Exercise 3: Linear Discriminant Analysis

Implement the Linear Discriminant Analysis algorithm in your own code for class classification. Also implement the Discriminant Analysis algorithm by using existing library (e.g. scikit-learn). Compare the performance of both implementations and show the results.

Manual Method

In [ ]:

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import sklearn.metrics
import warnings
warnings.filterwarnings('ignore')
import seaborn as sns
from sklearn import preprocessing, svm, linear_model, decomposition
from sklearn.metrics import mean_squared_error, r2_score, confusion_matri
from sklearn.metrics import accuracy_score, classification_report
from sklearn.model_selection import train_test_split
from sklearn.discriminant_analysis import LinearDiscriminantAnalysis
from sklearn.preprocessing import LabelEncoder, StandardScaler
from sklearn.neighbors import KNeighborsClassifier
np.set_printoptions(precision=4)

# Input: Dataset
iris = pd.read_csv('iris.csv', header=None)

# Encode Categorical Class Labels
class_le = LabelEncoder()
Y = class_le.fit_transform(iris[4].values)

# Standardize features
stdsc = StandardScaler()
X = stdsc.fit_transform(iris.iloc[:,range(0,4)].values)

# Construct within-class covariant scatter matrix S_W
S_W = np.zeros((4,4))
for i in range(3):
    S_W += np.cov(X[Y==i].T)

# Construct between-class scatter matrix S_B
N=np.bincount(Y)
vecs=[]
[vecs.append(np.mean(X[Y==i],axis=0)) for i in range(3)] # Class Means
mean_overall = np.mean(X, axis=0)                       # Overall Mean
S_B=np.zeros((4,4))
for i in range(3):
    S_B += N[i]*(((vecs[i]-mean_overall).reshape(4,1))
                 .dot(((vecs[i]-mean_overall).reshape(1,4))))

# Calculate Sorted Eigen Values and Eigen Vectors of  inverse(S_W)dot(S_B
eigen_vals, eigen_vecs = np.linalg.eig(np.linalg.inv(S_W).dot(S_B))
eigen_pairs = [(np.abs(eigen_vals[i]), eigen_vecs[:,i])
               for i in range(len(eigen_vals))]
eigen_pairs = sorted(eigen_pairs,key=lambda k: k[0], reverse=True)
```

```
# Project original features onto the new feature space
W=np.hstack((eigen_pairs[0][1][:, ].reshape(4,1),eigen_pairs[1][1][:, ].
             reshape(4,1))).real
X_lda = X.dot(W)

data=pd.DataFrame(X_lda)
data['class']=Y
data.columns=["LD1","LD2","class"]

# Save the Reduced Dimension Dataset
irisLDA_Manual = pd.concat([data],axis=1)
irisLDA_Manual.to_csv('irisLDA_Manual.csv')
```

(SciKit-Learn) Method.

In [ ]:
```
# Create Linear Discriminant Analysis object
LDA = LinearDiscriminantAnalysis(n_components=2)

# Train the model
X_lda2 = LDA.fit_transform(X, Y)

data2=pd.DataFrame(X_lda2)
data2['class']=Y
data2.columns=["LD1","LD2","class"]

# Save the Reduced Dimension Dataset
irisLDA_SKL = pd.concat([data2],axis=1)
irisLDA_SKL.to_csv('irisLDA_SKL.csv')
```

Output and Comparison of Both Methods.

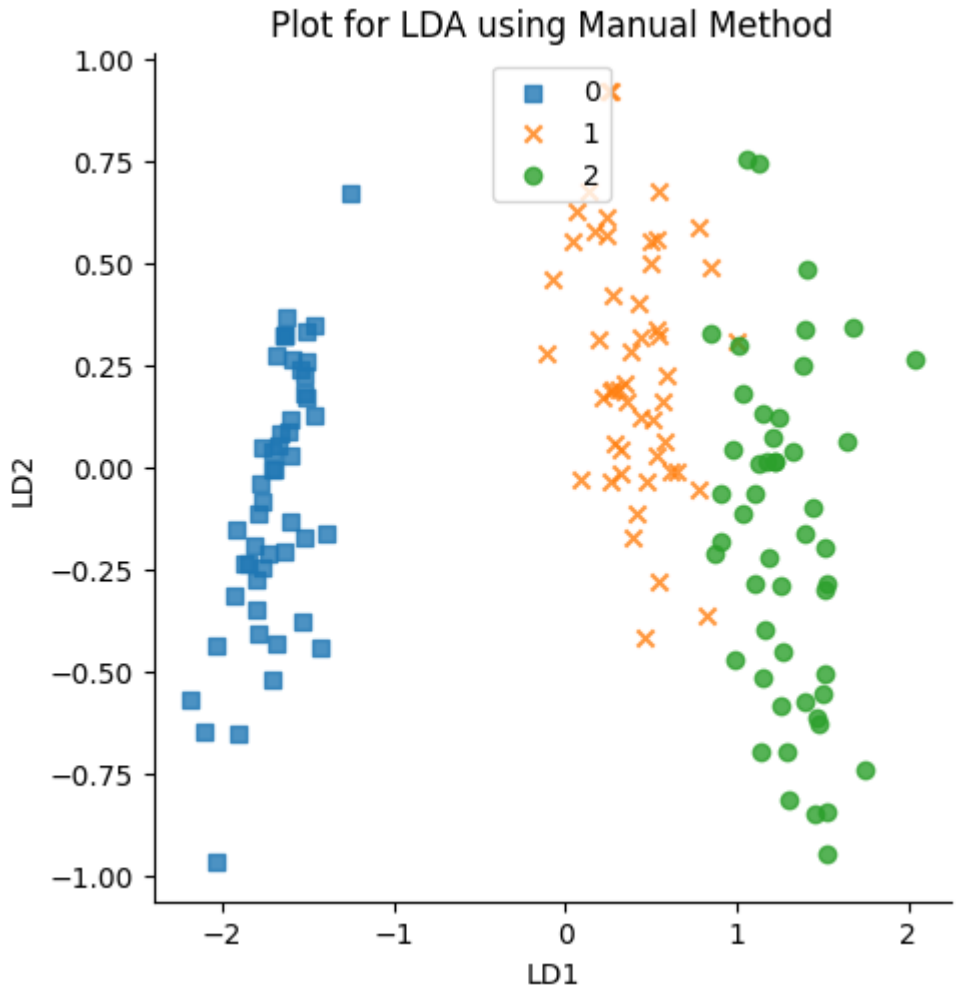
In [ ]:
```
# Metric Calculation for Original Dataset
# Check Accuracy over Original Dataset
print("\nACCURACY METRIC OF THE ORIGINAL DATASET\n")
# Split the Original Dataset into Training and Testing Datasets and
X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size = 0.3
Y_train = Y_train.ravel()
Y_test = Y_test.ravel()

# Output: The Shape of the Original Dataset and its Accuracy over KNN Cla
print("\nShape of Original Dataset : X = ", X.shape," Y = ", Y.shape)
print('\nAccuracy of IRIS Dataset Before LDA \n')
for K in range(25):
    K_value = K+1
    #Using KNN Classifier to Check Accuracy before LDA
    neigh = KNeighborsClassifier(n_neighbors = K_value, weights='uniform'
                                 algorithm='auto')
    neigh.fit(X_train, Y_train)
    Y_pred = neigh.predict(X_test)
    if(K_value%2 == 0):
        print ("    Accuracy = ", accuracy_score(Y_test,Y_pred)*100,
               "% for K-Value = ",K_value)


# Metric Calculation for Reduced Dataset obtained by LDA using Manual Met
print("\n_____________________________________________________________
print("\nFOR LINEAR DISCRIMINANT ANALYSIS USING MANUAL METHOD\n")
```

```
# Load the Reduced Dataset into Pandas DataFrame
irisldam = pd.read_csv("irisLDA_Manual.csv")

features = ['LD1', 'LD2']
# Separating out the Features
X1 = irisldam.loc[:, features].values
# Separating out the Target
Y1 = irisldam.loc[:,['class']].values

# Check Accuracy over Reduced Dataset
# Split the Original Dataset into Training and Testing Datasets
X_train1, X_test1, Y_train1, Y_test1 = train_test_split( X1, Y1, test_siz
Y_train1 = Y_train1.ravel()
Y_test1 = Y_test1.ravel()

# Output: The Shape of Reduced Dataset, its Plot & its Accuracy over KNN
print("\nShape of Reduced Dataset  : X = ", X1.shape," Y = ", Y1.shape)
print('\nAccuracy of IRIS Dataset after LDA\n')
for K in range(25):
    K_value = K+1

    # Using KNN Classifier to Check Accuracy after LDA
    neigh = KNeighborsClassifier(n_neighbors = K_value, weights='uniform'
                                 algorithm='auto')
    neigh.fit(X_train1, Y_train1)
    Y_pred1 = neigh.predict(X_test1)
    if(K_value%2 == 0):
        print ("    Accuracy = ", accuracy_score(Y_test1,Y_pred1)*100,
               "% for K-Value =",K_value)

markers = ['s', 'x','o']
sns.lmplot(x="LD1", y="LD2", data=data,markers=markers,fit_reg=False,
           hue='class', legend=False)
plt.legend(loc='upper center')
plt.title('Plot for LDA using Manual Method')
plt.show()

# Metric Calculation for Reduced Dataset obtained by LDA using SciKit-Lea
print("\n_____________________________________________________________________
print("\nFOR LINEAR DISCRIMINANT ANALYSIS USING SCIKIT-LEARN METHOD\n")
# Load the Reduced Dataset into Pandas DataFrame
irisldas = pd.read_csv("irisLDA_SKL.csv")

features = ['LD1', 'LD2']
# Separating out the Features
X2 = irisldas.loc[:, features].values
# Separating out the Target
Y2 = irisldas.loc[:,['class']].values

# Check Accuracy over Reduced Dataset
# Split the Original Dataset into Training and Testing Datasets
X_train2, X_test2, Y_train2, Y_test2 = train_test_split( X2, Y2, test_siz
Y_train2 = Y_train2.ravel()
Y_test2 = Y_test2.ravel()

# Output: The Shape of Reduced Dataset, its Plot & its Accuracy over KNN
print("\nShape of Reduced Dataset  : X = ", X2.shape," Y = ", Y2.shape)
print('\nAccuracy of IRIS Dataset after LDA\n')
for K in range(25):
    K_value = K+1
```

```
    # Using KNN Classifier to Check Accuracy after LDA
    neigh = KNeighborsClassifier(n_neighbors = K_value, weights='uniform'
                                 algorithm='auto')
    neigh.fit(X_train2, Y_train2)
    Y_pred2 = neigh.predict(X_test2)
    if(K_value%2 == 0):
        print ("    Accuracy = ", accuracy_score(Y_test2,Y_pred2)*100,
               "% for K-Value =",K_value)

markers = ['s', 'x','o']
sns.lmplot(x="LD1", y="LD2", data=data2, markers=markers, fit_reg=False,
           hue='class', legend=False)
plt.legend(loc='upper center')
plt.title('Plot for LDA using SciKit-Learn Method')
plt.show()
```

```
ACCURACY METRIC OF THE ORIGINAL DATASET


Shape of Original Dataset : X =  (150, 4)  Y =  (150,)

Accuracy of IRIS Dataset Before LDA

    Accuracy =  91.11111111111111 % for K-Value =  2
    Accuracy =  91.11111111111111 % for K-Value =  4
    Accuracy =  91.11111111111111 % for K-Value =  6
    Accuracy =  93.33333333333333 % for K-Value =  8
    Accuracy =  93.33333333333333 % for K-Value =  10
    Accuracy =  93.33333333333333 % for K-Value =  12
    Accuracy =  95.55555555555556 % for K-Value =  14
    Accuracy =  93.33333333333333 % for K-Value =  16
    Accuracy =  93.33333333333333 % for K-Value =  18
    Accuracy =  91.11111111111111 % for K-Value =  20
    Accuracy =  88.88888888888889 % for K-Value =  22
    Accuracy =  88.88888888888889 % for K-Value =  24
```

```
FOR LINEAR DISCRIMINANT ANALYSIS USING MANUAL METHOD


Shape of Reduced Dataset  : X =  (150, 2)  Y =  (150, 1)

Accuracy of IRIS Dataset after LDA

    Accuracy =  97.77777777777777 % for K-Value = 2
    Accuracy =  100.0 % for K-Value = 4
    Accuracy =  100.0 % for K-Value = 6
    Accuracy =  100.0 % for K-Value = 8
    Accuracy =  100.0 % for K-Value = 10
    Accuracy =  100.0 % for K-Value = 12
    Accuracy =  100.0 % for K-Value = 14
    Accuracy =  100.0 % for K-Value = 16
    Accuracy =  100.0 % for K-Value = 18
    Accuracy =  100.0 % for K-Value = 20
    Accuracy =  100.0 % for K-Value = 22
    Accuracy =  100.0 % for K-Value = 24
```

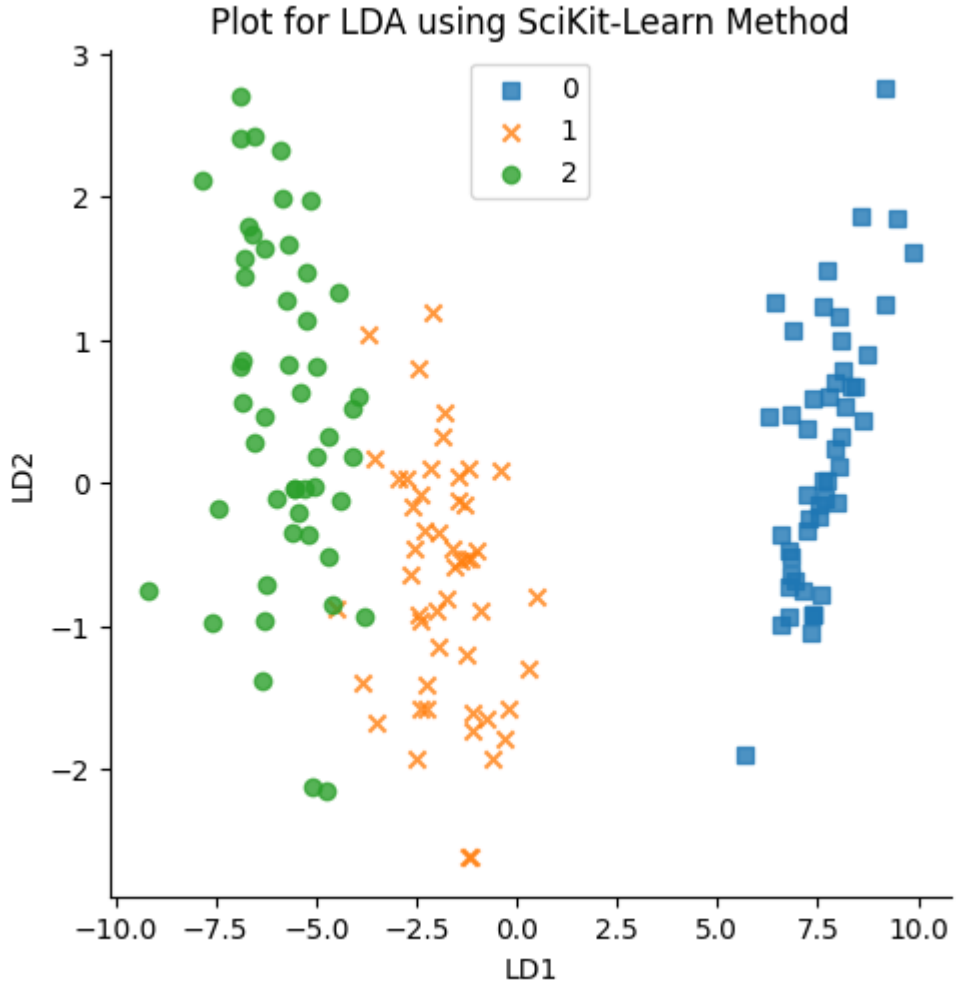


FOR LINEAR DISCRIMINANT ANALYSIS USING SCIKIT-LEARN METHOD

Shape of Reduced Dataset : X = (150, 2) Y = (150, 1)

Accuracy of IRIS Dataset after LDA

```
    Accuracy =  95.55555555555556 % for K-Value = 2
    Accuracy =  97.77777777777777 % for K-Value = 4
    Accuracy =  97.77777777777777 % for K-Value = 6
    Accuracy =  97.77777777777777 % for K-Value = 8
    Accuracy =  97.77777777777777 % for K-Value = 10
    Accuracy =  97.77777777777777 % for K-Value = 12
    Accuracy =  97.77777777777777 % for K-Value = 14
    Accuracy =  97.77777777777777 % for K-Value = 16
    Accuracy =  97.77777777777777 % for K-Value = 18
    Accuracy =  97.77777777777777 % for K-Value = 20
    Accuracy =  97.77777777777777 % for K-Value = 22
    Accuracy =  100.0 % for K-Value = 24
```



On comparison, we can see that both the methods (viz. Linear Discriminant Analysis Manually and Linear Discriminant Analysis with SciKit-Learn) reduce the dataset from 4 dimensions to 2 dimensions.

On comparing the Accuracy of a Classifier (here KNN Classifier) we can see that the Reduced Datasets obtained using LDA increases with respect to the Classifier Accuracy over Original Dataset.

The KNN Classifier gives higher accuracy for Dataset reduced by Manual Method over SciKit-Learn Method for smaller values of k, but attains higher accuracy for Dataset reduced by SciKit-Learn Method over Manual Method for larger k values.