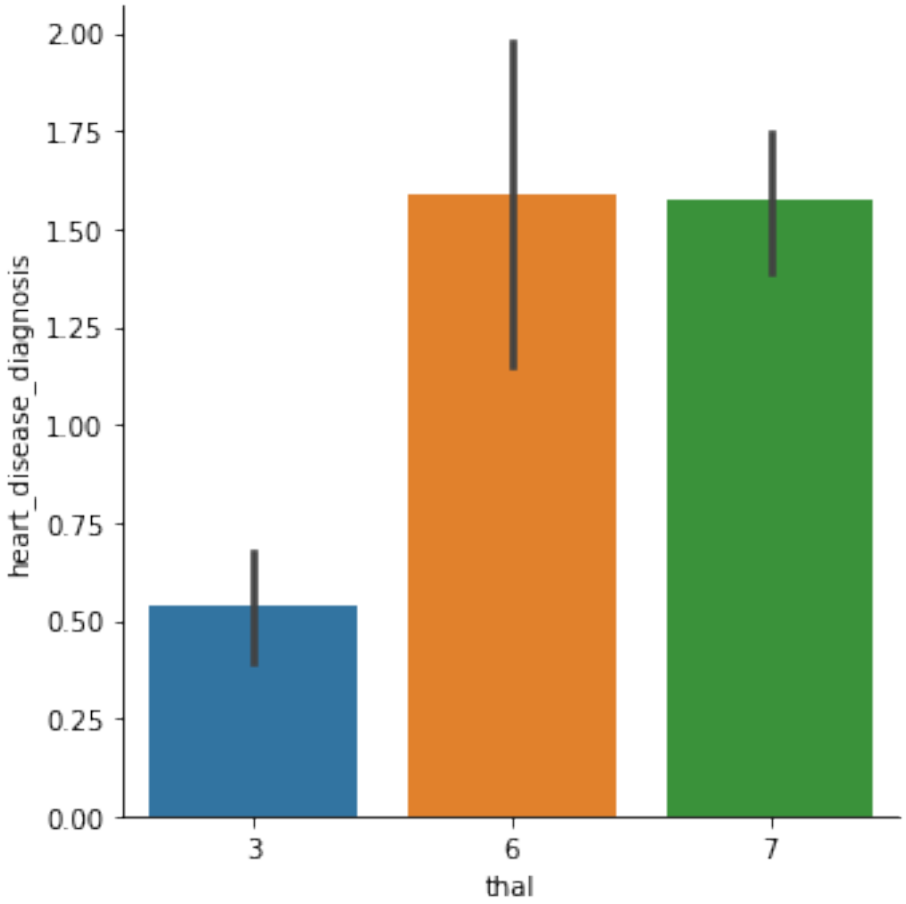
```
In [25]: clean_data = train_df.loc[train_df['num_of_major_vessels'].astype(str) != '?' ]
         clean_data = clean_data[['num_of_major_vessels', 'heart_disease_diagnosis']].astype(f
         sns.boxplot(x="heart_disease_diagnosis", y="num_of_major_vessels",
                     data=clean_data)
         plt.show()
```



The figure above shows the box plot of the number of major vessels for each person. No major vessel is found in the person with negative heart disease diagnosis.

0.3.12 Thal

```
In [26]: clean_data = train_df.loc[train_df['thal'].astype(str) != '?']
         clean_data = clean_data.loc[~clean_data['thal'].isna()]
         clean_data = clean_data[['thal', 'heart_disease_diagnosis']].astype(int)
         sns.catplot(x="thal", y="heart_disease_diagnosis",
                     data=clean_data, kind='bar')
         plt.show()
```



The figure above shows the catplot of the thal for each diagnosed person. There is no apparent difference between the 3 type of thal, looking at the frequency of each heart disease category

2. Data Preprocessing and Feature Engineering

November 21, 2018

In [18]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

pd.options.display.max_columns = 1000

%matplotlib inline
```

0.1 Load Data

0.1.1 Initialize Path Constants

In [19]:
```
RAW_DATA_PATH = '../data/raw'
PROCESSED_DATA_PATH = '../data/processed'
```

0.1.2 Load CSV Files

In [20]:
```
train_df = pd.read_csv('{}/tubes2_HeartDisease_train.csv'.format(RAW_DATA_PATH))
test_df = pd.read_csv('{}/tubes2_HeartDisease_test.csv'.format(RAW_DATA_PATH))
```

0.2 Rename Column Names & Convert '?' to NaN

The '?' symbol is converted into py.NaN in order to let the program classify the columns with missing values ('?') as a number, not an object.

In [21]:
```
from copy import deepcopy

test_columns_replacement = {
    'Column1': 'age',
    'Column2': 'sex',
    'Column3': 'chest_pain_type',
    'Column4': 'resting_blood_pressure',
    'Column5': 'serum_cholestrol',
    'Column6': 'fasting_blood_sugar',
    'Column7': 'resting_ECG',
    'Column8': 'max_heart_rate_achieved',
    'Column9': 'excercise_induced_angina',
```

```
    'Column10': 'ST_depression',
    'Column11': 'peak_exercise_ST_segment',
    'Column12': 'num_of_major_vessels',
    'Column13': 'thal',
}

train_columns_replacement = test_columns_replacement.copy()
train_columns_replacement['Column14'] = 'heart_disease_diagnosis'

train_df = train_df.rename(columns=train_columns_replacement).replace('?', np.NaN)
test_df = test_df.rename(columns=test_columns_replacement).replace('?', np.NaN)

combine = [train_df,test_df]
```

In [22]:
```
train_df.head()
```

Out[22]:

	age	sex	chest_pain_type	resting_blood_pressure	serum_cholestrol	fasting_blood_sugar	resting_ECG	max_heart_rate_achieved	excercise_induced_angina	ST_depression	peak_exercise_ST_segment	num_of_major_vessels	thal	heart_disease_diagnosis
0	54	1	4	125	216	0	0	140	0	0	NaN	NaN	NaN	1
1	55	1	4	158	217	0	0	110	1	2.5	2	NaN	NaN	1
2	54	0	3	135	304	1	0	170	0	0	1	0	3	0
3	48	0	3	120	195	0	0	125	0	0	NaN	NaN	NaN	0
4	50	1	4	120	0	0	1	156	1	0	1	NaN	6	3

In [23]:
```
test_df.head()
```

Out[23]:

	age	sex	chest_pain_type	resting_blood_pressure	serum_cholestrol
0	60	1	2	160	267
1	61	1	4	148	203

```
2   54    1                4                   130                242
3   48    1                4                   120                260
4   57    0                1                   130                308

  fasting_blood_sugar  resting_ECG max_heart_rate_achieved  \
0                   1            1                      157
1                   0            0                      161
2                   0            0                       91
3                   0            0                      115
4                   0            0                       98

  excercise_induced_angina ST_depression peak_exercise_ST_segment  \
0                        0           0.5                        2
1                        0             0                        1
2                        1             1                        2
3                        0             2                        2
4                        0             1                        2

  num_of_major_vessels thal
0                  NaN  NaN
1                    1    7
2                  NaN  NaN
3                  NaN  NaN
4                  NaN  NaN
```

0.3 Data Preprocessing

0.4 Impute Null Data

0.4.1 to make it simple, we encode null values with the median (numerical features)

```
In [24]: def stringify_categorical_data(df, colnames):
             for colname in colnames:
                 df[colname] = df[colname].astype(str)

         def impute_numerical_data(df,colnames):
             for colname in colnames:
                 df[colname].fillna(df.loc[df[colname]!=np.NaN][colname].median(),inplace=True)
                 df[colname] = df[colname].astype(np.float64)
```

0.4.2 Categorical data :

Categorical data is a categorical measurement expressed not in terms of numbers, but rather by means of a natural language description. In statistics, it is often used interchangeably with "categorical" data. Categorical data represent characteristics such as a person's gender, marital status, hometown, or the types of movies they like. Categorical data can take on numerical values (such as "1" indicating male and "2" indicating female), but those numbers don't have mathematical meaning. You couldn't add them together, for example.

0.4.3 Fields which is considered as Categorical in our problem :

- peak_exercise_ST_segment
- exercise_induced_angina
- thal

0.4.4 Numerical data :

Numerical data is a numerical measurement expressed not by means of a natural language description, but rather in terms of numbers.These data have meaning as a measurement, such as a person's height, weight, IQ, or blood pressure; or they're a count, such as the number of stock shares a person owns, how many teeth a dog has, or how many pages you can read of your favorite book before you fall asleep.

0.4.5 Fields which is considered as Numerical in our problem :

- max_heart_rate_achieved
- ST_depression
- num_of_major_vessels
- resting_blood_pressure
- fasting_blood_sugar
- serum_cholestrol
- resting_ECG

```
In [25]: categorical_data_colname = ['peak_exercise_ST_segment','excercise_induced_angina','tha
         numerical_data_colname = ['max_heart_rate_achieved',
                                   'ST_depression',
                                   'num_of_major_vessels',
                                   'resting_blood_pressure',
                                   'fasting_blood_sugar',
                                   'serum_cholestrol',
                                   'resting_ECG']

         for df in [train_df, test_df]:
             impute_numerical_data(df, numerical_data_colname)
             stringify_categorical_data(df, categorical_data_colname)

         train_df.head()
```

Out[25]:

	age	sex	chest_pain_type	resting_blood_pressure	serum_cholestrol	\
0	54	1	4	125.0	216.0	
1	55	1	4	158.0	217.0	
2	54	0	3	135.0	304.0	
3	48	0	3	120.0	195.0	
4	50	1	4	120.0	0.0	

	fasting_blood_sugar	resting_ECG	max_heart_rate_achieved	\
0	0.0	0.0	140.0	
1	0.0	0.0	110.0	

```
2                  1.0          0.0                   170.0
3                  0.0          0.0                   125.0
4                  0.0          1.0                   156.0

   excercise_induced_angina  ST_depression peak_exercise_ST_segment  \
0                         0            0.0                      nan
1                         1            2.5                        2
2                         0            0.0                        1
3                         0            0.0                      nan
4                         1            0.0                        1

    num_of_major_vessels thal  heart_disease_diagnosis
0                    0.0  nan                        1
1                    0.0  nan                        1
2                    0.0    3                        0
3                    0.0  nan                        0
4                    0.0    6                        3
```

In [26]:
```
test_df.head()
```

Out[26]:
```
   age  sex  chest_pain_type  resting_blood_pressure  serum_cholestrol  \
0   60    1                2                   160.0             267.0
1   61    1                4                   148.0             203.0
2   54    1                4                   130.0             242.0
3   48    1                4                   120.0             260.0
4   57    0                1                   130.0             308.0

    fasting_blood_sugar  resting_ECG  max_heart_rate_achieved  \
0                   1.0          1.0                   157.0
1                   0.0          0.0                   161.0
2                   0.0          0.0                    91.0
3                   0.0          0.0                   115.0
4                   0.0          0.0                    98.0

   excercise_induced_angina  ST_depression peak_exercise_ST_segment  \
0                         0            0.5                        2
1                         0            0.0                        1
2                         1            1.0                        2
3                         0            2.0                        2
4                         0            1.0                        2

    num_of_major_vessels thal
0                    0.0  nan
1                    1.0    7
2                    0.0  nan
3                    0.0  nan
4                    0.0  nan
```

In [27]:
```
train_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 779 entries, 0 to 778
Data columns (total 14 columns):
age                          779 non-null int64
sex                          779 non-null int64
chest_pain_type              779 non-null int64
resting_blood_pressure       779 non-null float64
serum_cholestrol             779 non-null float64
fasting_blood_sugar          779 non-null float64
resting_ECG                  779 non-null float64
max_heart_rate_achieved      779 non-null float64
excercise_induced_angina     779 non-null object
ST_depression                779 non-null float64
peak_exercise_ST_segment     779 non-null object
num_of_major_vessels         779 non-null float64
thal                         779 non-null object
heart_disease_diagnosis      779 non-null int64
dtypes: float64(7), int64(4), object(3)
memory usage: 85.3+ KB
```

0.5 One-Hot Encoding

```
In [28]: train_df = pd.get_dummies(train_df)
         test_df = pd.get_dummies(test_df)

In [29]: train_df.head()
```

Out[29]:

	age	sex	chest_pain_type	resting_blood_pressure	serum_cholestrol	\
0	54	1	4	125.0	216.0	
1	55	1	4	158.0	217.0	
2	54	0	3	135.0	304.0	
3	48	0	3	120.0	195.0	
4	50	1	4	120.0	0.0	

	fasting_blood_sugar	resting_ECG	max_heart_rate_achieved	ST_depression	\
0	0.0	0.0	140.0	0.0	
1	0.0	0.0	110.0	2.5	
2	1.0	0.0	170.0	0.0	
3	0.0	0.0	125.0	0.0	
4	0.0	1.0	156.0	0.0	

	num_of_major_vessels	heart_disease_diagnosis	excercise_induced_angina_0	\
0	0.0	1	1	
1	0.0	1	0	
2	0.0	0	1	
3	0.0	0	1	
4	0.0	3	0	

```
   excercise_induced_angina_1  excercise_induced_angina_nan  \
0                           0                             0
1                           1                             0
2                           0                             0
3                           0                             0
4                           1                             0

   peak_exercise_ST_segment_1  peak_exercise_ST_segment_2  \
0                           0                          0
1                           0                          1
2                           1                          0
3                           0                          0
4                           1                          0

   peak_exercise_ST_segment_3  peak_exercise_ST_segment_nan  thal_3  thal_6  \
0                           0                            1       0       0
1                           0                            0       0       0
2                           0                            0       1       0
3                           0                            1       0       0
4                           0                            0       0       1

   thal_7  thal_nan
0       0         1
1       0         1
2       0         0
3       0         1
4       0         0
```

In [30]: `train_df.values.shape`

Out[30]: (779, 22)

In [31]: `test_df.head()`

Out[31]:
```
   age  sex  chest_pain_type  resting_blood_pressure  serum_cholestrol  \
0   60    1                2                   160.0             267.0
1   61    1                4                   148.0             203.0
2   54    1                4                   130.0             242.0
3   48    1                4                   120.0             260.0
4   57    0                1                   130.0             308.0

   fasting_blood_sugar  resting_ECG  max_heart_rate_achieved  ST_depression  \
0                  1.0          1.0                    157.0            0.5
1                  0.0          0.0                    161.0            0.0
2                  0.0          0.0                     91.0            1.0
3                  0.0          0.0                    115.0            2.0
4                  0.0          0.0                     98.0            1.0
```

```
   num_of_major_vessels  excercise_induced_angina_0  \
0                   0.0                           1
1                   1.0                           1
2                   0.0                           0
3                   0.0                           1
4                   0.0                           1

   excercise_induced_angina_1  excercise_induced_angina_nan  \
0                           0                             0
1                           0                             0
2                           1                             0
3                           0                             0
4                           0                             0

   peak_exercise_ST_segment_1  peak_exercise_ST_segment_2  \
0                           0                           1
1                           1                           0
2                           0                           1
3                           0                           1
4                           0                           1

   peak_exercise_ST_segment_3  peak_exercise_ST_segment_nan  thal_3  thal_6  \
0                           0                             0       0       0
1                           0                             0       0       0
2                           0                             0       0       0
3                           0                             0       0       0
4                           0                             0       0       0

   thal_7  thal_nan
0       0         1
1       1         0
2       0         1
3       0         1
4       0         1
```

```
In [32]: test_df.shape
```

```
Out[32]: (141, 21)
```

```
In [39]: test_df = test_df[train_df.drop('heart_disease_diagnosis', axis=1).columns]
```

0.6 Save Processed Data

Save the processed data to the ../raw/processed folder

```
In [53]: train_df.to_csv('{}/processed_train_data.csv'.format(PROCESSED_DATA_PATH),index=False)
         test_df.to_csv('{}/processed_test_data.csv'.format(PROCESSED_DATA_PATH),index=False)
```

0.7 Reference

1. http://scaryscientist.blogspot.com/2015/02/classification-of-data-types.html

In [ ]:

3. Modelling and Tuning

November 21, 2018

In [18]:
```
import pandas as pd
import numpy as np

from sklearn import preprocessing
from sklearn.naive_bayes import GaussianNB
from sklearn.linear_model import LogisticRegression
from sklearn.neighbors import KNeighborsClassifier
from sklearn.tree import DecisionTreeClassifier
from sklearn.neural_network import MLPClassifier

from sklearn.model_selection import train_test_split, KFold, cross_val_score, GridSea

from sklearn.metrics import accuracy_score, recall_score, precision_score

import pickle

import warnings

warnings.filterwarnings('ignore')
```

1 Load data

1.0.1 Initialize path constant

In [19]:
```
DATA_PATH = '../data'
RAW_DATA_PATH = '{}/raw'.format(DATA_PATH)
PROCESSED_DATA_PATH = '{}/processed'.format(DATA_PATH)

MODEL_PATH = '../models'
```

1.0.2 Read processed data from CSV

In [32]:
```
# data = pd.read_csv('{}/processed_data.csv'.format(PROCESSED_DATA_PATH))
data = pd.read_csv('{}/processed_train_data.csv'.format(PROCESSED_DATA_PATH))
X_df = data.drop(['heart_disease_diagnosis'], axis=1)
X = X_df
y = data['heart_disease_diagnosis']
```

2 Feature Elimination Function

In [4]:
```
from itertools import chain, combinations

        # RFE-ish with no rank. kwargs = arguments to be passed to the scorer
        # Maybe create a custom scoring function for combining multiple score?
        # X HAS TO BE DATAFRAME, because it supports .drop()
        def rfe_no_rank(model, X_train, X_vali, y_train, y_vali, scorer, **kwargs):
            attr_to_drop = []
            best_target_yet = 0
            attributes = X_train.columns.values.tolist()
            # For every element in the attribute powerset...
            for subset in chain.from_iterable(combinations(attributes, r) for r in range(len(at
                # ...fit, predict, and calculate score without them
                model.fit(X_train.drop(list(subset), axis=1), y_train)
                y_pred = model.predict(X_vali.drop(list(subset), axis=1))
                target_now = scorer(y_pred, y_vali, **kwargs)
                if target_now > best_target_yet:
                    best_target_yet = target_now
                    attr_to_drop = list(subset)
            return attr_to_drop, best_target_yet
```

3 Evaluation

We decided to use accuracy as out main evaluation metric to optimize so that we can see the performance of each model in predicting the correct label.

4 Cross Validation

4.0.1 CV Function

In [13]:
```
def get_kfold():
            return KFold(n_splits=5, shuffle=True, random_state=1)

        def print_cv_result(model, X, y):
            accuracy_scores = []
            precision_scores = []
            recall_scores = []

            kfold = get_kfold()

            for train_idx, validation_idx in kfold.split(X, y):
                X_train = X[train_idx]
                y_train = y[train_idx]
                X_validation = X[validation_idx]
                y_validation = y[validation_idx]
```

```
            model.fit(X_train, y_train)

            prediction = model.predict(X_validation)

            accuracy = accuracy_score(y_validation, prediction)
            precision = precision_score(y_validation, prediction, average='macro')
            recall = recall_score(y_validation, prediction, average='macro')

            accuracy_scores.append(accuracy)
            precision_scores.append(precision)
            recall_scores.append(recall)

        print('--- Validation Metrics ---')
        print('Accuracy  = {:.3f}'.format(np.mean(accuracy_scores)))
        print('Precision = {:.3f}'.format(np.mean(precision_scores)))
        print('Recall    = {:.3f}'.format(np.mean(recall_scores)))
```

4.1 Models

4.1.1 Naive Bayes

```
In [7]: model_name = 'Naive Bayes'
        nb_model = GaussianNB()

        print('=== {} ===\n'.format(model_name))
        print_cv_result(nb_model, X, y)
```

```
=== Naive Bayes ===

--- Validation Metrics ---
Accuracy  = 0.546
Precision = 0.353
Recall    = 0.370
```

4.1.2 KNN

In K-Nearest Neighbors algorithm, it's really important to scale the features first (feature scaling). Since the range of values of raw data varies widely, in K-Nearest Neighbors algoritm, objective functions will not work properly without normalization. For example, the majority of classifiers calculate the distance between two points by the Euclidean distance. If one of the features has a broad range of values, the distance will be governed by this particular feature. Therefore, the range of all features should be normalized so that each feature contributes approximately proportionately to the final distance.

```
In [8]: model_name = 'K-Nearest Neighbor'
        knn_model = KNeighborsClassifier()
        X_Scaled = preprocessing.scale(X)
```

```
        print('=== {} ===\n'.format(model_name))
        print_cv_result(knn_model, X_Scaled, y)
```

```
=== K-Nearest Neighbor ===

--- Validation Metrics ---
Accuracy  = 0.548
Precision = 0.298
Recall    = 0.314
```

4.1.3 Decision Tree

```
In [10]: model_name = 'Decision Tree'
         dtc_model = DecisionTreeClassifier(criterion='entropy', random_state=1)

         print('=== {} ===\n'.format(model_name))
         print_cv_result(dtc_model, X, y)

         # rfe_no_rank(dtc_model, X_df[:500], X_df[500:], y[:500], y[500:], accuracy_score)
```

```
=== Decision Tree ===

--- Validation Metrics ---
Accuracy  = 0.458
Precision = 0.313
Recall    = 0.313
```

4.1.4 ANN

```
In [11]: model_name = 'ANN'
         ann_model = MLPClassifier(random_state=1, activation='logistic')
         X_Scaled = preprocessing.scale(X)

         print('=== {} ===\n'.format(model_name))
         print_cv_result(ann_model, X_Scaled, y)
```

```
=== ANN ===

--- Validation Metrics ---
Accuracy  = 0.582
Precision = 0.347
Recall    = 0.351
```

5 Feature Elimination

```
In [38]: from sklearn.base import clone

         def rfe_no_rank(model, X, y, n_remove):
             if n_remove <= 0:
                 return

             best_score = -1
             best_removed = None
             for feat in X.columns:
                 score = cross_val_score(clone(model),
                                         preprocessing.scale(X.drop(feat, axis=1).values),
                                         y,
                                         cv=get_kfold(),
                                         scoring='accuracy').mean()
                 if score > best_score:
                     best_score = score
                     best_removed = feat

             print('remove', best_removed, '- Best accuracy:', best_score)

             rfe_no_rank(model, X.drop(best_removed, axis=1), y, n_remove - 1)

In [39]: rfe_no_rank(MLPClassifier(random_state=1, activation='logistic'), X, y, 5)
```

```
remove sex - Best accuracy: 0.5943507030603804
remove fasting_blood_sugar - Best accuracy: 0.582803970223325
remove max_heart_rate_achieved - Best accuracy: 0.5853598014888337
remove peak_exercise_ST_segment_1 - Best accuracy: 0.5892059553349875
remove resting_blood_pressure - Best accuracy: 0.5879239040529363
```

6 Tune Best Base Model

```
In [41]: param_grid = {
             'hidden_layer_sizes': [(50,), (100,), (50, 50), (100, 100)],
             'solver': ['lbfgs', 'sgd', 'adam'],
             'alpha': [1e-4, 1e-3, 1e-2, 1e-1],
             'learning_rate': ['constant', 'invscaling', 'adaptive']
         }

         best_model = GridSearchCV(MLPClassifier(random_state=1, activation='logistic'),
                                   param_grid,
                                   cv=get_kfold(),
                                   scoring='accuracy',
                                   verbose=20)
```

```
        best_model.fit(preprocessing.scale(X.drop('sex', axis=1).values), y)
```

```
Fitting 5 folds for each of 144 candidates, totalling 720 fits
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=lbfgs


[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=lbfgs, score=0.467
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=lbfgs, score=0.525
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=lbfgs


[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    0.3s remaining:    0.0s
[Parallel(n_jobs=1)]: Done   2 out of   2 | elapsed:    0.5s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=lbfgs, score=0.467
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=lbfgs


[Parallel(n_jobs=1)]: Done   3 out of   3 | elapsed:    0.7s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=lbfgs, score=0.474
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=lbfgs


[Parallel(n_jobs=1)]: Done   4 out of   4 | elapsed:    0.9s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=lbfgs, score=0.477
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=sgd


[Parallel(n_jobs=1)]: Done   5 out of   5 | elapsed:    1.1s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=sgd, score=0.55769
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=sgd


[Parallel(n_jobs=1)]: Done   6 out of   6 | elapsed:    1.6s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=sgd, score=0.57051
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=sgd
```

```
[Parallel(n_jobs=1)]: Done   7 out of   7 | elapsed:    2.2s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=sgd, score=0.55128
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=sgd


[Parallel(n_jobs=1)]: Done   8 out of   8 | elapsed:    2.7s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=sgd, score=0.63461
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=sgd


[Parallel(n_jobs=1)]: Done   9 out of   9 | elapsed:    3.3s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=sgd, score=0.53548
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=adam


[Parallel(n_jobs=1)]: Done  10 out of  10 | elapsed:    3.7s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=adam, score=0.5897
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=adam


[Parallel(n_jobs=1)]: Done  11 out of  11 | elapsed:    4.3s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=adam, score=0.5897
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=adam


[Parallel(n_jobs=1)]: Done  12 out of  12 | elapsed:    4.9s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=adam, score=0.5641
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=adam


[Parallel(n_jobs=1)]: Done  13 out of  13 | elapsed:    5.4s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=adam, score=0.5705
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=adam


[Parallel(n_jobs=1)]: Done  14 out of  14 | elapsed:    6.0s remaining:    0.0s
```

```
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=constant, solver=adam, score=0.548
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=lbfgs, score=0.4
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=lbfgs


[Parallel(n_jobs=1)]: Done  15 out of  15 | elapsed:    6.4s remaining:    0.0s
[Parallel(n_jobs=1)]: Done  16 out of  16 | elapsed:    6.6s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=lbfgs, score=0.5
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=lbfgs, score=0.4
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=lbfgs


[Parallel(n_jobs=1)]: Done  17 out of  17 | elapsed:    6.8s remaining:    0.0s
[Parallel(n_jobs=1)]: Done  18 out of  18 | elapsed:    7.0s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=lbfgs, score=0.4
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=lbfgs


[Parallel(n_jobs=1)]: Done  19 out of  19 | elapsed:    7.2s remaining:    0.0s


[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=lbfgs, score=0.4
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=sgd, score=0.435
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=sgd, score=0.435
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=sgd, score=0.423
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=sgd
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[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=sgd, score=0.419
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=adam, score=0.58
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=adam, score=0.58
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=adam, score=0.56
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=adam, score=0.57
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=invscaling, solver=adam, score=0.54
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=lbfgs
```

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[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=lbfgs, score=0.467
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=lbfgs, score=0.525
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=lbfgs, score=0.467
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=lbfgs, score=0.474
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=lbfgs, score=0.477
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=sgd, score=0.55769
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[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=sgd, score=0.57051
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=sgd, score=0.55128
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=sgd
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[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=sgd, score=0.53548
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=adam, score=0.589
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=adam, score=0.589
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=adam, score=0.564
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=adam, score=0.570
[CV] alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(50,), learning_rate=adaptive, solver=adam, score=0.548
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=lbfgs, score=0.5
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[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=lbfgs, score=0.56
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=lbfgs, score=0.53
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=lbfgs, score=0.46
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=lbfgs, score=0.55
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=sgd, score=0.564
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=sgd, score=0.551
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=sgd, score=0.538
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=sgd, score=0.615
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=sgd
```

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[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=sgd, score=0.5225
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=adam, score=0.596
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=adam, score=0.602
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=adam, score=0.596
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[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=constant, solver=adam, score=0.593
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=lbfgs, score=0
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=lbfgs, score=0
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=lbfgs, score=0
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=lbfgs, score=0
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=lbfgs, score=0
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=sgd, score=0.43
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=sgd, score=0.42
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=sgd, score=0.43
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=sgd
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[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=sgd, score=0.43
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[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=adam, score=0.5
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[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=invscaling, solver=adam, score=0.5
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=lbfgs
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=lbfgs, score=0.5
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=lbfgs
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[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=lbfgs, score=0.53
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=lbfgs
```

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[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=lbfgs, score=0.46
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=lbfgs
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[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=sgd, score=0.564
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[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=sgd, score=0.551
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=sgd, score=0.538
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=sgd, score=0.615
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=sgd
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[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=adam, score=0.59
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=adam, score=0.58
[CV] alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=adam
[CV]  alpha=0.0001, hidden_layer_sizes=(100,), learning_rate=adaptive, solver=adam, score=0.59
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[CV] alpha=0.0001, hidden_layer_sizes=(50, 50), learning_rate=constant, solver=adam
```

```
[CV]  alpha=0.0001, hidden_layer_sizes=(50, 50), learning_rate=constant, solver=adam, score=0.5
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[CV]  alpha=0.0001, hidden_layer_sizes=(50, 50), learning_rate=invscaling, solver=sgd, score=0
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[CV]  alpha=0.0001, hidden_layer_sizes=(50, 50), learning_rate=adaptive, solver=lbfgs, score=0
[CV] alpha=0.0001, hidden_layer_sizes=(50, 50), learning_rate=adaptive, solver=sgd
[CV]  alpha=0.0001, hidden_layer_sizes=(50, 50), learning_rate=adaptive, solver=sgd, score=0.43
[CV] alpha=0.0001, hidden_layer_sizes=(50, 50), learning_rate=adaptive, solver=sgd
```

```
[CV]  alpha=0.0001, hidden_layer_sizes=(50, 50), learning_rate=adaptive, solver=sgd, score=0.42
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[CV]  alpha=0.0001, hidden_layer_sizes=(50, 50), learning_rate=adaptive, solver=sgd, score=0.43
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[CV]  alpha=0.0001, hidden_layer_sizes=(50, 50), learning_rate=adaptive, solver=sgd, score=0.43
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```

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```

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```

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```

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```

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[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=sgd, score=0.4
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=sgd
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=sgd, score=0.5
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=sgd
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=sgd, score=0.4
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=adam
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=adam, score=0
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=adam
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=adam, score=0
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=adam
```

```
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=adam, score=0
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=adam
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=adam, score=0
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=adam
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=invscaling, solver=adam, score=0
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=lbfgs
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=lbfgs, score=0.5
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=lbfgs
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=lbfgs, score=0.5
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=lbfgs
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=lbfgs, score=0.5
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=lbfgs
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=lbfgs, score=0.4
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=lbfgs
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=lbfgs, score=0.4
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=sgd
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=sgd, score=0.435
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=sgd
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=sgd, score=0.429
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=sgd
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=sgd, score=0.435
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=sgd
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=sgd, score=0.5,
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=sgd
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=sgd, score=0.438
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=adam
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=adam, score=0.59
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=adam
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=adam, score=0.58
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=adam
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=adam, score=0.54
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=adam
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=adam, score=0.58
[CV] alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=adam
[CV]  alpha=0.1, hidden_layer_sizes=(100, 100), learning_rate=adaptive, solver=adam, score=0.57
```

```
[Parallel(n_jobs=1)]: Done 720 out of 720 | elapsed:  8.1min finished
```

```
Out[41]: GridSearchCV(cv=KFold(n_splits=5, random_state=1, shuffle=True),
                error_score='raise-deprecating',
                estimator=MLPClassifier(activation='logistic', alpha=0.0001, batch_size='auto'
                beta_1=0.9, beta_2=0.999, early_stopping=False, epsilon=1e-08,
                hidden_layer_sizes=(100,), learning_rate='constant',
                learning_rate_init=0.001, max_iter=200, momentum=0.9,
                n_iter_no_change=10, nesterovs_momentum=True, power_t=0.5,
                random_state=1, shuffle=True, solver='adam', tol=0.0001,
```

```
                validation_fraction=0.1, verbose=False, warm_start=False),
                fit_params=None, iid='warn', n_jobs=None,
                param_grid={'hidden_layer_sizes': [(50,), (100,), (50, 50), (100, 100)], 'solve
                pre_dispatch='2*n_jobs', refit=True, return_train_score='warn',
                scoring='accuracy', verbose=20)
```

```
In [42]: print('Best accuracy :', best_model.best_score_)
         print('Best params   :', best_model.best_params_)
```

```
Best accuracy : 0.5943517329910141
Best params   : {'alpha': 0.0001, 'hidden_layer_sizes': (100,), 'learning_rate': 'constant', 's
```

```
In [45]: best_params = {'alpha': 0.0001, 'hidden_layer_sizes': (100,), 'learning_rate': 'consta
         model = MLPClassifier(random_state=1, activation='logistic', **best_params)
         print_cv_result(model, preprocessing.scale(X.drop('sex', axis=1).values), y)
```

```
--- Validation Metrics ---
Accuracy  = 0.594
Precision = 0.367
Recall    = 0.368
```

7 Final Train

```
In [46]: best_params = {'alpha': 0.0001, 'hidden_layer_sizes': (100,), 'learning_rate': 'consta
         model = MLPClassifier(random_state=1, activation='logistic', **best_params)
         model.fit(X_Scaled, y)
```

```
Out[46]: MLPClassifier(activation='logistic', alpha=0.0001, batch_size='auto',
                beta_1=0.9, beta_2=0.999, early_stopping=False, epsilon=1e-08,
                hidden_layer_sizes=(100,), learning_rate='constant',
                learning_rate_init=0.001, max_iter=200, momentum=0.9,
                n_iter_no_change=10, nesterovs_momentum=True, power_t=0.5,
                random_state=1, shuffle=True, solver='adam', tol=0.0001,
                validation_fraction=0.1, verbose=False, warm_start=False)
```

8 Predict Test Data

```
In [47]: test_data = pd.read_csv('{}/processed_test_data.csv'.format(PROCESSED_DATA_PATH))
         X_test = test_data.values
```

```
In [48]: X_test_scaled = preprocessing.scale(X_test)
```

```
In [49]: model.predict(X_test_scaled)
```

```
Out[49]: array([0, 1, 1, 1, 0, 0, 3, 1, 0, 0, 1, 1, 0, 2, 0, 3, 1, 0, 0, 1, 0, 1,
                0, 1, 1, 0, 1, 1, 3, 1, 0, 1, 2, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 1,
```

```
2, 1, 1, 3, 1, 1, 0, 0, 2, 1, 1, 0, 0, 1, 1, 0, 0, 0, 1, 2, 0, 0,
1, 0, 0, 0, 1, 0, 0, 2, 0, 1, 1, 0, 0, 0, 0, 3, 1, 3, 0, 3, 0, 0,
0, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0, 2, 0, 0, 0, 1, 0, 0, 1, 1, 3,
0, 0, 0, 0, 0, 2, 0, 3, 0, 1, 3, 1, 0, 1, 1, 0, 1, 2, 0, 0, 0, 1,
3, 2, 1, 2, 0, 0, 0, 0, 0])
```

8.1 Save Best Model

```
In [50]: pickle.dump(model, open('{}/best_model.pkl'.format(MODEL_PATH), 'wb'))
```

8.2 Reference

1. https://en.wikipedia.org/wiki/Feature_scaling


```
In [ ]:
```