```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

Dataset

https://www.kaggle.com/datasets/rashikrahmanpritom/heart-attack-analysis-prediction-dataset

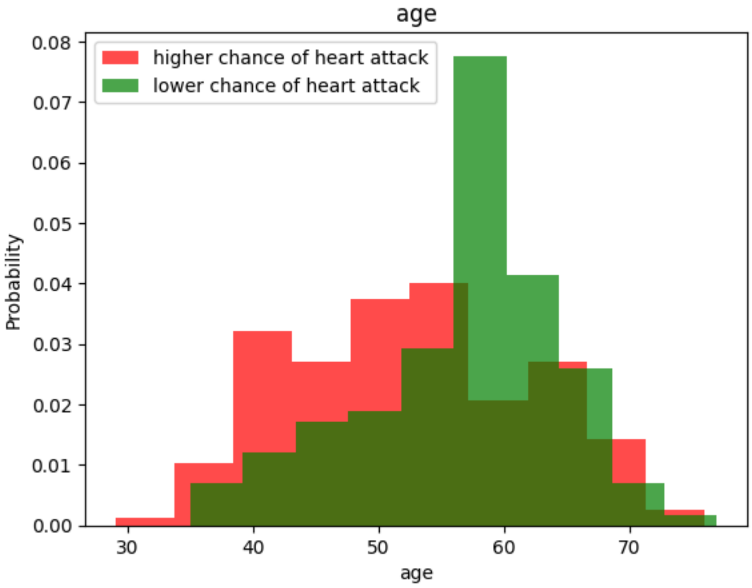
```
df=pd.read_csv("heart.csv")
df.head()
```

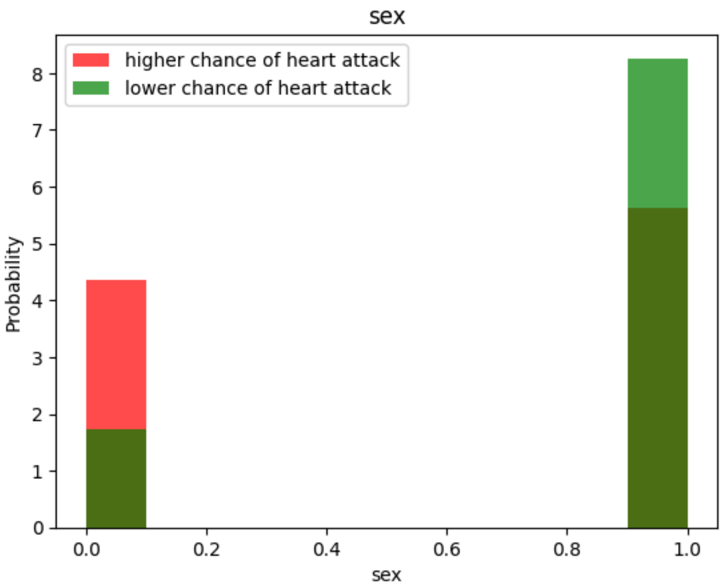
	age	sex	cp	trtbps	chol	fbs	restecg	thalachh	exng	oldpeak	slp	caa	thall	output
0	63	1	3	145	233	1	0	150	0	2.3	0	0	1	1
1	37	1	2	130	250	0	1	187	0	3.5	0	0	2	1
2	41	0	1	130	204	0	0	172	0	1.4	2	0	2	1
3	56	1	1	120	236	0	1	178	0	0.8	2	0	2	1
4	57	0	0	120	354	0	1	163	1	0.6	2	0	2	1

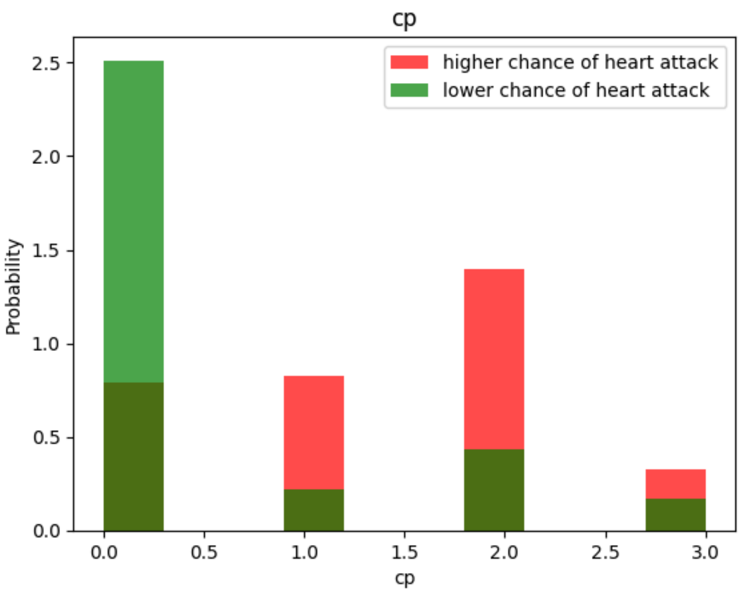
```
# Predictor variables (X)
X =df.drop(columns=['output'])

# Response variable (Y)
Y = df['output']

# Print the predictor and response variable
print("Predictor variables (X):\n", X.head())
print("\nResponse variable (Y):\n", Y.head())
```

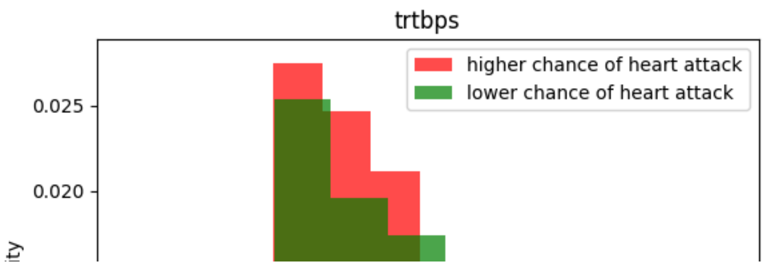
```
Predictor variables (X):
    age  sex  cp  trtbps  chol  fbs  restecg  thalachh  exng  oldpeak  slp  \
0   63    1   3     145   233    1        0       150     0      2.3    0
1   37    1   2     130   250    0        1       187     0      3.5    0
2   41    0   1     130   204    0        0       172     0      1.4    2
3   56    1   1     120   236    0        1       178     0      0.8    2
4   57    0   0     120   354    0        1       163     1      0.6    2

   caa  thall
0    0      1
1    0      2
2    0      2
3    0      2
4    0      2

Response variable (Y):
 0    1
1    1
2    1
3    1
4    1
Name: output, dtype: int64
```

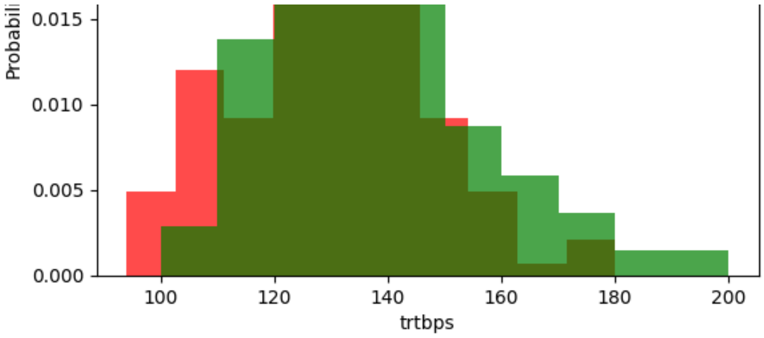
```
for label in df.columns[:-1]:
  plt.hist(df[df["output"]==1][label],color='red',label="higher chance of heart attack",alpha=0.7,density=True)
  plt.hist(df[df["output"]==0][label],color='green',label="lower chance of heart attack",alpha=0.7,density=True)
  plt.title(label)
  plt.ylabel("Probability")
  plt.xlabel(label)
  plt.legend()
  plt.show()
```


age
higher chance of heart attack
lower chance of heart attack
Probability
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
30
40
50
60
70
age

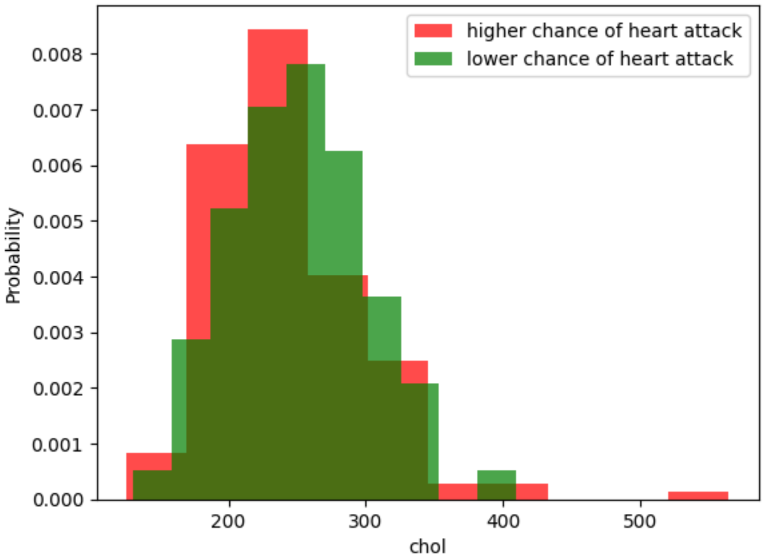

sex
higher chance of heart attack
lower chance of heart attack
Probability
8
7
6
5
4
3
2
1
0
0.0
0.2
0.4
0.6
0.8
1.0
sex


cp
higher chance of heart attack
lower chance of heart attack
Probability
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
cp

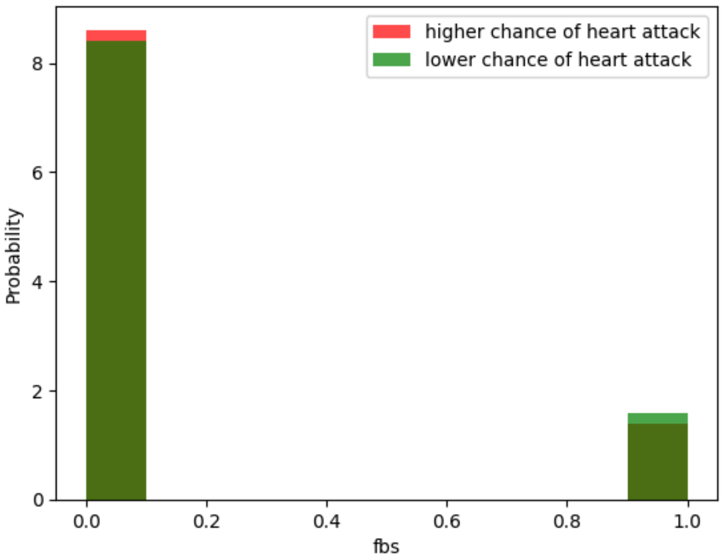

trtbps
higher chance of heart attack
lower chance of heart attack
0.025
0.020



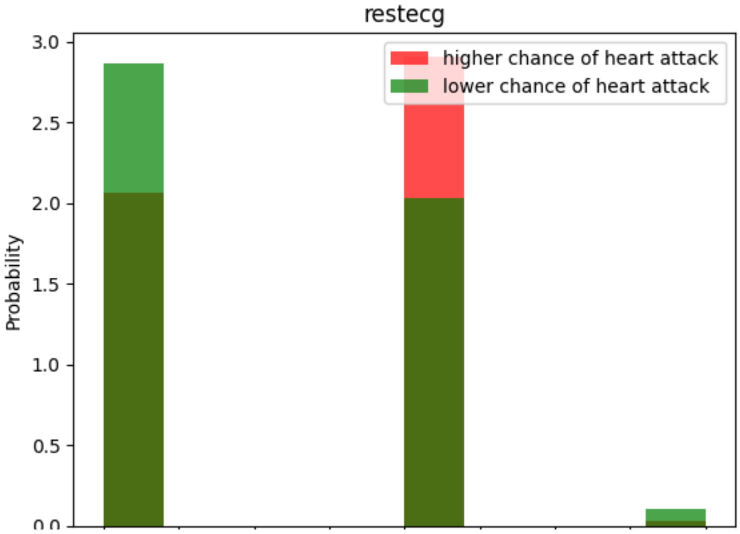
chol

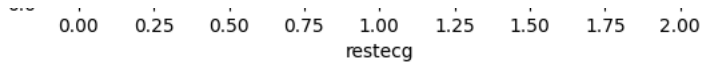


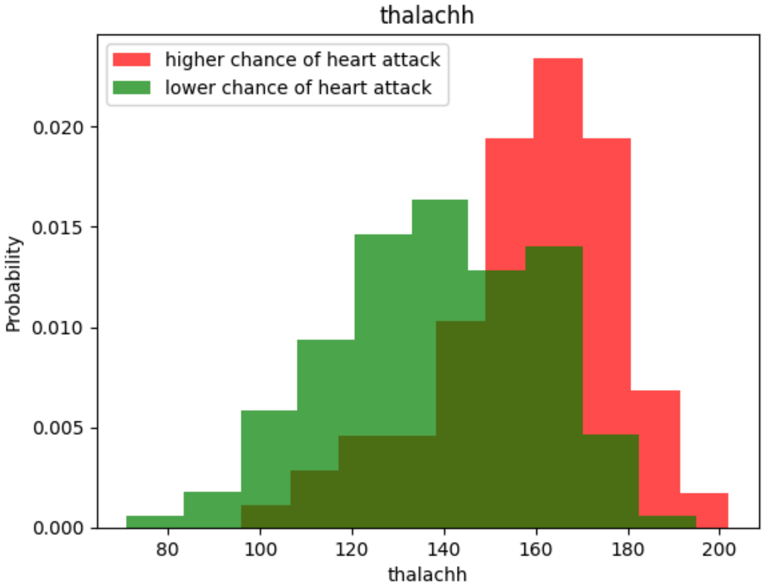
fbs

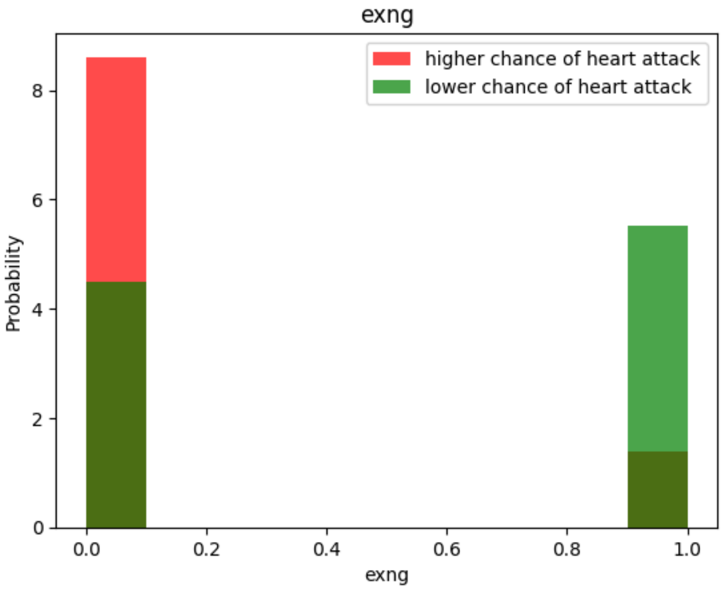


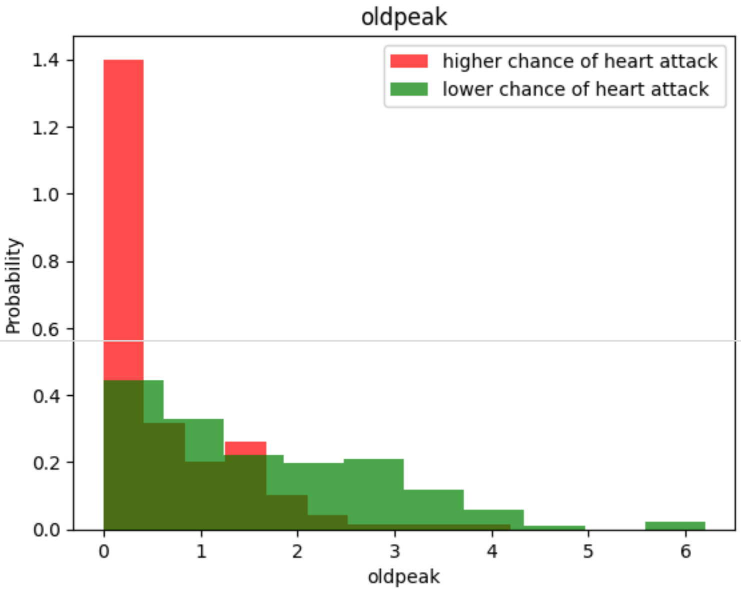
restecg

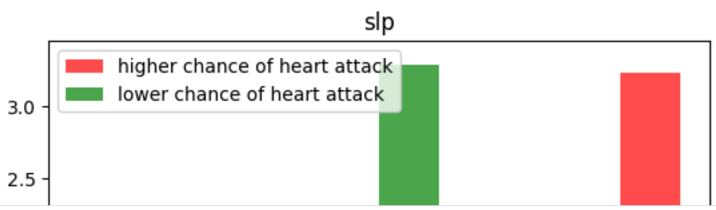



0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
restecg


thalachh
higher chance of heart attack
lower chance of heart attack
Probability
0.000 0.005 0.010 0.015 0.020
80 100 120 140 160 180 200
thalachh


exng
higher chance of heart attack
lower chance of heart attack
Probability
0 2 4 6 8
0.0 0.2 0.4 0.6 0.8 1.0
exng


oldpeak
higher chance of heart attack
lower chance of heart attack
Probability
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
0 1 2 3 4 5 6
oldpeak


slp
higher chance of heart attack
lower chance of heart attack
2.5 3.0

Splitting the data into train & test data 80:20(First Case)

```
train,test=np.split(df.sample(frac=1),[int(0.8*len(df))])
```

```
# Importing the required modules for scaling data
from sklearn.preprocessing import StandardScaler
from imblearn.over_sampling import SMOTE

def scale_dataset(data, oversample=False):


  # Scale the data
  scaler = StandardScaler()
  scaled_data = scaler.fit_transform(data.drop('output', axis=1))

  # Separate features and labels
  features = scaled_data
  labels = data['output']

  # Oversample the data
  if oversample:
    smote = SMOTE(random_state=42)
    features, labels = smote.fit_resample(features, labels)

  return data, features, labels

# Scale the train and test data
train, X_train, Y_train = scale_dataset(train, oversample=True)
test, X_test, Y_test = scale_dataset(test, oversample=True)
```

```
# Print shapes of the arrays
print("Shapes for train, X_train, and Y_train:")
print("Train shape:", train.shape)
print("X_train shape:", X_train.shape)
print("Y_train shape:", Y_train.shape)

print("\nShapes for test, X_test, and Y_test:")
print("Test shape:", test.shape)
print("X_test shape:", X_test.shape)
print("Y_test shape:", Y_test.shape)
```

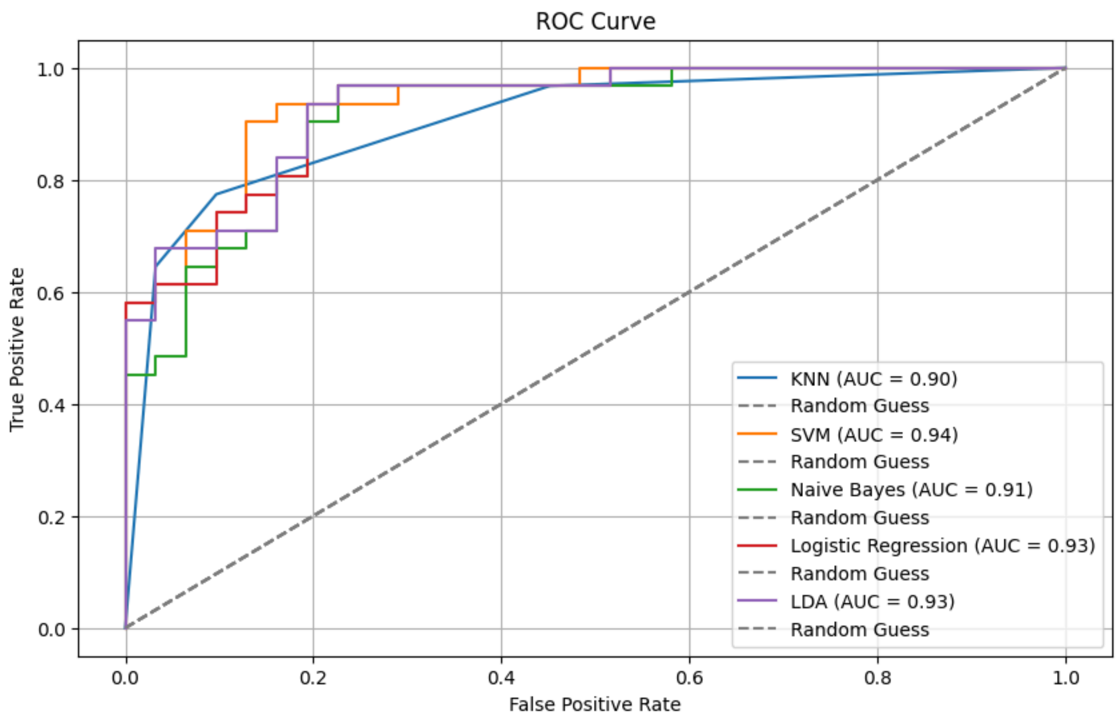
```
Shapes for train, X_train, and Y_train:
Train shape: (242, 14)
X_train shape: (270, 13)
Y_train shape: (270,)

Shapes for test, X_test, and Y_test:
Test shape: (61, 14)
X_test shape: (62, 13)
Y_test shape: (62,)
```

Applying different classifications models on data (KNN,SVM,Naivebayes,Logestic Regression and LDA classifier) [80:20]

```
#Will give confusion matrix and classification report for each classifier for two thresholds 0.5 & 0.6 for 80:20 train-test.
from sklearn.neighbors import KNeighborsClassifier
from sklearn.svm import SVC
from sklearn.naive_bayes import GaussianNB
from sklearn.linear_model import LogisticRegression
from sklearn.discriminant_analysis import LinearDiscriminantAnalysis
from sklearn.metrics import confusion_matrix, classification_report

# A function to train and evaluate a classifier
def train_and_evaluate(classifier, X_train, Y_train, X_test, Y_test,threshold=0.5):
    # Train the classifier
    classifier.fit(X_train, Y_train)

    # Predict probabilities
    Y_prob = classifier.predict_proba(X_test)[:, 1]

    # Apply threshold
    Y_pred = (Y_prob > threshold).astype(int)
ts
```

```
    # Print confusion matrix
    print("Confusion Matrix (Threshold = {}):".format(threshold))
    print(confusion_matrix(Y_test, Y_pred))

    # Print classification report
    print("\nClassification Report (Threshold = {}):".format(threshold))
    print(classification_report(Y_test, Y_pred))

# Initialize classifiers
knn_classifier = KNeighborsClassifier(n_neighbors=3)
svm_classifier = SVC(probability=True)  # Set probability=True for SVC to enable probability estimates
nb_classifier = GaussianNB()
lr_classifier = LogisticRegression()
lda_classifier = LinearDiscriminantAnalysis()

# Train and evaluate classifiers
classifiers = [knn_classifier, svm_classifier, nb_classifier, lr_classifier, lda_classifier]
classifier_names = ['KNN', 'SVM', 'Naive Bayes', 'Logistic Regression', 'LDA']

# Define threshold values
thresholds = [0.5, 0.6]

# Loop over classifiers and threshold values
for classifier, name in zip(classifiers, classifier_names):
    for threshold in thresholds:
        print("\nTraining and evaluating", name, "classifier with threshold", threshold)
        train_and_evaluate(classifier, X_train, Y_train, X_test, Y_test, threshold)
```

```
from sklearn.metrics import roc_curve, auc

# Define a function to plot ROC-AUC curve
def plot_roc_curve(classifier, X_test, Y_test, name):
    # Predict probabilities
    Y_prob = classifier.predict_proba(X_test)[:, 1]

    # Calculate false positive rate, true positive rate, and thresholds
    fpr, tpr, thresholds = roc_curve(Y_test, Y_prob)

    # Calculate area under the curve (AUC)
    roc_auc = auc(fpr, tpr)

    # Plot ROC curve
    plt.plot(fpr, tpr, label=name + ' (AUC = %0.2f)' % roc_auc)
    plt.plot([0, 1], [0, 1], linestyle='--', color='gray', label='Random Guess')
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.title('ROC Curve')
    plt.legend()
    plt.grid(True)


for classifier, name in zip(classifiers, classifier_names):
    classifier.fit(X_train, Y_train)

# Plot ROC curves for all classifiers
plt.figure(figsize=(10, 6))
for classifier, name in zip(classifiers, classifier_names):
    plot_roc_curve(classifier, X_test, Y_test, name)
plt.legend(loc='lower right')
plt.show()
```



Splitting the data into train & test data 70:30(Second Case)

```
train2,test2=np.split(df.sample(frac=1),[int(0.7*len(df))])
```

```
# Scale the train and test data
train2, X_train2, Y_train2 = scale_dataset(train2, oversample=True)
test2, X_test2, Y_test2 = scale_dataset(test2, oversample=True)
```

```
# Print shapes of the arrays
print("Shapes for train, X_train, and Y_train:")
```

```
print("Train shape:", train2.shape)
print("X_train shape:", X_train2.shape)
print("Y_train shape:", Y_train2.shape)

print("\nShapes for test, X_test, and Y_test:")
print("Test shape:", test2.shape)
print("X_test shape:", X_test2.shape)
print("Y_test shape:", Y_test2.shape)
```

```
Shapes for train, X_train, and Y_train:
Train shape: (212, 14)
X_train shape: (220, 13)
Y_train shape: (220,)

Shapes for test, X_test, and Y_test:
Test shape: (91, 14)
X_test shape: (110, 13)
Y_test shape: (110,)
```

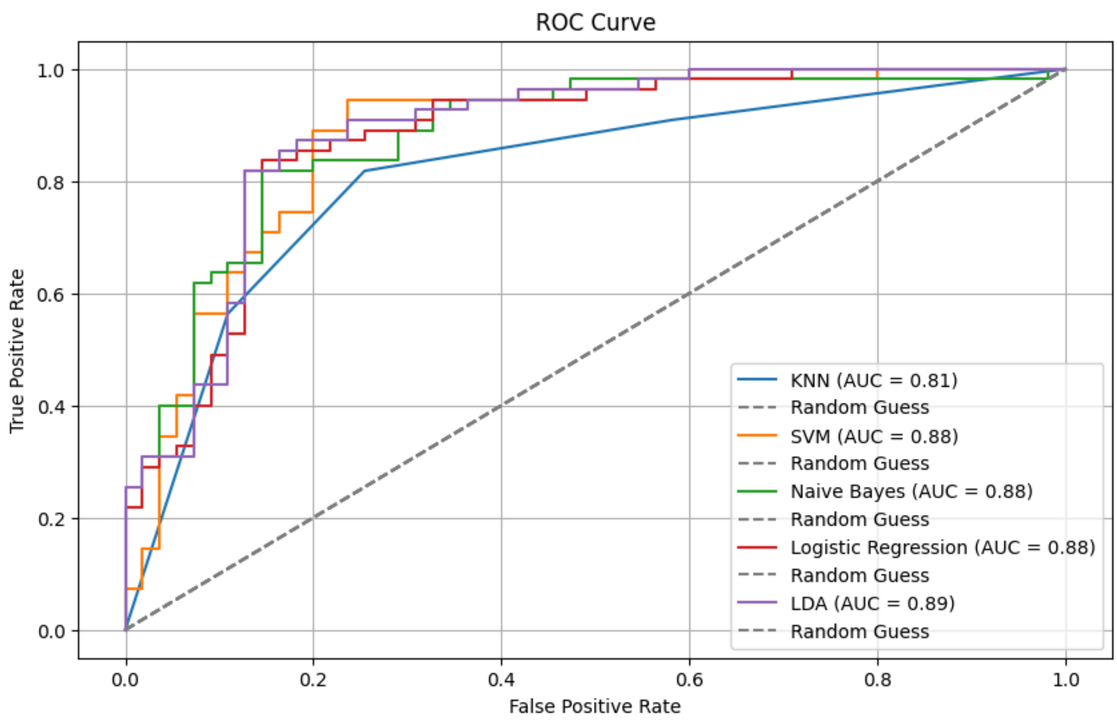
Applying different classifications models on data (KNN,SVM,Naivebayes,Logestic Regression and LDA classifier) [70:30]

```
#Will give confusion matrix and classification report for each classifier for two thresholds 0.5 & 0.6 for 70:30 train-test.

# Loop over classifiers and threshold values
for classifier, name in zip(classifiers, classifier_names):
    for threshold in thresholds:
        print("\nTraining and evaluating", name, "classifier with threshold", threshold)
        train_and_evaluate(classifier, X_train2, Y_train2, X_test2, Y_test2, threshold)
```

```
Training and evaluating KNN classifier with threshold 0.5
Confusion Matrix (Threshold = 0.5):
[[41 14]
 [10 45]]

Classification Report (Threshold = 0.5):
              precision    recall  f1-score   support

           0       0.80      0.75      0.77        55
           1       0.76      0.82      0.79        55

    accuracy                           0.78       110
   macro avg       0.78      0.78      0.78       110
weighted avg       0.78      0.78      0.78       110


Training and evaluating KNN classifier with threshold 0.6
Confusion Matrix (Threshold = 0.6):
[[41 14]
 [10 45]]

Classification Report (Threshold = 0.6):
              precision    recall  f1-score   support

           0       0.80      0.75      0.77        55
           1       0.76      0.82      0.79        55

    accuracy                           0.78       110
   macro avg       0.78      0.78      0.78       110
weighted avg       0.78      0.78      0.78       110


Training and evaluating SVM classifier with threshold 0.5
Confusion Matrix (Threshold = 0.5):
[[45 10]
 [14 41]]

Classification Report (Threshold = 0.5):
              precision    recall  f1-score   support

           0       0.76      0.82      0.79        55
           1       0.80      0.75      0.77        55

    accuracy                           0.78       110
   macro avg       0.78      0.78      0.78       110
weighted avg       0.78      0.78      0.78       110


Training and evaluating SVM classifier with threshold 0.6
```

```
Confusion Matrix (Threshold = 0.6):
[[47  8]
 [17 38]]

Classification Report (Threshold = 0.6):
              precision    recall  f1-score   support
```

```
for classifier, name in zip(classifiers, classifier_names):
    classifier.fit(X_train2, Y_train2)

# Plot ROC curves for all classifiers
plt.figure(figsize=(10, 6))
for classifier, name in zip(classifiers, classifier_names):
    plot_roc_curve(classifier, X_test2, Y_test2, name)
plt.legend(loc='lower right')
plt.show()
```



Ablation Study for 80:20 and threshold=0.5

```
from sklearn.metrics import accuracy_score
def ablation_study(classifier, X_train, Y_train, X_test, Y_test):
    feature_accuracies = {}

    # Iterate over each feature
    for feature in X_train.columns:
        # Train the classifier with only the current feature
        classifier.fit(X_train[[feature]], Y_train)

        # Predict on the test set
        Y_pred = classifier.predict(X_test[[feature]])

        # Calculate accuracy
        accuracy = accuracy_score(Y_test, Y_pred)

        # Store accuracy for the current feature
        feature_accuracies[feature] = accuracy

    # Sort features by accuracy
    sorted_features = sorted(feature_accuracies, key=feature_accuracies.get, reverse=True)

    return sorted_features
```

```
# Convert arrays to DataFrames
X_train_df = pd.DataFrame(X_train, columns=df.columns[:-1])
X_test_df = pd.DataFrame(X_test, columns=df.columns[:-1])
```

```
# Perform ablation study for each classifier
for classifier, name in zip(classifiers, classifier_names):
    print("\nAblation study for", name, "classifier:")
    sorted_features = ablation_study(classifier, X_train_df, Y_train, X_test_df, Y_test)

    # Print ranked features
    print("Ranked features based on accuracy:")
    for i, feature in enumerate(sorted_features):
        print(f"{i+1}. {feature}")
```

```
Ablation study for KNN classifier:
Ranked features based on accuracy:
1. slp
2. cp
3. restecg
4. thalachh
5. age
6. fbs
7. exng
8. caa
9. thall
10. trtbps
11. oldpeak
12. chol
13. sex

Ablation study for SVM classifier:
Ranked features based on accuracy:
1. cp
2. thall
3. exng
4. oldpeak
5. caa
6. thalachh
7. slp
8. age
9. sex
10. restecg
11. trtbps
12. chol
13. fbs

Ablation study for Naive Bayes classifier:
Ranked features based on accuracy:
1. cp
2. thall
3. exng
4. oldpeak
5. thalachh
6. slp
7. caa
8. age
9. sex
10. restecg
11. trtbps
12. chol
13. fbs

Ablation study for Logistic Regression classifier:
Ranked features based on accuracy:
1. cp
2. thall
3. exng
4. oldpeak
5. caa
6. thalachh
7. age
```

Bar Graph & Performance metrices values for all case.

```
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score, roc_auc_score

# Define function to calculate performance metrics
def calculate_metrics(classifier, X_train, Y_train, X_test, Y_test, threshold):
    # Train the classifier
    classifier.fit(X_train, Y_train)

    # Predict probabilities
    Y_prob = classifier.predict_proba(X_test)[:, 1]

    # Apply threshold
```

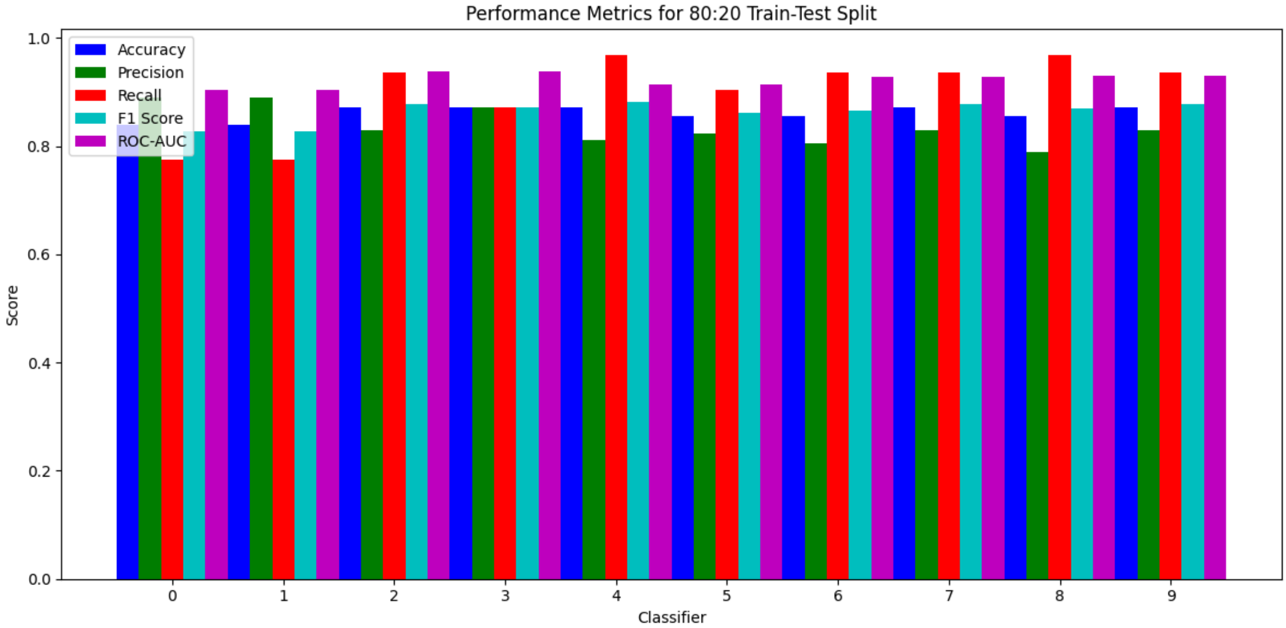
```
    Y_pred = (Y_prob > threshold).astype(int)

    # Calculate metrics
    accuracy = accuracy_score(Y_test, Y_pred)
    precision = precision_score(Y_test, Y_pred)
    recall = recall_score(Y_test, Y_pred)
    f1 = f1_score(Y_test, Y_pred)
    roc_auc = roc_auc_score(Y_test, Y_prob)

    return accuracy, precision, recall, f1, roc_auc
```

```
# Initializing dictionaries to store metrics
metrics_80_20 = {'Accuracy': [], 'Precision': [], 'Recall': [], 'F1 Score': [], 'ROC-AUC': []}
metrics_70_30 = {'Accuracy': [], 'Precision': [], 'Recall': [], 'F1 Score': [], 'ROC-AUC': []}


# Loop over classifiers and threshold values
for classifier, name in zip(classifiers, classifier_names):
    for threshold in thresholds:
        # Calculate metrics for 80:20 split
        accuracy_80_20, precision_80_20, recall_80_20, f1_80_20, roc_auc_80_20 = calculate_metrics(classifier, X_train, Y_tra

        # Append metrics to dictionary for 80:20 split
        metrics_80_20['Accuracy'].append(accuracy_80_20)
        metrics_80_20['Precision'].append(precision_80_20)
        metrics_80_20['Recall'].append(recall_80_20)
        metrics_80_20['F1 Score'].append(f1_80_20)
        metrics_80_20['ROC-AUC'].append(roc_auc_80_20)

        # Calculate metrics for 70:30 split
        accuracy_70_30, precision_70_30, recall_70_30, f1_70_30, roc_auc_70_30 = calculate_metrics(classifier, X_train2, Y_tra

        # Append metrics to dictionary for 70:30 split
        metrics_70_30['Accuracy'].append(accuracy_70_30)
        metrics_70_30['Precision'].append(precision_70_30)
        metrics_70_30['Recall'].append(recall_70_30)
        metrics_70_30['F1 Score'].append(f1_70_30)
        metrics_70_30['ROC-AUC'].append(roc_auc_70_30)
```

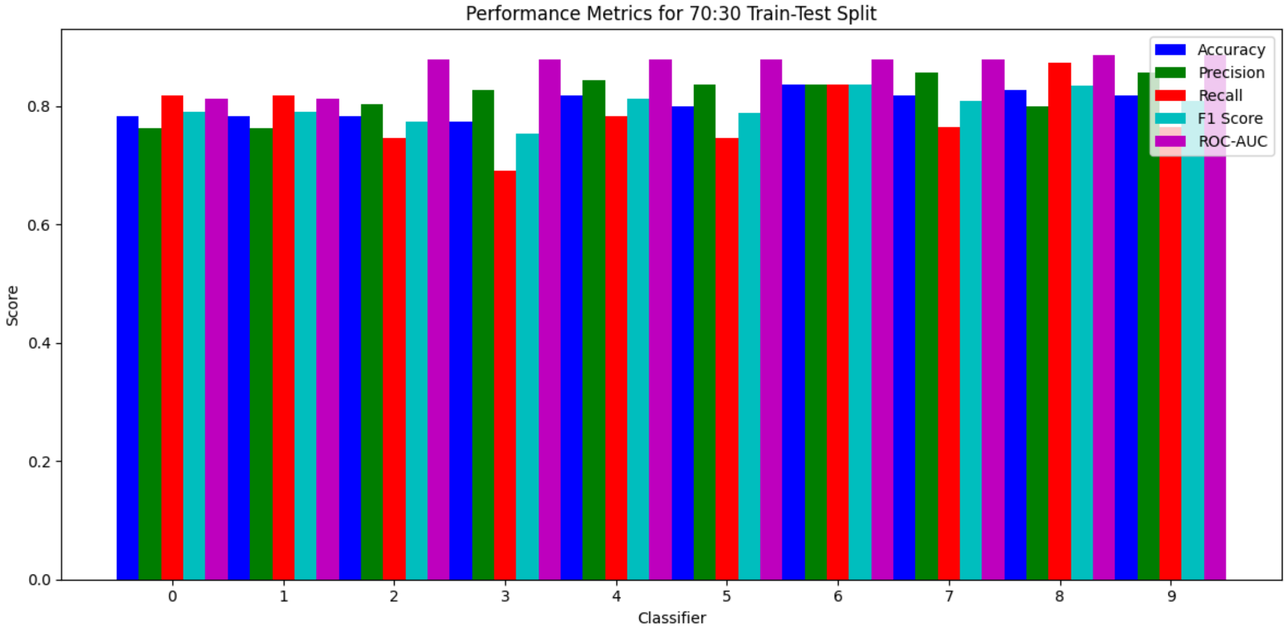
```
def plot_bar_graph(metrics_df, title):
    fig, ax = plt.subplots(figsize=(12, 6))

    # Set the width of each bar
    bar_width = 0.2
    index = np.arange(len(metrics_df))

    # Define color palette for bars
    colors = ['b', 'g', 'r', 'c', 'm']

    # Iterate over metrics and plot bars for each metric
    for i, (metric_name, metric_values) in enumerate(metrics_df.items()):
        # Calculate the position of bars for each classifier
        bar_positions = index + i * bar_width - (len(metrics_df.columns) - 1) * bar_width / 2

        # Plot bars for each classifier
        ax.bar(bar_positions, metric_values, bar_width, label=metric_name, color=colors[i])

    # Set labels and title
    ax.set_xlabel('Classifier')
    ax.set_ylabel('Score')
    ax.set_title(title)
    ax.set_xticks(index)
    ax.set_xticklabels(metrics_df.index)
    ax.legend()

    # Show plot
    plt.tight_layout()
    plt.show()
```

```
metrics_80_20_df = pd.DataFrame.from_dict(metrics_80_20, orient='index')  # converting from dictionary to dataframe
metrics_70_30_df = pd.DataFrame.from_dict(metrics_70_30, orient='index')
```

```
plot_bar_graph(metrics_80_20_df.T,'Performance Metrics for 80:20 Train-Test Split')
```




```
plot_bar_graph(metrics_70_30_df.T,'Performance Metrics for 70:30 Train-Test Split')
```




```
print(metrics_80_20_df.T)
```

```
   Accuracy  Precision    Recall  F1 Score   ROC-AUC
0  0.838710   0.888889  0.774194  0.827586  0.904787
1  0.838710   0.888889  0.774194  0.827586  0.904787
2  0.870968   0.828571  0.935484  0.878788  0.938606
3  0.870968   0.870968  0.870968  0.870968  0.938606
4  0.870968   0.810811  0.967742  0.882353  0.913632
5  0.854839   0.823529  0.903226  0.861538  0.913632
6  0.854839   0.805556  0.935484  0.865672  0.928200
7  0.870968   0.828571  0.935484  0.878788  0.928200
8  0.854839   0.789474  0.967742  0.869565  0.929240
9  0.870968   0.828571  0.935484  0.878788  0.929240
```