Q1

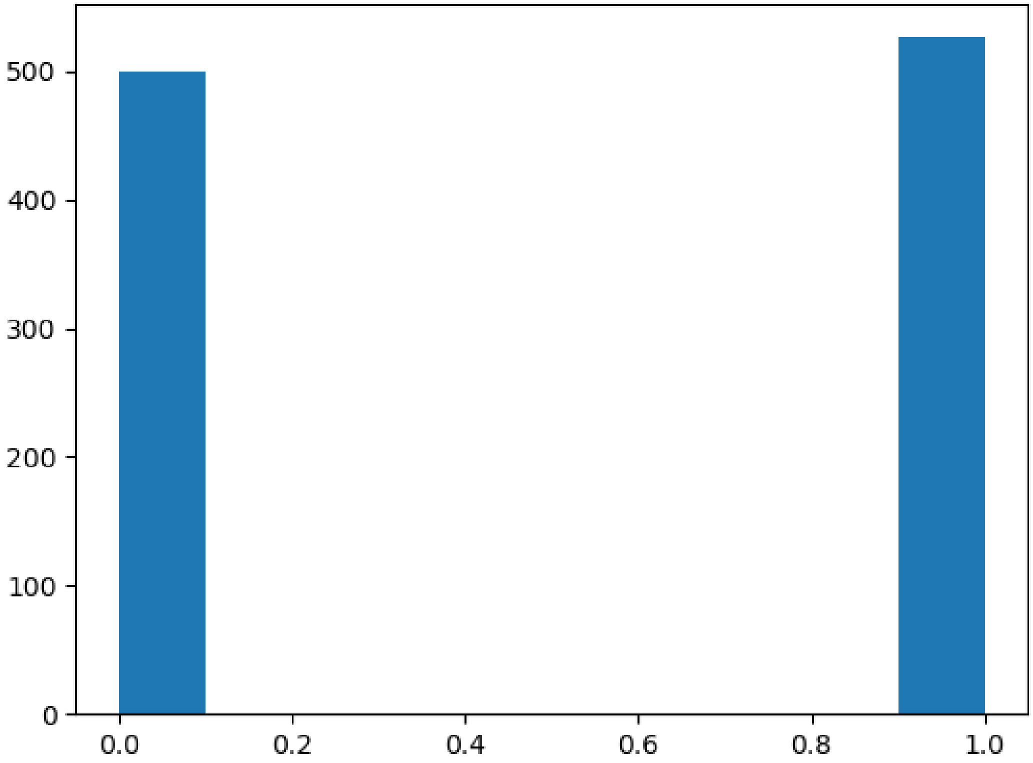
May 17, 2023

```
[63]: import numpy as np
      import pandas as pd
      import matplotlib.pyplot as plt
      from sklearn.model_selection import train_test_split
      from sklearn.neural_network import MLPClassifier
      from sklearn.metrics import classification_report, confusion_matrix ,␣
        ↪accuracy_score
```

```
[2]: df = pd.read_csv("AI_heart.csv")
     df.head()
```

```
[2]:     age sex  cp  trestbps  chol  fbs  restecg  thalach  exang  oldpeak  slope  \
     0  52.0   M   0       125   212    0        1      168      0      1.0      2
     1  53.0   M   0       140   203    1        0      155      1      3.1      0
     2  70.0   M   0       145   174    0        1      125      1      2.6      0
     3  61.0   M   0       148   203    0        1      161      0      0.0      2
     4  62.0   F   0       138   294    1        1      106      0      1.9      1

        ca  thal  target
     0   2     3       0
     1   0     3       0
     2   0     3       0
     3   1     3       0
     4   3     2       0
```

```
[7]: plt.hist(df['target'])
     plt.show()
```



[8]:
```
# Data is not imbalanced
```

[10]:
```
corr_matrix = df.corr()
corr_matrix
```

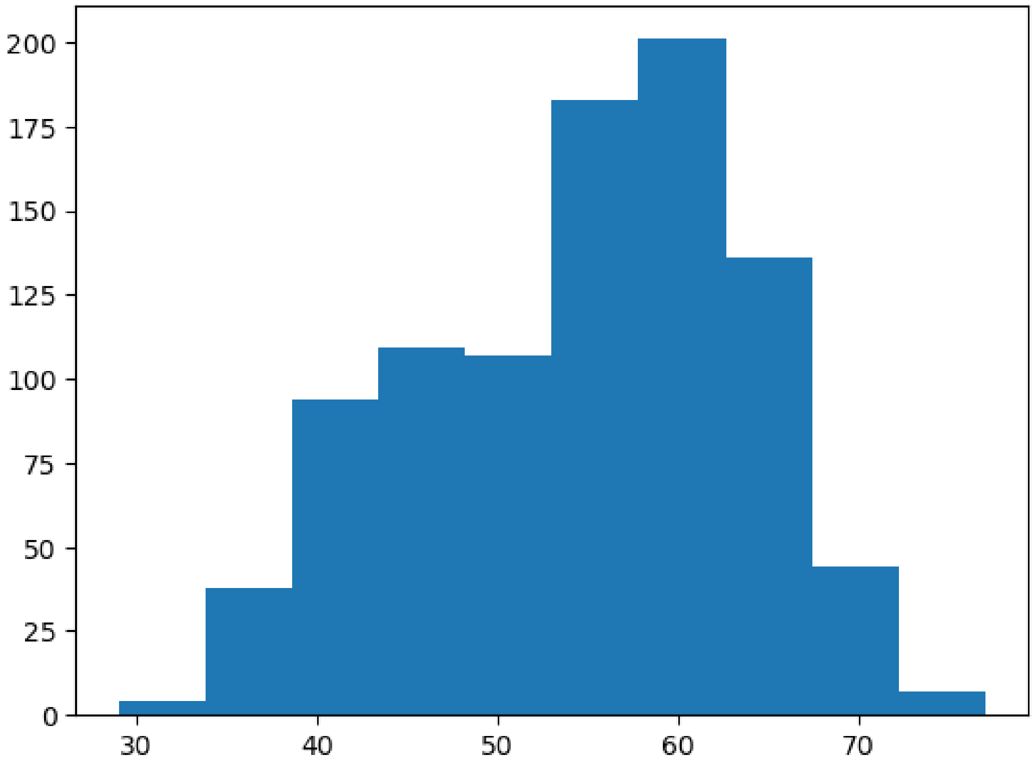
[10]:
```
               age        cp  trestbps      chol       fbs   restecg  \
age       1.000000 -0.081711  0.265283  0.217452  0.113552 -0.135061
cp       -0.081711  1.000000  0.038177 -0.081641  0.079294  0.043581
trestbps  0.265283  0.038177  1.000000  0.127977  0.181767 -0.123794
chol      0.217452 -0.081641  0.127977  1.000000  0.026917 -0.147410
fbs       0.113552  0.079294  0.181767  0.026917  1.000000 -0.104051
restecg  -0.135061  0.043581 -0.123794 -0.147410 -0.104051  1.000000
thalach  -0.398372  0.306839 -0.039264 -0.021772 -0.008866  0.048411
exang     0.086225 -0.401513  0.061197  0.067382  0.049261 -0.065606
oldpeak   0.196630 -0.174733  0.187434  0.064880  0.010859 -0.050114
slope    -0.168715  0.131633 -0.120445 -0.014248 -0.061902  0.086086
ca        0.262819 -0.176206  0.104554  0.074259  0.137156 -0.078072
thal      0.060679 -0.163341  0.059276  0.100244 -0.042177 -0.020504
target   -0.222158  0.434854 -0.138772 -0.099966 -0.041164  0.134468

           thalach     exang   oldpeak     slope        ca      thal    target
age      -0.398372  0.086225  0.196630 -0.168715  0.262819  0.060679 -0.222158
```

```
cp         0.306839 -0.401513 -0.174733  0.131633 -0.176206 -0.163341  0.434854
trestbps -0.039264  0.061197  0.187434 -0.120445  0.104554  0.059276 -0.138772
chol      -0.021772  0.067382  0.064880 -0.014248  0.074259  0.100244 -0.099966
fbs       -0.008866  0.049261  0.010859 -0.061902  0.137156 -0.042177 -0.041164
restecg    0.048411 -0.065606 -0.050114  0.086086 -0.078072 -0.020504  0.134468
thalach    1.000000 -0.380281 -0.349796  0.395308 -0.207888 -0.098068  0.422895
exang     -0.380281  1.000000  0.310844 -0.267335  0.107849  0.197201 -0.438029
oldpeak   -0.349796  0.310844  1.000000 -0.575189  0.221816  0.202672 -0.438441
slope      0.395308 -0.267335 -0.575189  1.000000 -0.073440 -0.094090  0.345512
ca        -0.207888  0.107849  0.221816 -0.073440  1.000000  0.149014 -0.382085
thal      -0.098068  0.197201  0.202672 -0.094090  0.149014  1.000000 -0.337838
target     0.422895 -0.438029 -0.438441  0.345512 -0.382085 -0.337838  1.000000
```

[11]:
```
df.isna().sum()
```

[11]:
```
age         102
sex           0
cp            0
trestbps      0
chol          0
fbs           0
restecg       0
thalach       0
exang         0
oldpeak       0
slope         0
ca            0
thal          0
target        0
dtype: int64
```

[14]:
```
plt.hist(df['age'],bins=10)
plt.show()
```



```
[16]: df['age'].mean()
```

```
[16]: 54.522210184182015
```

```
[17]: # The maximum patients lie between 50-65, so I will fill the missing values␣
       ↪with mean
```

```
[23]: df['age'] = df['age'].fillna(df['age'].mean())
```

```
[24]: df.isna().sum()
```

```
[24]: age         0
      sex         0
      cp          0
      trestbps    0
      chol        0
      fbs         0
      restecg     0
      thalach     0
      exang       0
      oldpeak     0
      slope       0
```

```
ca          0
thal        0
target      0
dtype: int64
```

[25]:
```
df.head()
```

[25]:
```
    age sex  cp  trestbps  chol  fbs  restecg  thalach  exang  oldpeak  slope  \
0  52.0   M   0       125   212    0        1      168      0      1.0      2
1  53.0   M   0       140   203    1        0      155      1      3.1      0
2  70.0   M   0       145   174    0        1      125      1      2.6      0
3  61.0   M   0       148   203    0        1      161      0      0.0      2
4  62.0   F   0       138   294    1        1      106      0      1.9      1

   ca  thal  target
0   2     3       0
1   0     3       0
2   0     3       0
3   1     3       0
4   3     2       0
```

[28]:
```
df['sex'].unique()
```

[28]:
```
array(['M', 'F'], dtype=object)
```

[31]:
```
# Replace Male with 0 and Female with 1
```

[29]:
```
df['sex'] = df['sex'].replace('M',0)
df['sex'] = df['sex'].replace('F',1)
```

[30]:
```
df.head()
```

[30]:
```
    age  sex  cp  trestbps  chol  fbs  restecg  thalach  exang  oldpeak  \
0  52.0    0   0       125   212    0        1      168      0      1.0
1  53.0    0   0       140   203    1        0      155      1      3.1
2  70.0    0   0       145   174    0        1      125      1      2.6
3  61.0    0   0       148   203    0        1      161      0      0.0
4  62.0    1   0       138   294    1        1      106      0      1.9

   slope  ca  thal  target
0      2   2     3       0
1      0   0     3       0
2      0   0     3       0
3      2   1     3       0
4      1   3     2       0
```

[32]:
```
df['sex'].unique()
```

[32]:
```
array([0, 1])
```

[40]:
```
df
```

[40]:
```
              age  sex  cp  trestbps  chol  fbs  restecg  thalach  exang  \
0     52.00000    0   0       125   212    0        1      168      0
1     53.00000    0   0       140   203    1        0      155      1
2     70.00000    0   0       145   174    0        1      125      1
3     61.00000    0   0       148   203    0        1      161      0
4     62.00000    1   0       138   294    1        1      106      0
…        …  …   ..      …   …  …      …      …    …
1020  59.00000    0   1       140   221    0        1      164      1
1021  60.00000    0   0       125   258    0        0      141      1
1022  47.00000    0   0       110   275    0        0      118      1
1023  50.00000    1   0       110   254    0        0      159      0
1024  54.52221    0   0       120   188    0        1      113      0

      oldpeak  slope  ca  thal  target
0         1.0      2   2     3       0
1         3.1      0   0     3       0
2         2.6      0   0     3       0
3         0.0      2   1     3       0
4         1.9      1   3     2       0
…       …    …   ..  …     …
1020      0.0      2   0     2       1
1021      2.8      1   1     3       0
1022      1.0      1   1     2       0
1023      0.0      2   0     2       1
1024      1.4      1   1     3       0

[1025 rows x 14 columns]
```

[42]:
```
# In co-relation matrix, no two features had any close relation, noone was more␣
 ↪the 0.8, so everyone is contributing
# in the dataset
```

[44]:
```
df.head()
```

[44]:
```
    age  sex  cp  trestbps  chol  fbs  restecg  thalach  exang  oldpeak  \
0  52.0    0   0       125   212    0        1      168      0      1.0
1  53.0    0   0       140   203    1        0      155      1      3.1
2  70.0    0   0       145   174    0        1      125      1      2.6
3  61.0    0   0       148   203    0        1      161      0      0.0
4  62.0    1   0       138   294    1        1      106      0      1.9

   slope  ca  thal  target
0      2   2     3       0
```

```
1      0   0     3       0
2      0   0     3       0
3      2   1     3       0
4      1   3     2       0
```

[54]:

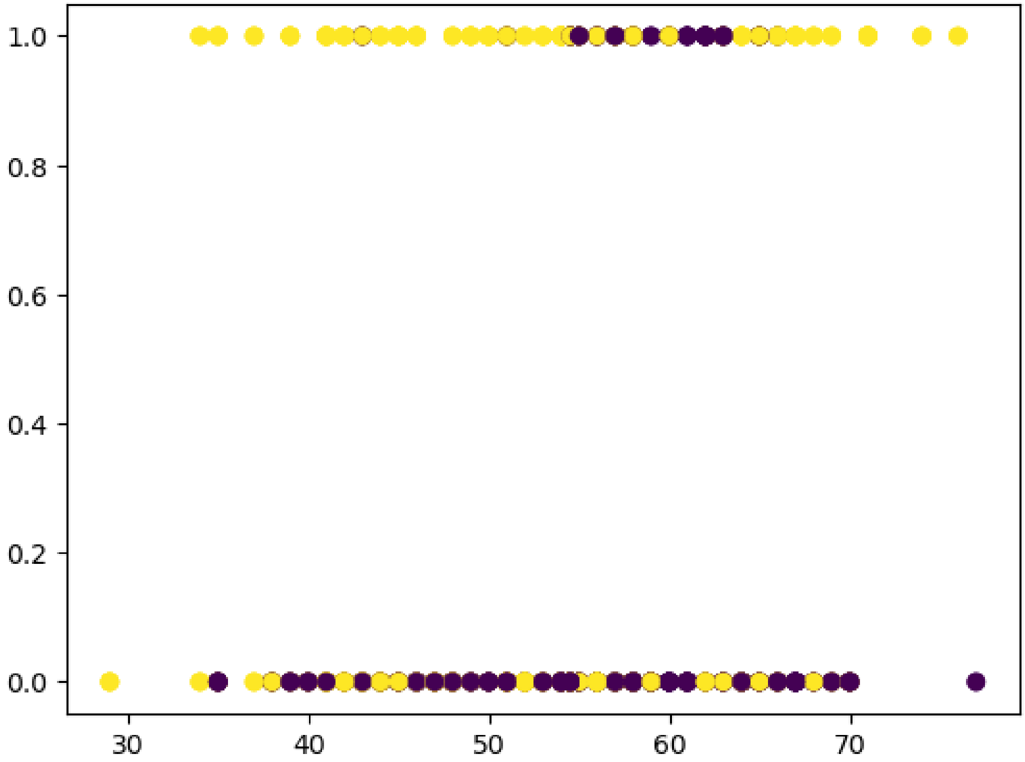
```
corr_matrix = df.corr()
corr_matrix
```

[54]:

```
               age       sex        cp  trestbps      chol       fbs  \
age       1.000000  0.102784 -0.077598  0.254872  0.201472  0.106852
sex       0.102784  1.000000  0.041119  0.078974  0.198258 -0.027200
cp       -0.077598  0.041119  1.000000  0.038177 -0.081641  0.079294
trestbps  0.254872  0.078974  0.038177  1.000000  0.127977  0.181767
chol      0.201472  0.198258 -0.081641  0.127977  1.000000  0.026917
fbs       0.106852 -0.027200  0.079294  0.181767  0.026917  1.000000
restecg  -0.127490  0.055117  0.043581 -0.123794 -0.147410 -0.104051
thalach  -0.376334  0.049365  0.306839 -0.039264 -0.021772 -0.008866
exang     0.081909 -0.139157 -0.401513  0.061197  0.067382  0.049261
oldpeak   0.188428 -0.084687 -0.174733  0.187434  0.064880  0.010859
slope    -0.160123  0.026666  0.131633 -0.120445 -0.014248 -0.061902
ca        0.252277 -0.111729 -0.176206  0.104554  0.074259  0.137156
thal      0.057229 -0.198424 -0.163341  0.059276  0.100244 -0.042177
target   -0.210822  0.279501  0.434854 -0.138772 -0.099966 -0.041164

           restecg   thalach     exang   oldpeak     slope        ca  \
age      -0.127490 -0.376334  0.081909  0.188428 -0.160123  0.252277
sex       0.055117  0.049365 -0.139157 -0.084687  0.026666 -0.111729
cp        0.043581  0.306839 -0.401513 -0.174733  0.131633 -0.176206
trestbps -0.123794 -0.039264  0.061197  0.187434 -0.120445  0.104554
chol     -0.147410 -0.021772  0.067382  0.064880 -0.014248  0.074259
fbs      -0.104051 -0.008866  0.049261  0.010859 -0.061902  0.137156
restecg   1.000000  0.048411 -0.065606 -0.050114  0.086086 -0.078072
thalach   0.048411  1.000000 -0.380281 -0.349796  0.395308 -0.207888
exang    -0.065606 -0.380281  1.000000  0.310844 -0.267335  0.107849
oldpeak  -0.050114 -0.349796  0.310844  1.000000 -0.575189  0.221816
slope     0.086086  0.395308 -0.267335 -0.575189  1.000000 -0.073440
ca       -0.078072 -0.207888  0.107849  0.221816 -0.073440  1.000000
thal     -0.020504 -0.098068  0.197201  0.202672 -0.094090  0.149014
target    0.134468  0.422895 -0.438029 -0.438441  0.345512 -0.382085

              thal    target
age       0.057229 -0.210822
sex      -0.198424  0.279501
cp       -0.163341  0.434854
trestbps  0.059276 -0.138772
chol      0.100244 -0.099966
fbs      -0.042177 -0.041164
```

```
restecg   -0.020504  0.134468
thalach   -0.098068  0.422895
exang      0.197201 -0.438029
oldpeak    0.202672 -0.438441
slope     -0.094090  0.345512
ca         0.149014 -0.382085
thal       1.000000 -0.337838
target    -0.337838  1.000000
```

[56]:
```
plt.scatter(df['age'],df['sex'],c=df['target'])
plt.show()
```



[46]:
```
temp = df[df['age']<30]
temp
```

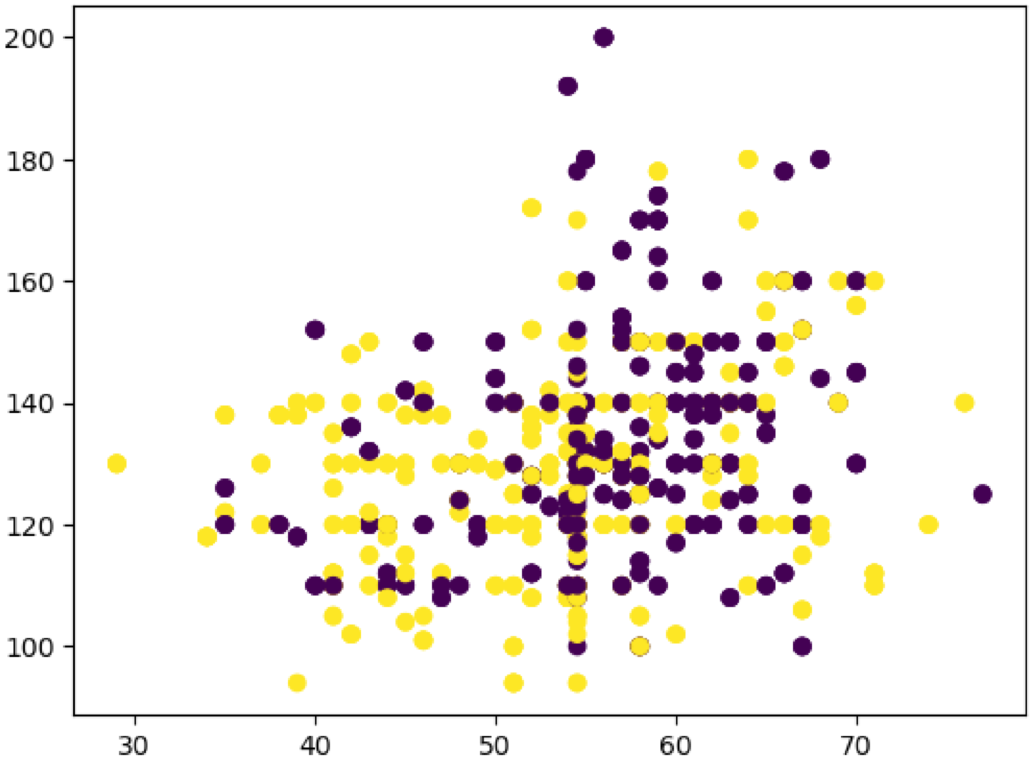
[46]:
```
      age  sex  cp  trestbps  chol  fbs  restecg  thalach  exang  oldpeak  \
60   29.0    0   1       130   204    0        0      202      0      0.0
64   29.0    0   1       130   204    0        0      202      0      0.0
118  29.0    0   1       130   204    0        0      202      0      0.0
668  29.0    0   1       130   204    0        0      202      0      0.0

     slope  ca  thal  target
```

```
60          2    0      2         1
64          2    0      2         1
118         2    0      2         1
668         2    0      2         1
```

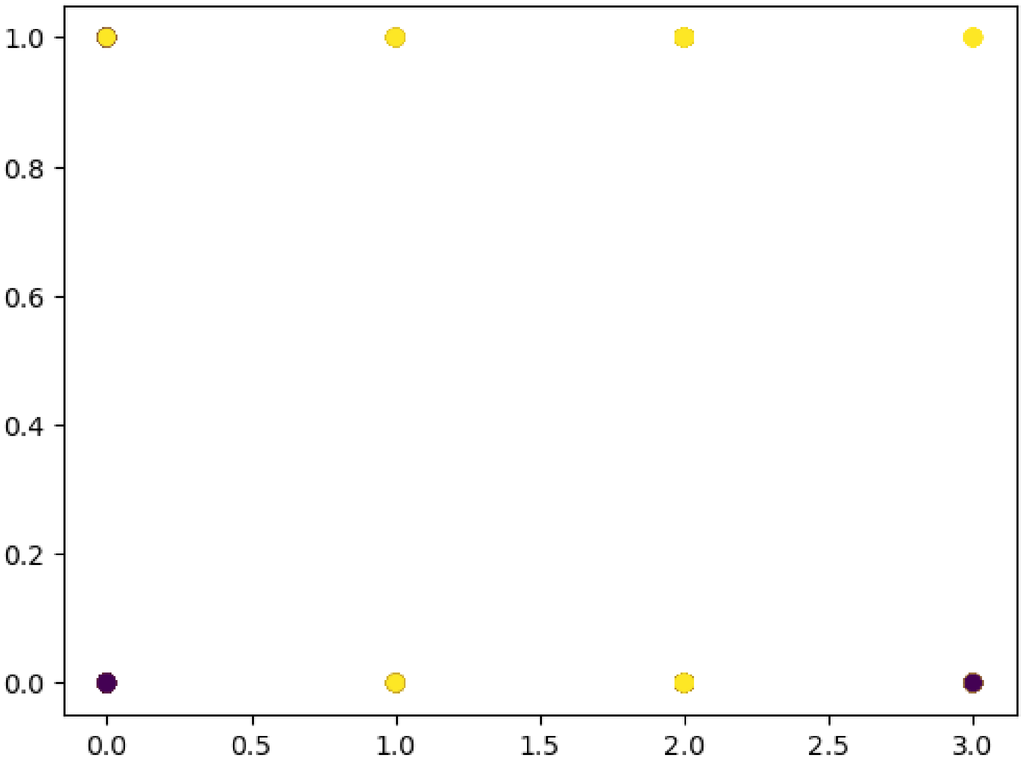
[47]:
```
# So we can see yellow means that patient have cancer.Females are more likely␣
↪to have cancers
```

[55]:
```
plt.scatter(df['age'],df['trestbps'],c=df['target'])
```

[55]:
```
<matplotlib.collections.PathCollection at 0x7fac694927f0>
```



[53]:
```
plt.scatter(df['cp'],df['sex'],c=df['target'])
plt.show()
```



```
[60]: y = df['target']
      X = df.drop('target',axis=1)
      X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3)
```

```
[64]: clf = MLPClassifier(hidden_layer_sizes=(100, ), activation='relu',␣
       ↪solver='adam', max_iter=100)

      clf.fit(X_train, y_train)

      y_pred = clf.predict(X_test)

      print(classification_report(y_test, y_pred))
      print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.89      0.80      0.84       161
           1       0.80      0.89      0.84       147

    accuracy                           0.84       308
   macro avg       0.84      0.84      0.84       308
weighted avg       0.85      0.84      0.84       308
```

```
Accuracy: 0.8409090909090909

/home/h/anaconda3/lib/python3.9/site-
packages/sklearn/neural_network/_multilayer_perceptron.py:686:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (100) reached and
the optimization hasn't converged yet.
  warnings.warn(
```

[66]:

```
clf = MLPClassifier(hidden_layer_sizes=(100,100 ), activation='relu', solver='sgd', max_iter=100)

clf.fit(X_train, y_train)

y_pred = clf.predict(X_test)

print(classification_report(y_test, y_pred))
print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.83      0.28      0.42       161
           1       0.54      0.94      0.69       147

    accuracy                           0.59       308
   macro avg       0.69      0.61      0.55       308
weighted avg       0.69      0.59      0.55       308

Accuracy: 0.5941558441558441

/home/h/anaconda3/lib/python3.9/site-
packages/sklearn/neural_network/_multilayer_perceptron.py:686:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (100) reached and
the optimization hasn't converged yet.
  warnings.warn(
```

[74]:

```
clf = MLPClassifier(hidden_layer_sizes=(10,10 ), activation='relu', solver='adam', max_iter=500)

clf.fit(X_train, y_train)

y_pred = clf.predict(X_test)

print(classification_report(y_test, y_pred))
print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.89      0.78      0.83       161
           1       0.78      0.89      0.83       147

    accuracy                           0.83       308
   macro avg       0.84      0.83      0.83       308
weighted avg       0.84      0.83      0.83       308

Accuracy: 0.8311688311688312
```

[77]:

```
clf = MLPClassifier(hidden_layer_sizes=(20,10,10 ), activation='relu',␣
 ↪solver='adam', max_iter=500)

clf.fit(X_train, y_train)

y_pred = clf.predict(X_test)

print(classification_report(y_test, y_pred))
print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.89      0.78      0.83       161
           1       0.79      0.89      0.84       147

    accuracy                           0.83       308
   macro avg       0.84      0.84      0.83       308
weighted avg       0.84      0.83      0.83       308

Accuracy: 0.8344155844155844
```

[78]:

```
clf = MLPClassifier(hidden_layer_sizes=(20,10,10 ), activation='relu',␣
 ↪solver='sgd', max_iter=500)

clf.fit(X_train, y_train)

y_pred = clf.predict(X_test)

print(classification_report(y_test, y_pred))
print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.75      0.71      0.73       161
           1       0.70      0.73      0.72       147

    accuracy                           0.72       308
   macro avg       0.72      0.72      0.72       308
weighted avg       0.73      0.72      0.72       308
```

```
Accuracy: 0.724025974025974
```

[83]:

```
clf = MLPClassifier(hidden_layer_sizes=(20,10 ), activation='relu',␣
 ↪solver='sgd', max_iter=500)

clf.fit(X_train, y_train)

y_pred = clf.predict(X_test)

print(classification_report(y_test, y_pred))
print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.52      1.00      0.69       161
           1       0.00      0.00      0.00       147

    accuracy                           0.52       308
   macro avg       0.26      0.50      0.34       308
weighted avg       0.27      0.52      0.36       308

Accuracy: 0.5227272727272727

/home/h/anaconda3/lib/python3.9/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/home/h/anaconda3/lib/python3.9/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/home/h/anaconda3/lib/python3.9/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

[80]:

```
# adam is always giving more accuracy
```

[82]:

```
clf = MLPClassifier(hidden_layer_sizes=(20,10 ), activation='relu',␣
 ↪solver='adam', max_iter=500)

clf.fit(X_train, y_train)

y_pred = clf.predict(X_test)
```

```
print(classification_report(y_test, y_pred))
print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.87      0.82      0.85       161
           1       0.82      0.87      0.84       147

    accuracy                           0.84       308
   macro avg       0.84      0.85      0.84       308
weighted avg       0.85      0.84      0.84       308

Accuracy: 0.8441558441558441
```

[88]:
```
clf = MLPClassifier(hidden_layer_sizes=(25,10 ), activation='relu',␣
 ↪solver='adam', max_iter=500)

clf.fit(X_train, y_train)

y_pred = clf.predict(X_test)

print(classification_report(y_test, y_pred))
print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.86      0.74      0.80       161
           1       0.75      0.87      0.81       147

    accuracy                           0.80       308
   macro avg       0.81      0.80      0.80       308
weighted avg       0.81      0.80      0.80       308

Accuracy: 0.801948051948052
```

[89]:
```
clf = MLPClassifier(solver="lbfgs",hidden_layer_sizes = (20,20),random_state =␣
 ↪1)

clf.fit(X_train, y_train)

y_pred = clf.predict(X_test)

print(classification_report(y_test, y_pred))
print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.84      0.77      0.80       161
           1       0.77      0.84      0.80       147

    accuracy                           0.80       308
   macro avg       0.80      0.80      0.80       308
weighted avg       0.80      0.80      0.80       308

Accuracy: 0.801948051948052
```

```
/home/h/anaconda3/lib/python3.9/site-
packages/sklearn/neural_network/_multilayer_perceptron.py:541:
ConvergenceWarning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
  self.n_iter_ = _check_optimize_result("lbfgs", opt_res, self.max_iter)
```

[92]:

```
clf = MLPClassifier(hidden_layer_sizes=(20,20 ), activation='relu',␣
  ↪solver='adam', max_iter=500)

clf.fit(X_train, y_train)

y_pred = clf.predict(X_test)

print(classification_report(y_test, y_pred))
print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.79      0.88      0.84       161
           1       0.85      0.75      0.80       147

    accuracy                           0.82       308
   macro avg       0.82      0.82      0.82       308
weighted avg       0.82      0.82      0.82       308

Accuracy: 0.8181818181818182
```

[93]:

```
clf = MLPClassifier(hidden_layer_sizes=(50,50 ), activation='relu',␣
  ↪solver='adam', max_iter=500)

clf.fit(X_train, y_train)

y_pred = clf.predict(X_test)

print(classification_report(y_test, y_pred))
print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.87      0.83      0.85       161
           1       0.82      0.86      0.84       147

    accuracy                           0.84       308
   macro avg       0.84      0.85      0.84       308
weighted avg       0.85      0.84      0.84       308

Accuracy: 0.8441558441558441
```

[94]:

```
clf = MLPClassifier(hidden_layer_sizes=(100,100 ), activation='relu',␣
 ↪solver='adam', max_iter=500)

clf.fit(X_train, y_train)

y_pred = clf.predict(X_test)

print(classification_report(y_test, y_pred))
print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.77      0.89      0.83       161
           1       0.86      0.71      0.78       147

    accuracy                           0.81       308
   macro avg       0.81      0.80      0.80       308
weighted avg       0.81      0.81      0.80       308

Accuracy: 0.8051948051948052
```

[98]:

```
clf = MLPClassifier(hidden_layer_sizes=(50,50 ), activation='relu',␣
 ↪solver='adam', max_iter=500)

clf.fit(X_train, y_train)

y_pred = clf.predict(X_test)

print(classification_report(y_test, y_pred))
print("Accuracy:",accuracy_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.89      0.78      0.83       161
           1       0.79      0.89      0.84       147

    accuracy                           0.83       308
```

```
   macro avg       0.84      0.84      0.83       308
weighted avg       0.84      0.83      0.83       308

Accuracy: 0.8344155844155844
```

[99]:

```
# Accuracy at most is 0.84
```

1 Observation

This dataset is small and is not very good to train the whole model. We need more data to get more accurate results

[ ]:

```

```