j_version

October 31, 2022

[ ]:
```
import scipy.io as sio

import matplotlib.pyplot as plt
import numpy as np
import sklearn.discriminant_analysis
from sklearn import svm
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay
from function_plot import Load_mat_single
from function_plot import mat_to_array
from function_plot import plot_confusion_matrix
from function_plot import train_test
import time


# Load data
path_good = 'data//baseline_20220915_sv.mat'
path_bad = 'data//fault7_20220915_sv.mat'

mat_contents_good = Load_mat_single(path_good)
good_data = mat_to_array(mat_contents_good)

mat_contents_bad = Load_mat_single(path_bad)
bad_data = mat_to_array(mat_contents_bad)

show_time = True
# constuct the data

X = np.concatenate((good_data, bad_data))

n_sample = good_data.shape[0]
n_feature = good_data.shape[1]

Y = np.zeros(n_sample)
Y = np.concatenate((Y, np.ones(n_sample)))

# PCA
```

```
print("Start PCA process...")


X_mean = X - np.mean(X)


C_x = np.dot(X_mean.T, X_mean)

SS_pca, V = np.linalg.eig(C_x)

# from large to small

sortIndex = np.flip(np.argsort(SS_pca))

dimension = good_data.shape[1]
VSorted = np.empty((dimension, 0))

for i in range(dimension):
    VSorted = np.append(
        VSorted, V[:, sortIndex[i]].reshape(dimension, 1), axis=1)


classificationError_lda_pca = np.zeros(5,)
classificationError_svm_pca = np.zeros(5,)

Score_Sorted = np.dot(X, VSorted)

train_index = np.arange(0, n_sample*0.75).astype(int).tolist() + \
    np.arange(n_sample, n_sample+n_sample*0.75).astype(int).tolist()
test_index = np.arange(n_sample*0.75, n_sample).astype(int).tolist() + \
    np.arange(n_sample+n_sample*0.75, n_sample+n_sample).astype(int).tolist()

#  data for training and testing
X_train = Score_Sorted[train_index, :]
X_test = Score_Sorted[test_index, :]


Y_train = Y[train_index]
Y_test = Y[test_index]


# Classifier 1 LDA with PCA


for numDims in range(4, 9):

    Score_Reduced = X_train[:, 0:numDims]
```

```
    lda_pca = sklearn.discriminant_analysis.LinearDiscriminantAnalysis()
    X_test_temp = X_test[:, 0:numDims]

    error, prediction_lda_pca = train_test(
        Score_Reduced, Y_train, X_test_temp, Y_test,  lda_pca, show_time)

    classificationError_lda_pca[numDims-4] = error

    print("========= Confusion matrix for LDA with PCA,Reduced score shape is␣
 ↪{} ========== ".format(
        Score_Reduced.shape))

    plot_confusion_matrix(Y_test, prediction_lda_pca, lda_pca, Score_Reduced)


# Classifier 2 SVM with PCA

for numDims in range(4, 9):

    Score_Reduced = X_train[:, 0:numDims]

    clf_svm_pca = svm.SVC(kernel='linear')

    X_test_temp = X_test[:, 0:numDims]

    error, prediction_svm_pca = train_test(
        Score_Reduced, Y_train, X_test_temp, Y_test,  clf_svm_pca, show_time)

    classificationError_svm_pca[numDims-4] = error

    print("========= Confusion matrix for SVM with PCA, Reduced score shape is␣
 ↪{} ========== ".format(
        Score_Reduced.shape))
    plot_confusion_matrix(Y_test, prediction_svm_pca, lda_pca, Score_Reduced)


# # Feature selection-backward search

print("Start Feature Selection process...")

X_train_fs = X[train_index, :]

X_test_fs = X[test_index, :]

n_train = X_train_fs.shape[0]
n_test = X_test_fs.shape[0]
```

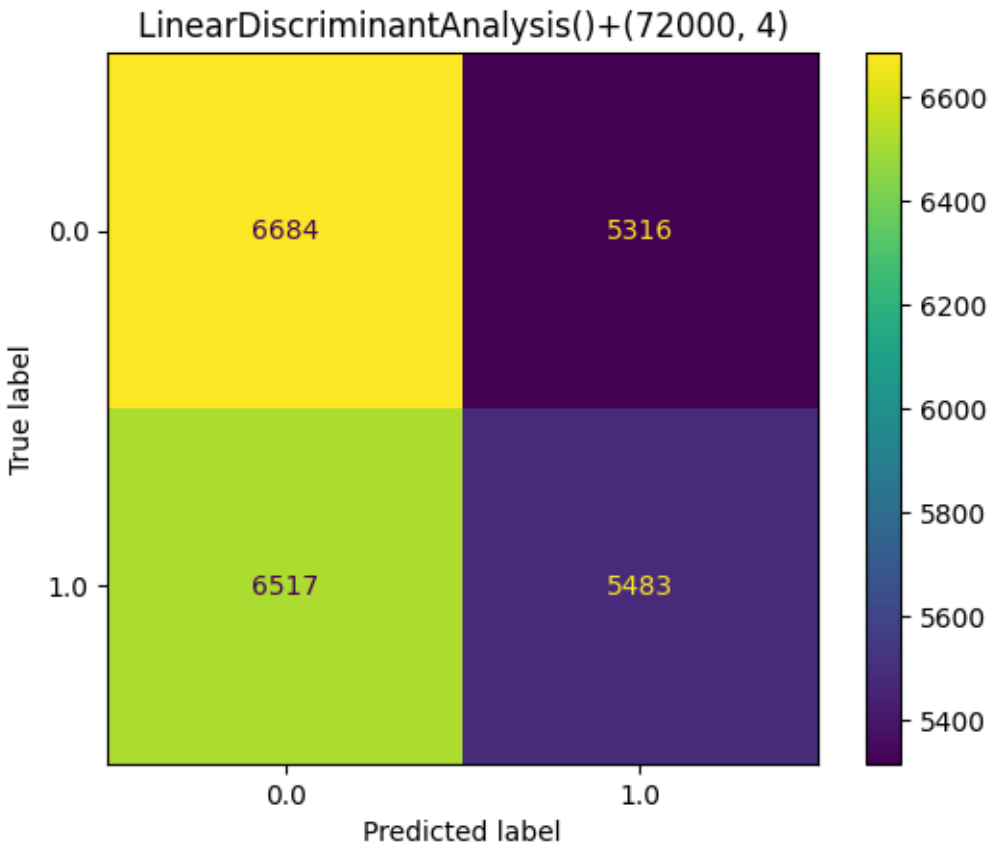
```
final_dimension = 5

# Classifier 1 LDA with Feature selection
print('Start Feature Selection with LDA...')


removed = []

index_all = [0, 1, 2, 3, 4, 5, 6, 7]
remaining = index_all[:]


classificationError_lda_fs = n_test*np.ones(final_dimension)

lda_fs = sklearn.discriminant_analysis.LinearDiscriminantAnalysis()

error_temp, prediction = train_test(
    X_train_fs, Y_train, X_test_fs, Y_test, lda_fs, show_time)

classificationError_lda_fs[0] = error_temp

print("========= Confusion matrix for LDA with FS, the training shape is {}␣
 ↪========== ".format(
    X_train_fs.shape))

plot_confusion_matrix(Y_test, prediction, lda_fs, X_train_fs)


for iteration in range(final_dimension-1):

    error_inside = n_test*np.ones(n_feature)
    for idx, item in enumerate(remaining):
        temp_removed = removed[:]
        temp_removed.append(item)
        # print(temp_removed)

        Xtrain_temp = np.delete(X_train_fs, temp_removed, axis=1)
        Xtest_temp = np.delete(X_test_fs, temp_removed, axis=1)

        lda_temp = sklearn.discriminant_analysis.LinearDiscriminantAnalysis()

        error_temp, item_ignored = train_test(Xtrain_temp, Y_train,
                                              Xtest_temp, Y_test, lda_temp)

        error_inside[idx] = error_temp

    worst_i = np.argmin(error_inside)
```

```
    worst_item = remaining[worst_i]

    removed.append(worst_item)
    print("The removed colomns", removed)

    remaining.remove(worst_item)
    print("================= The remained colomns {} ====================\n".
 ↪format(remaining))

    # calculate best remaining

    X_train_selection = np.delete(X_train_fs, removed, 1)
    X_test_selection = np.delete(X_test_fs, removed, 1)

    lda_fs = sklearn.discriminant_analysis.LinearDiscriminantAnalysis()

    error, prediction_lda_fs = train_test(X_train_selection, Y_train,
                                          X_test_selection, Y_test, lda_fs,␣
 ↪show_time)

    classificationError_lda_fs[iteration+1] = error

    print("========== Confusion matrix for LDA with FS, the training shape is {}␣
 ↪========== ".format(
        X_train_selection.shape))

    plot_confusion_matrix(Y_test, prediction_lda_fs, lda_fs, X_train_selection)


# Classifier 2 SVM with Feature selection

print('Start Feature Selection with SVM...')

classificationError_svm_fs = n_test*np.ones(final_dimension)

removed = []


remaining = index_all[:]


clf_svm_fs = svm.SVC(kernel='linear')
error_temp, prediction = train_test(
    X_train_fs, Y_train, X_test_fs, Y_test, clf_svm_fs)

classificationError_svm_fs[0] = error_temp
```

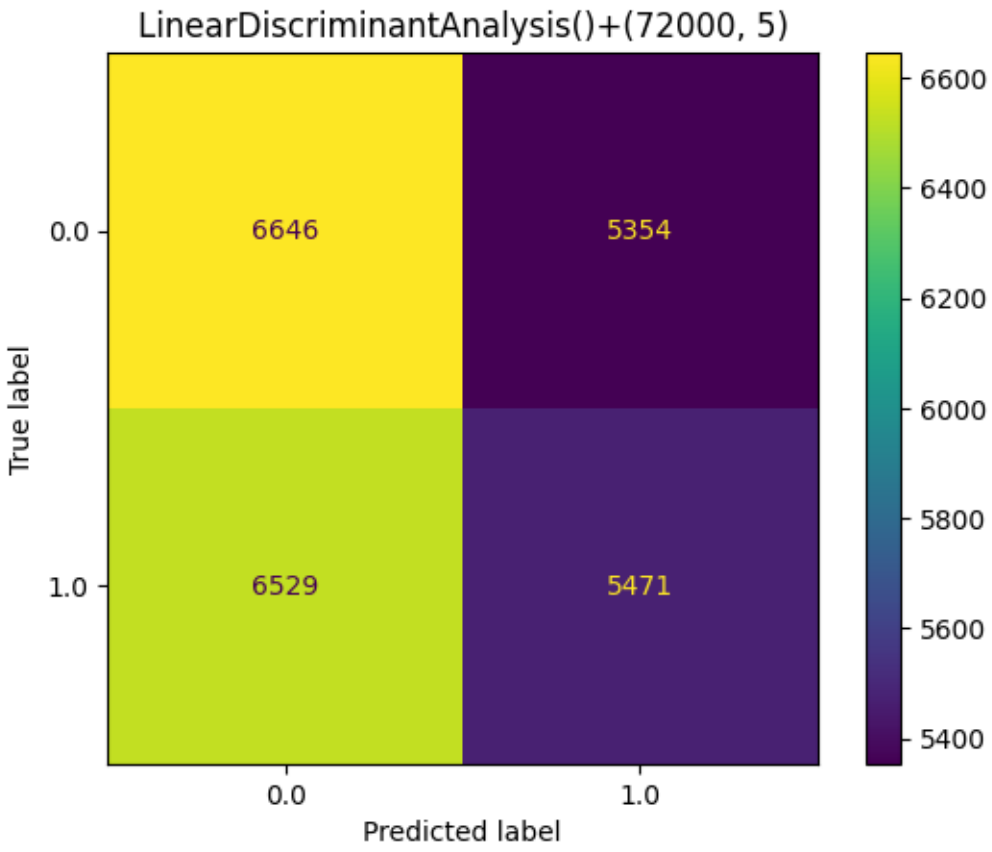
```
print("========= Confusion matrix for SVM with FS, the training shape is {}␣
 ↪========== ".format(
    X_train_fs.shape))

plot_confusion_matrix(Y_test, prediction, clf_svm_fs, X_train_fs)


for iteration in range(final_dimension-1):

    error_inside = n_test*np.ones(n_feature)
    for idx, item in enumerate(remaining):
        temp_removed = removed[:]
        temp_removed.append(item)
        # print(temp_removed)

        Xtrain_temp = np.delete(X_train_fs, temp_removed, axis=1)
        Xtest_temp = np.delete(X_test_fs, temp_removed, axis=1)

        svm_temp = svm.SVC(kernel='linear')
        error_temp, item_ignored = train_test(Xtrain_temp, Y_train,
                                              Xtest_temp, Y_test, svm_temp)

        error_inside[idx] = error_temp

    worst_i = np.argmin(error_inside)

    worst_item = remaining[worst_i]

    removed.append(worst_item)
    print("The removed colomns", removed)

    remaining.remove(worst_item)
    print("The remained colomns {}\n".format(remaining))

    X_train_selection = np.delete(X_train_fs, removed, 1)
    X_test_selection = np.delete(X_test_fs, removed, 1)

    svm_fs = svm.SVC(kernel='linear')

    error, prediction_svm_fs = train_test(X_train_selection, Y_train,
                                          X_test_selection, Y_test, svm_fs,␣
 ↪show_time)

    classificationError_svm_fs[iteration+1] = error
```

```
    print("========= Confusion matrix for SVM with FS, the training shape is {}␣
 ↪========== ".format(
        X_train_selection.shape))

    plot_confusion_matrix(Y_test, prediction_svm_fs, svm_fs, X_train_selection)


plt.figure()
plt.scatter([8, 7, 6, 5, 4], np.flip(classificationError_lda_pca),
            c='b', marker='*', label="PCA+LDA")
plt.scatter([8, 7, 6, 5, 4], classificationError_lda_fs,
            c='r', marker='o', label="Feature Selection+LDA")
plt.xlabel('Dimension')
plt.ylabel('Error')
plt.title('Classifier 1 LDA')
plt.legend()


plt.figure()
plt.scatter([8, 7, 6, 5, 4], np.flip(classificationError_svm_pca),
            c='b', marker='*', label="PCA+SVM")
plt.scatter([8, 7, 6, 5, 4], classificationError_svm_fs,
            c='r', marker='o', label="Feature Selection+SVM")
plt.xlabel('Dimension')
plt.ylabel('Error')
plt.title('Classifier 2 SVM')
plt.legend()
```

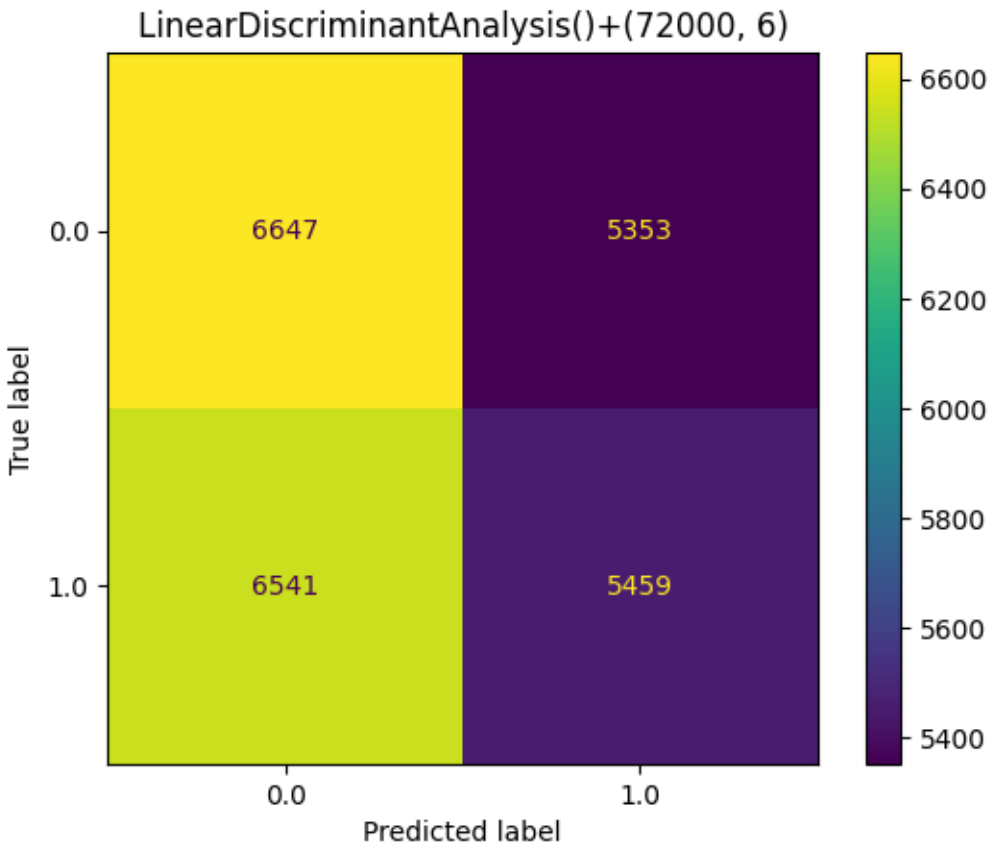
```
0 __header__
1 __version__
2 __globals__
3 sv
0 __header__
1 __version__
2 __globals__
3 sv
Start PCA process…
The experiment is LinearDiscriminantAnalysis()

The shape of X_train is (72000, 4)

The train time is --- 0.04088902 seconds ---
The test time is --- 0.00099659 seconds ---
========= Confusion matrix for LDA with PCA,Reduced score shape is (72000, 4)
==========
```



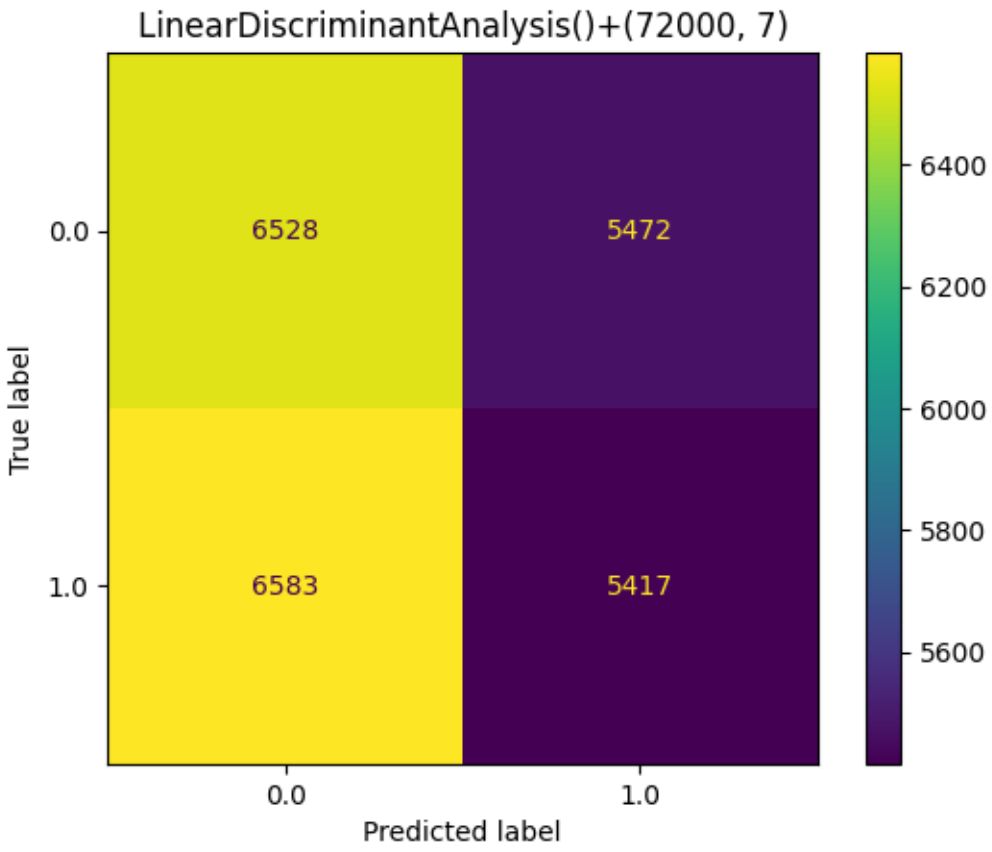

```
The experiment is LinearDiscriminantAnalysis()

The shape of X_train is (72000, 5)

The train time is --- 0.04886866 seconds ---
The test time is --- 0.00099754 seconds ---
========= Confusion matrix for LDA with PCA,Reduced score shape is (72000, 5)
==========
```



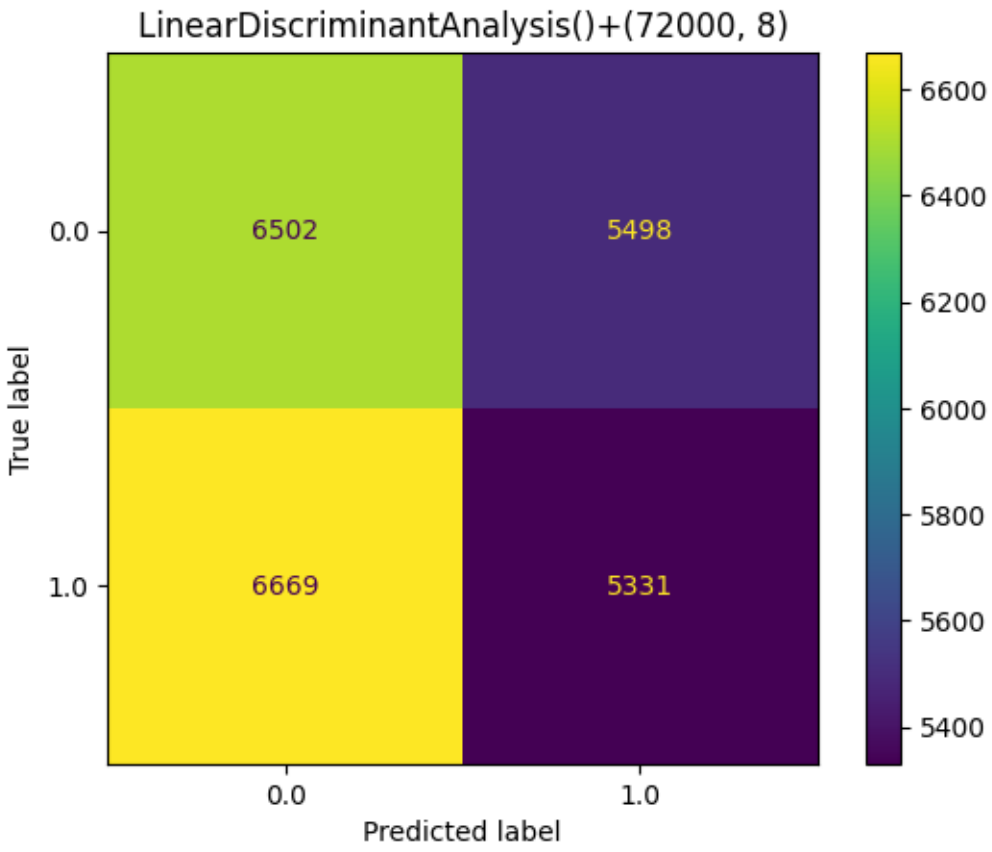

```
The experiment is LinearDiscriminantAnalysis()

The shape of X_train is (72000, 6)

The train time is --- 0.06083798 seconds ---
The test time is --- 0.00096536 seconds ---
========= Confusion matrix for LDA with PCA,Reduced score shape is (72000, 6)
==========
```



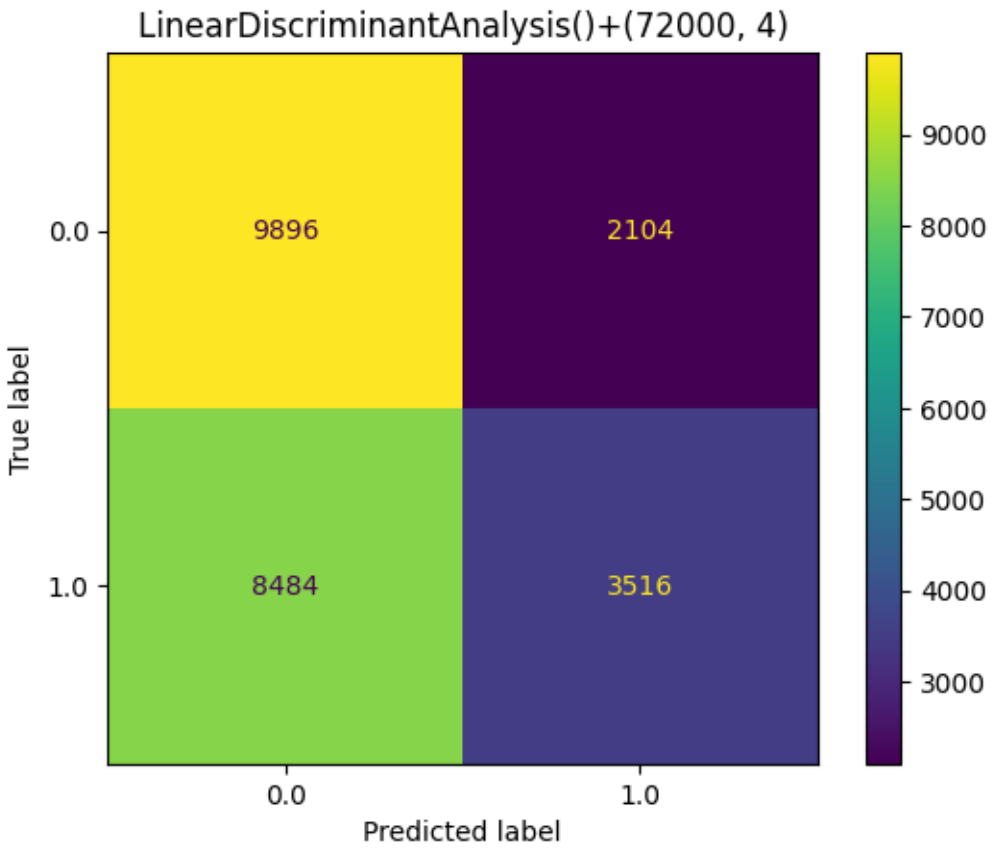

```
The experiment is LinearDiscriminantAnalysis()

The shape of X_train is (72000, 7)

The train time is --- 0.06881666 seconds ---
The test time is --- 0.00099635 seconds ---
========= Confusion matrix for LDA with PCA,Reduced score shape is (72000, 7)
==========
```



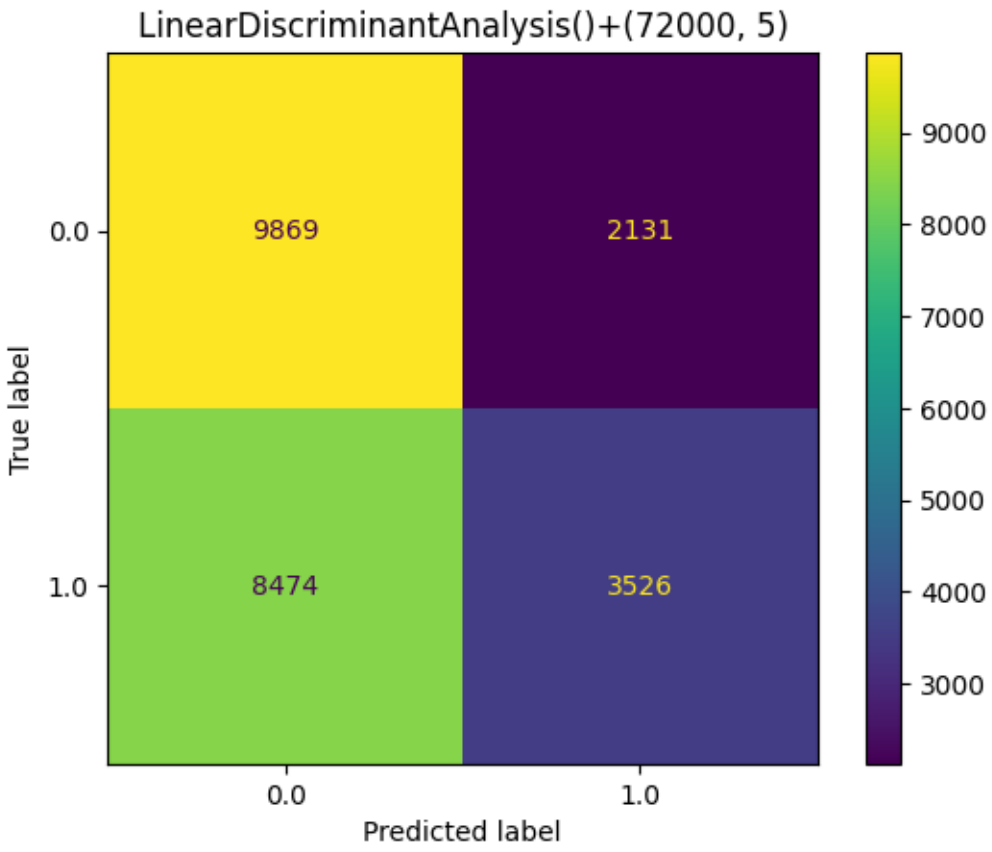

```
The experiment is LinearDiscriminantAnalysis()

The shape of X_train is (72000, 8)

The train time is --- 0.07682896 seconds ---
The test time is --- 0.00101137 seconds ---
========= Confusion matrix for LDA with PCA,Reduced score shape is (72000, 8)
==========
```



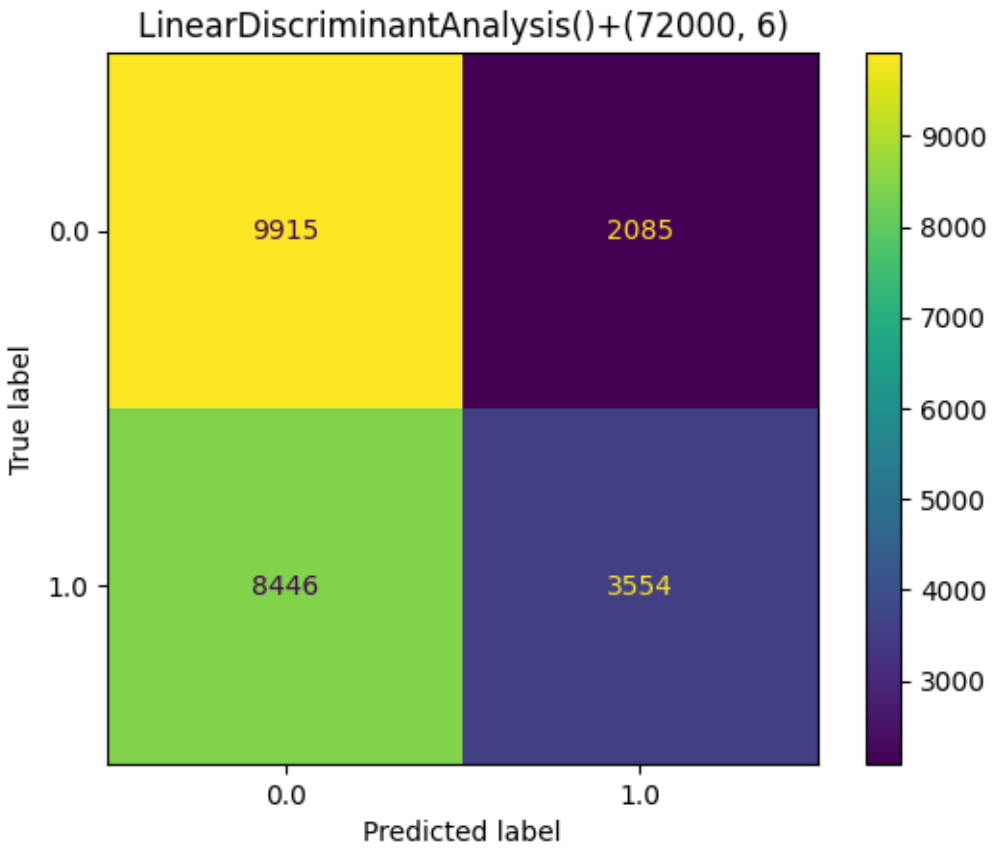

```
The experiment is SVC(kernel='linear')

The shape of X_train is (72000, 4)

The train time is --- 101.14606404 seconds ---
The test time is --- 24.38094330 seconds ---
========= Confusion matrix for SVM with PCA, Reduced score shape is (72000, 4)
==========
```



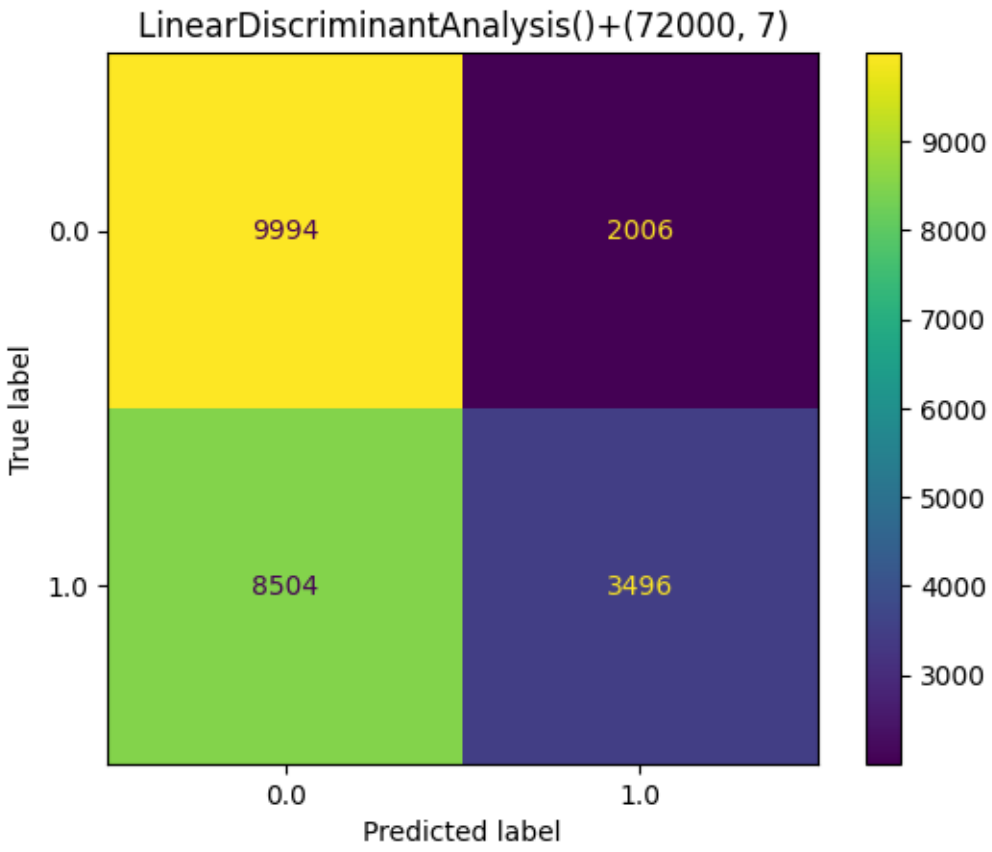

```
The experiment is SVC(kernel='linear')

The shape of X_train is (72000, 5)

The train time is --- 102.90769792 seconds ---
The test time is --- 25.33850074 seconds ---
========= Confusion matrix for SVM with PCA, Reduced score shape is (72000, 5)
==========
```



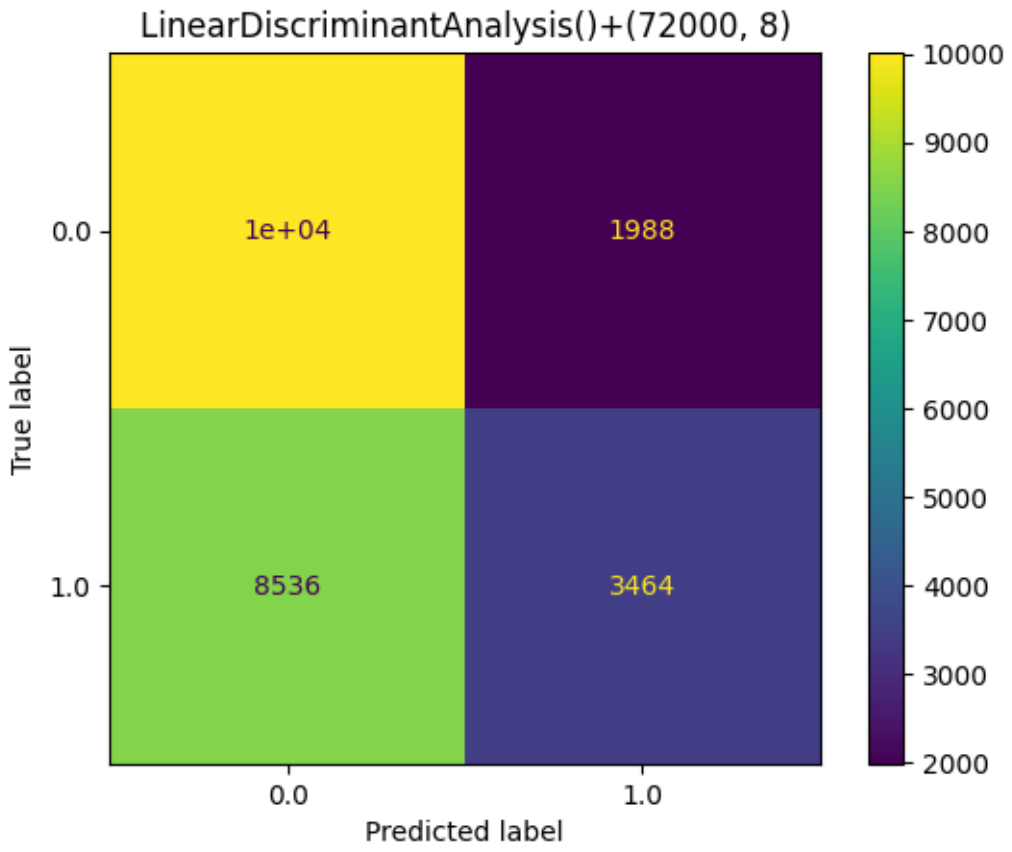

```
The experiment is SVC(kernel='linear')

The shape of X_train is (72000, 6)

The train time is --- 105.95546889 seconds ---
The test time is --- 25.70138359 seconds ---
========= Confusion matrix for SVM with PCA, Reduced score shape is (72000, 6)
==========
```



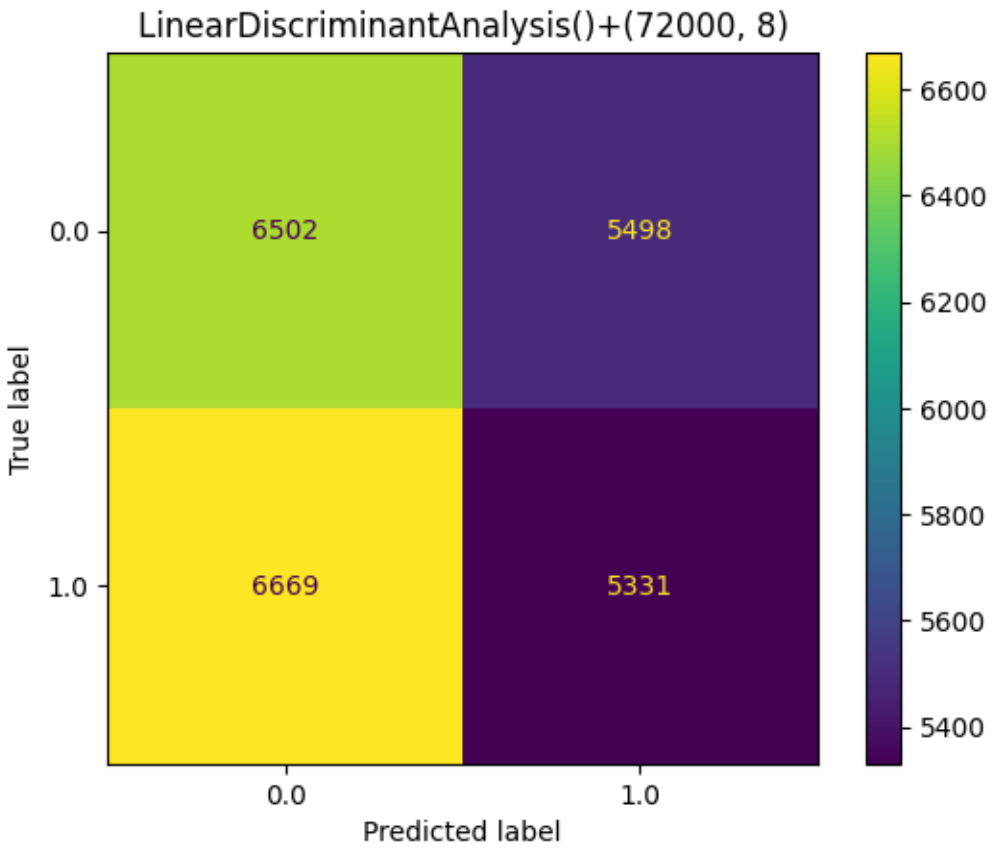

```
The experiment is SVC(kernel='linear')

The shape of X_train is (72000, 7)

The train time is --- 115.95480776 seconds ---
The test time is --- 27.22708750 seconds ---
========= Confusion matrix for SVM with PCA, Reduced score shape is (72000, 7)
==========
```



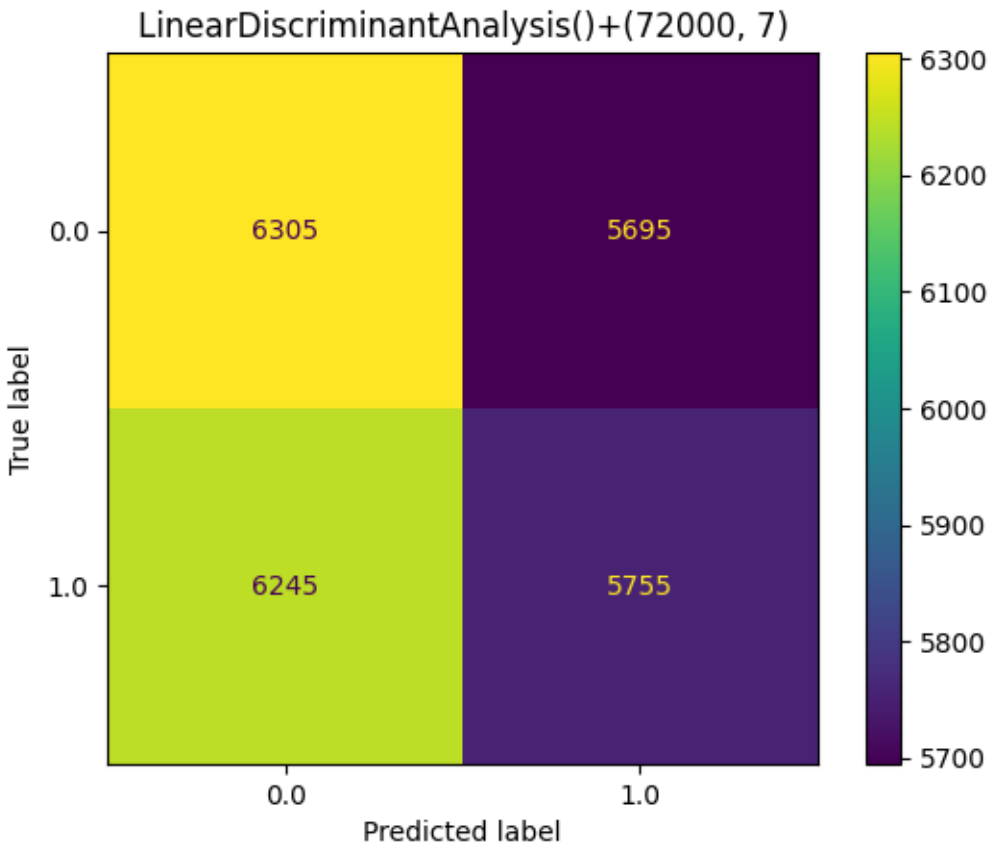

```
The experiment is SVC(kernel='linear')

The shape of X_train is (72000, 8)

The train time is --- 116.09141397 seconds ---
The test time is --- 27.43732071 seconds ---
========= Confusion matrix for SVM with PCA, Reduced score shape is (72000, 8)
==========
```



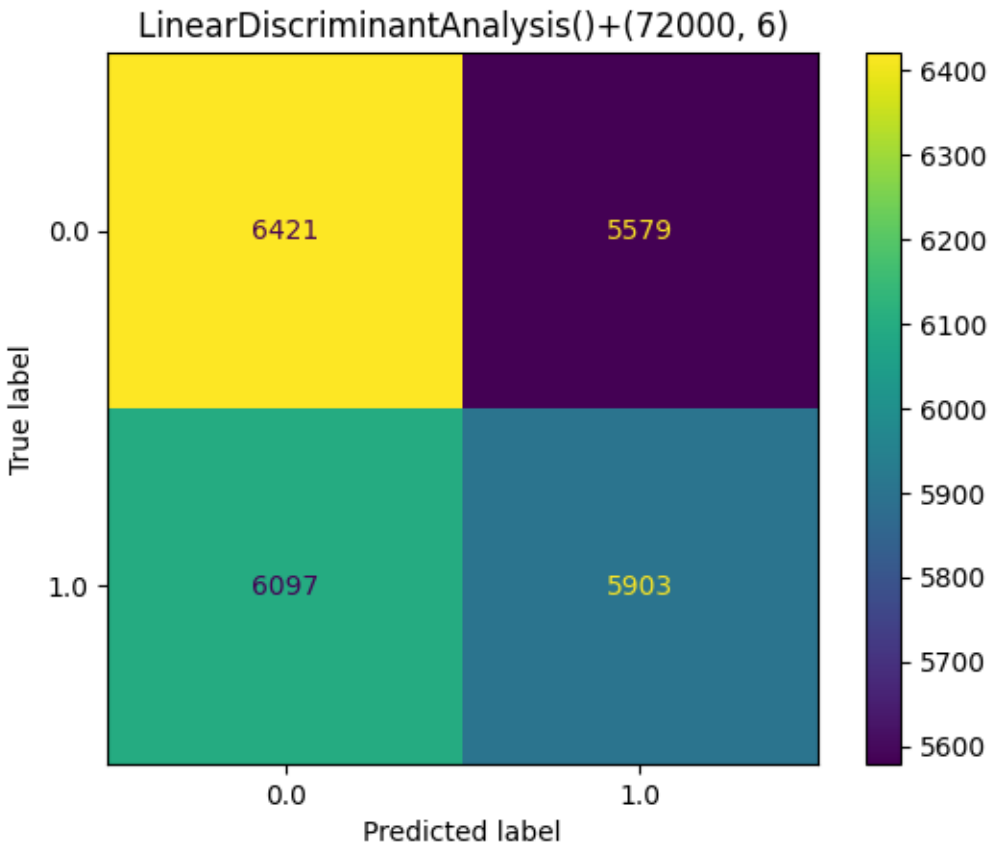

```
Start Feature Selection process…
Start Feature Selection with LDA…
The experiment is LinearDiscriminantAnalysis()

The shape of X_train is (72000, 8)

The train time is --- 0.07081032 seconds ---
The test time is --- 0.00099874 seconds ---
========= Confusion matrix for LDA with FS, the training shape is (72000, 8)
==========
```



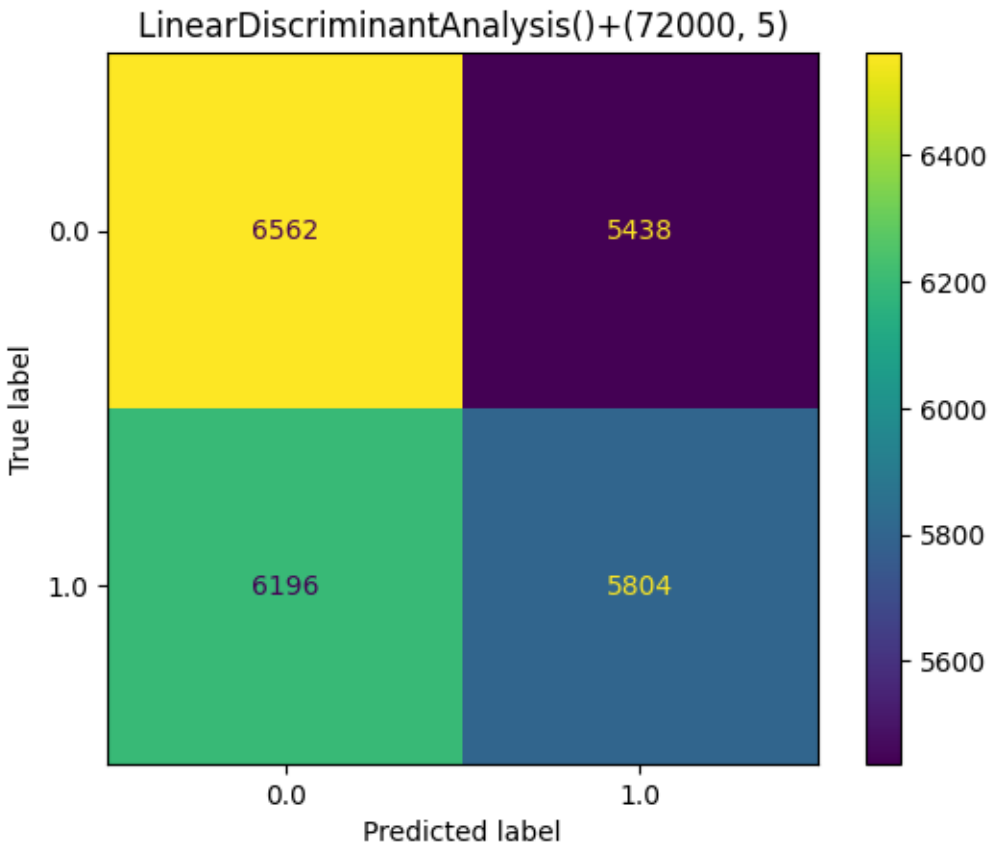

```
The removed colomns [2]
================= The remained colomns [0, 1, 3, 4, 5, 6, 7]
====================

The experiment is LinearDiscriminantAnalysis()

The shape of X_train is (72000, 7)

The train time is --- 0.05887485 seconds ---
The test time is --- 0.00096273 seconds ---
========= Confusion matrix for LDA with FS, the training shape is (72000, 7)
==========
```



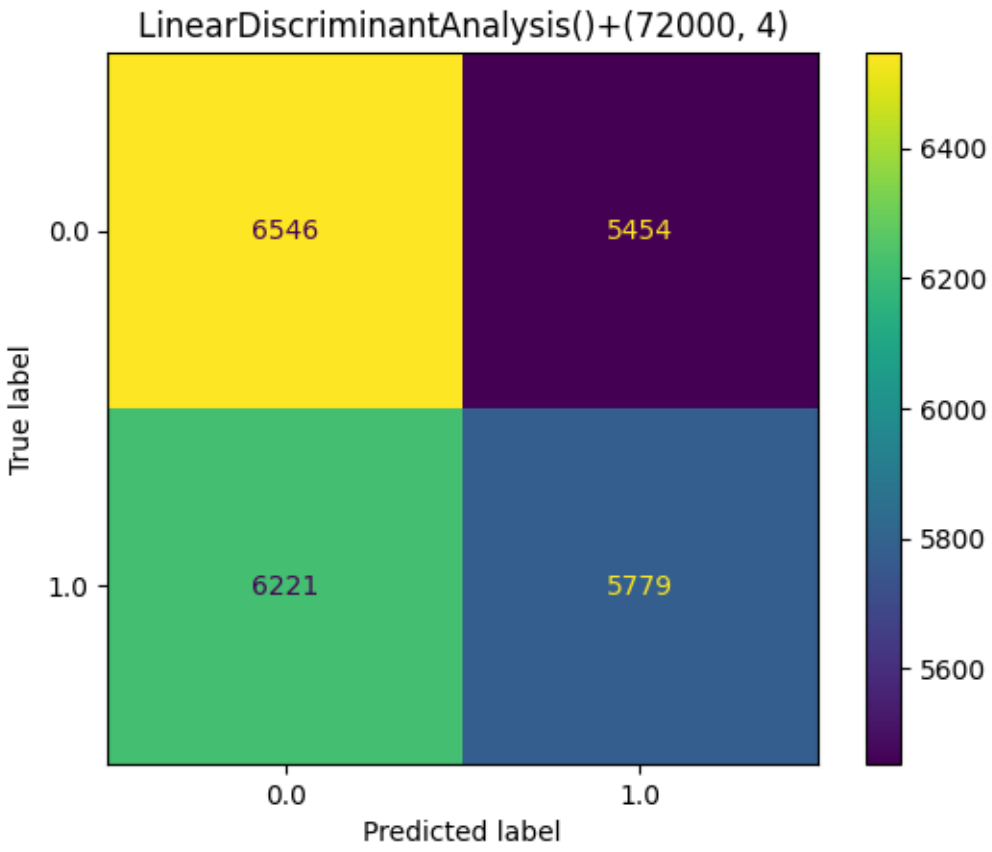

```
The removed colomns [2, 4]
================= The remained colomns [0, 1, 3, 5, 6, 7] ====================

The experiment is LinearDiscriminantAnalysis()

The shape of X_train is (72000, 6)

The train time is --- 0.05185819 seconds ---
The test time is --- 0.00100064 seconds ---
========= Confusion matrix for LDA with FS, the training shape is (72000, 6)
==========
```



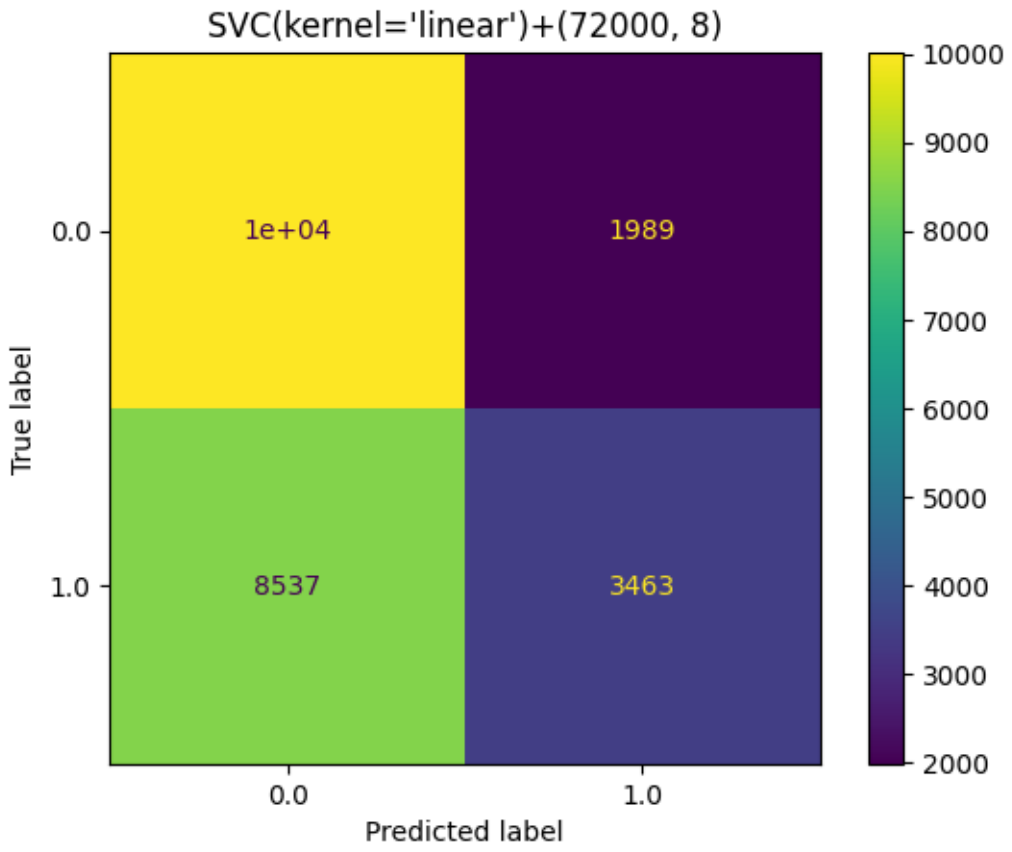

```
The removed colomns [2, 4, 1]
================= The remained colomns [0, 3, 5, 6, 7] ====================

The experiment is LinearDiscriminantAnalysis()

The shape of X_train is (72000, 5)

The train time is --- 0.04687524 seconds ---
The test time is --- 0.00099683 seconds ---
========= Confusion matrix for LDA with FS, the training shape is (72000, 5)
==========
```



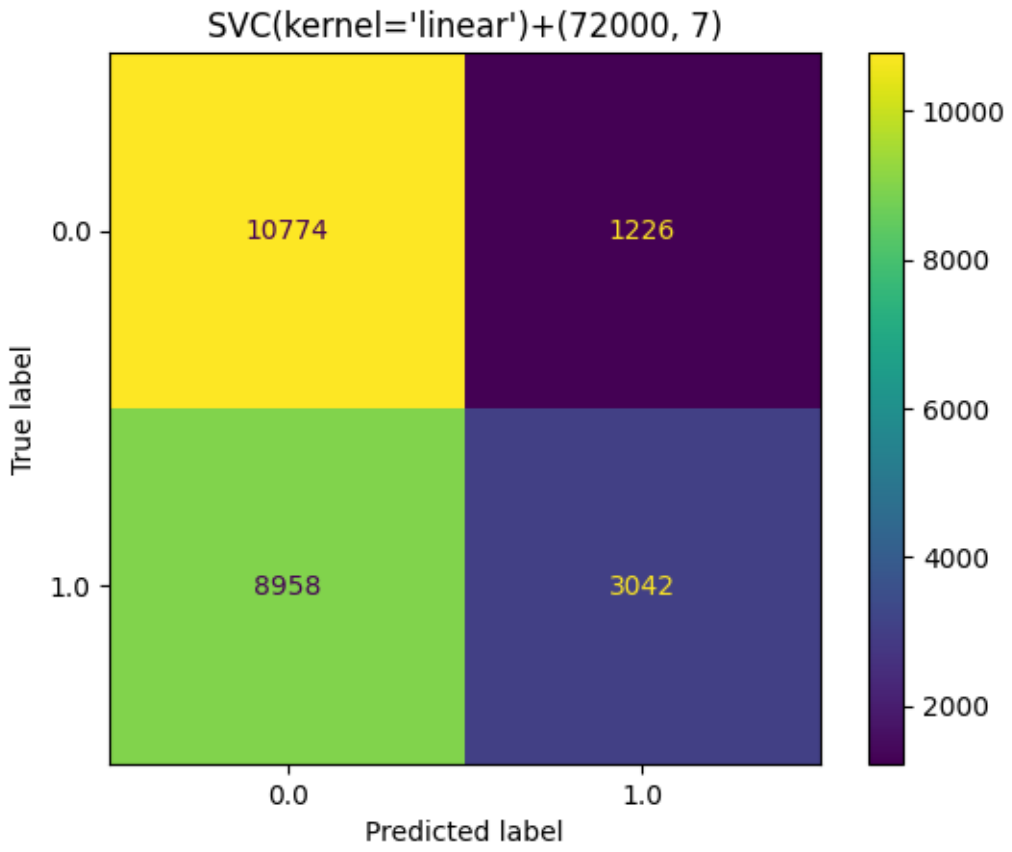

```
The removed colomns [2, 4, 1, 0]
================= The remained colomns [3, 5, 6, 7] ===================

The experiment is LinearDiscriminantAnalysis()

The shape of X_train is (72000, 4)

The train time is --- 0.03690171 seconds ---
The test time is --- 0.00102901 seconds ---
========= Confusion matrix for LDA with FS, the training shape is (72000, 4)
==========
```



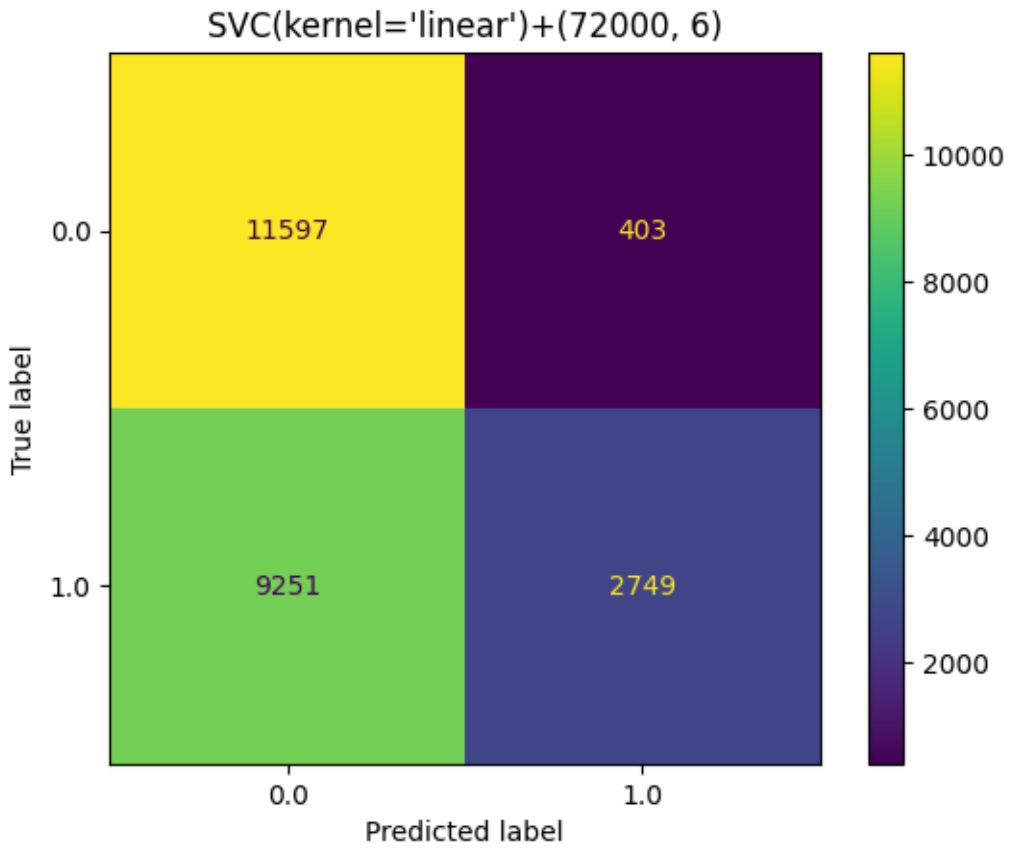

```
Start Feature Selection with SVM…
========= Confusion matrix for SVM with FS, the training shape is (72000, 8)
==========
```



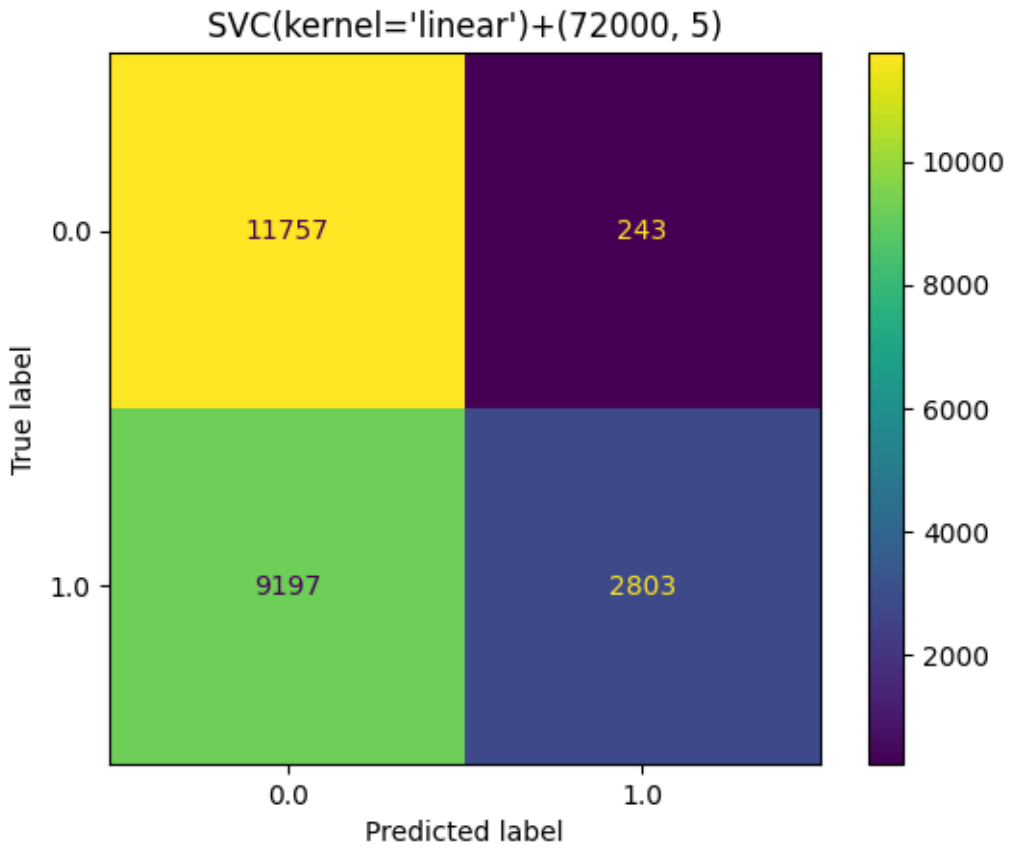

```
The removed colomns [3]
The remained colomns [0, 1, 2, 4, 5, 6, 7]

The experiment is SVC(kernel='linear')

The shape of X_train is (72000, 7)

The train time is --- 109.88118410 seconds ---
The test time is --- 27.06184483 seconds ---
========= Confusion matrix for SVM with FS, the training shape is (72000, 7)
==========
```



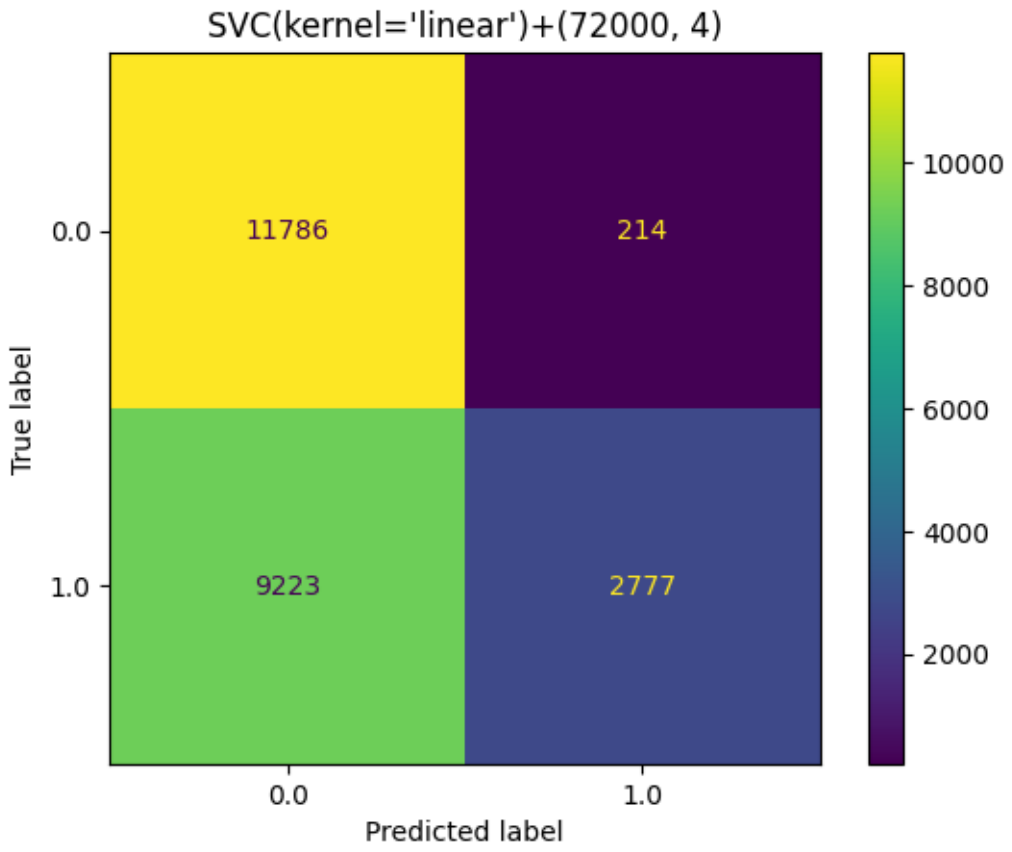

```
The removed colomns [3, 4]
The remained colomns [0, 1, 2, 5, 6, 7]

The experiment is SVC(kernel='linear')

The shape of X_train is (72000, 6)

The train time is --- 105.73561668 seconds ---
The test time is --- 25.08102965 seconds ---
========= Confusion matrix for SVM with FS, the training shape is (72000, 6)
==========
```




```
The removed colomns [3, 4, 1]
The remained colomns [0, 2, 5, 6, 7]

The experiment is SVC(kernel='linear')

The shape of X_train is (72000, 5)

The train time is --- 104.75766206 seconds ---
The test time is --- 25.33646107 seconds ---
========= Confusion matrix for SVM with FS, the training shape is (72000, 5)
==========
```




```
The removed colomns [3, 4, 1, 0]
The remained colomns [2, 5, 6, 7]

The experiment is SVC(kernel='linear')

The shape of X_train is (72000, 4)

The train time is --- 143.62490559 seconds ---
The test time is --- 24.23975325 seconds ---
========= Confusion matrix for SVM with FS, the training shape is (72000, 4)
==========
```



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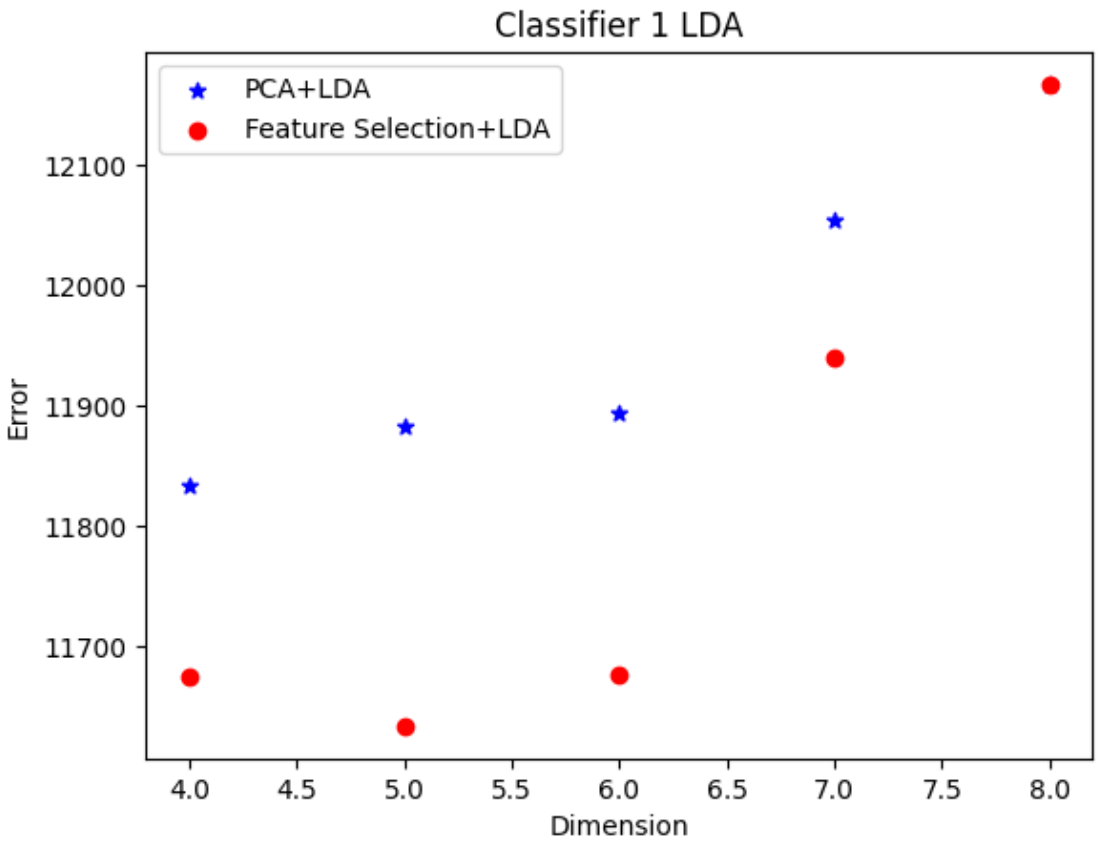
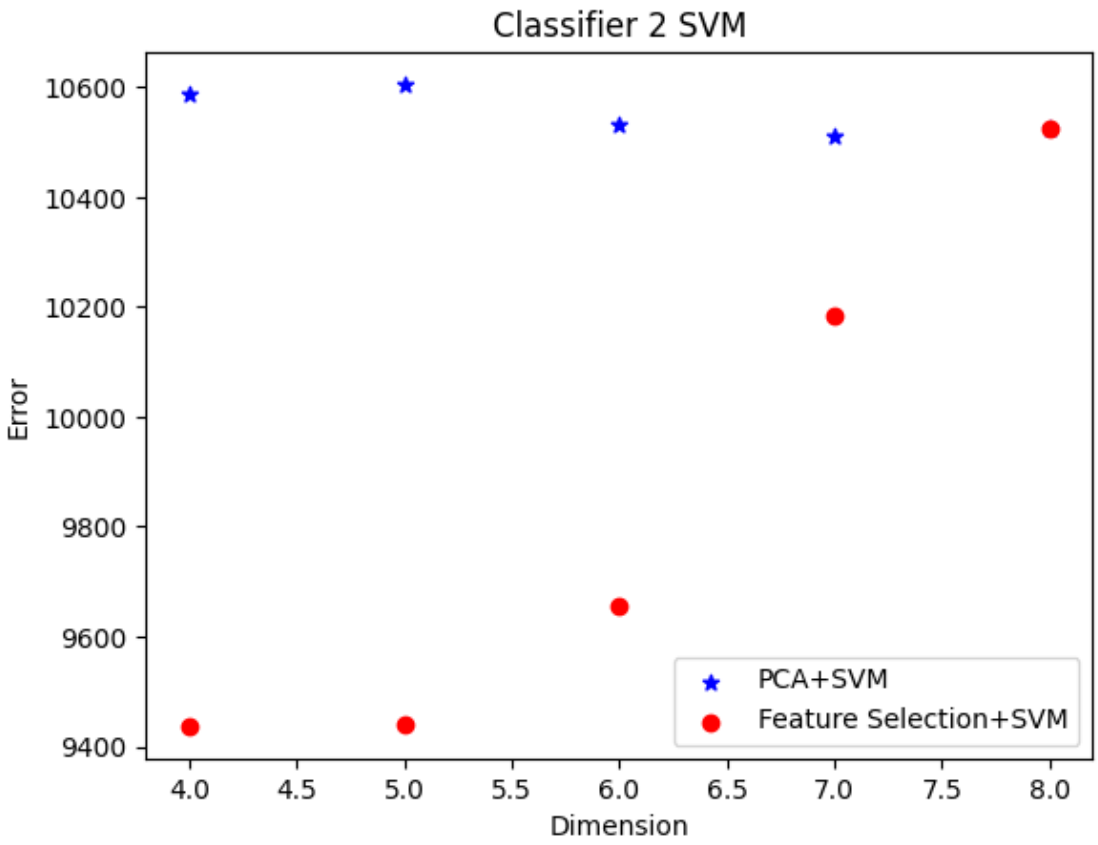

Classifier 1 LDA
PCA+LDA
Feature Selection+LDA
12100
12000
11900
11800
11700
Error
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
Dimension


Classifier 2 SVM
10600
10400
10200
10000
9800
9600
9400
Error
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
Dimension
PCA+SVM
Feature Selection+SVM