

SML Assignment 2

MNIST Classification using MLE, PCA, FDA, and Discriminant Analysis

Report

In the Assignment we were asked to randomly select 100 sample values for train data set as well as test data set. Therefore accuracy values will differ slightly at every attempt to run the code. A sample report of values is shown and comparison and analysis is done with this observation.

Discriminant Analysis Performance (Raw Features) :

LDA Train Accuracy: 1.000
LDA Test Accuracy: 0.837
QDA Train Accuracy: 1.000
QDA Test Accuracy: 0.987

QDA significantly outperforms LDA on the test set , showing that class-specific covariances improve classification.

Fisher's Discriminant Analysis (FDA) Performance :

LDA Train Accuracy after FDA: 1.000
LDA Test Accuracy after FDA: 0.833
QDA Train Accuracy after FDA: 1.000
QDA Test Accuracy after FDA: 0.727

FDA slightly reduces test accuracy compared to raw features. QDA accuracy drops more than LDA, indicating that FDA's linear projection might distort the covariance structure.

Principal Component Analysis (PCA) Performance :

PCA applied: 95% variance retained
PCA applied: 83 components retained
LDA Train Accuracy after PCA: 1.000
LDA Test Accuracy after PCA: 0.947

PCA applied: 90% variance retained
PCA applied: 52 components retained
LDA Train Accuracy after PCA: 0.980
LDA Test Accuracy after PCA: 0.960

PCA applied: 2 components retained
LDA Train Accuracy after PCA: 0.907
LDA Test Accuracy after PCA: 0.917

PCA (95% variance) significantly improves LDA performance, retaining only 90% variance causes only a slight accuracy drop and using only 2 PCA components still gives decent accuracy, but drops compared to full feature space. This indicates that the first two principal components do not capture all class-discriminative information.

QDA is best on raw features , but suffers under FDA.
LDA benefits from PCA (95%), reaching its highest accuracy .
FDA does not outperform PCA, suggesting PCA preserves class information better.

PCA affects Classification Performance :

PCA at 95% variance is the best setting, as it improves test accuracy significantly while keeping dimensions low. PCA at 90% variance is also effective, but reducing dimensions further causes performance degradation. Using only 2 principal components is insufficient for preserving class information, leading to reduced accuracy. PCA is an effective preprocessing step before LDA, as it enhances generalization and improves test accuracy.

PCA helps improve classification accuracy by reducing noise and irrelevant dimensions. However, aggressive dimensionality reduction (e.g., only 2 components) can lead to loss of class-discriminative information, reducing classification accuracy. The optimal number of principal components depends on the trade-off between computational efficiency and classification performance.

Visualization of Transformed Features :

PCA (2D Plot)

When PCA reduces data to 2D, the three classes show some overlap but are reasonably separated. PCA does not explicitly maximize class separability but still helps classification.

FDA (2D Plot)

FDA creates a linear boundary, grouping samples more distinctly than PCA. However, FDA's single projection direction may lose information, leading to lower classification performance.

```
○ python3 -u "/home/anveshan-khanna/Desktop/SML/Assi
anveshan-khanna@linux-ubuntu:~/
LDA Train Accuracy: 1.000
LDA Test Accuracy: 0.837
QDA Train Accuracy: 1.000
QDA Test Accuracy: 0.987
```

```
===== FDA =====
```

```
LDA Train Accuracy after FDA: 1.000
LDA Test Accuracy after FDA: 0.833
QDA Train Accuracy after FDA: 1.000
QDA Test Accuracy after FDA: 0.727
```

```
===== PCA =====
```

```
PCA applied: 95% variance retained
PCA applied: 83 components retained
LDA Train Accuracy after PCA: 1.000
LDA Test Accuracy after PCA: 0.947
```

```
===== PCA =====
```

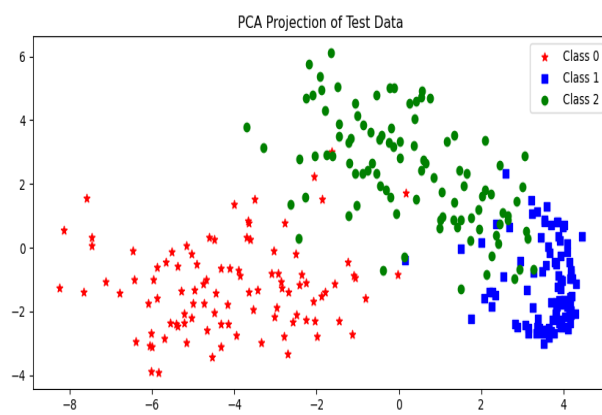
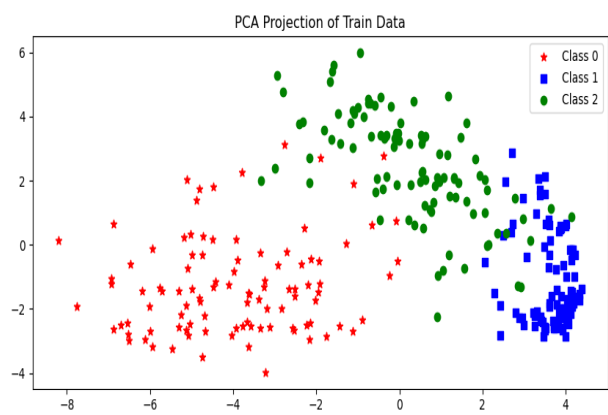
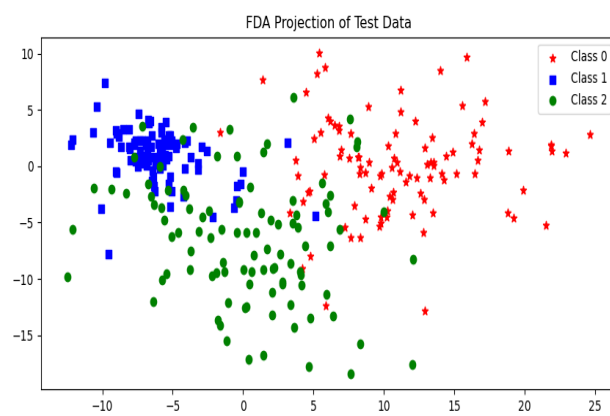
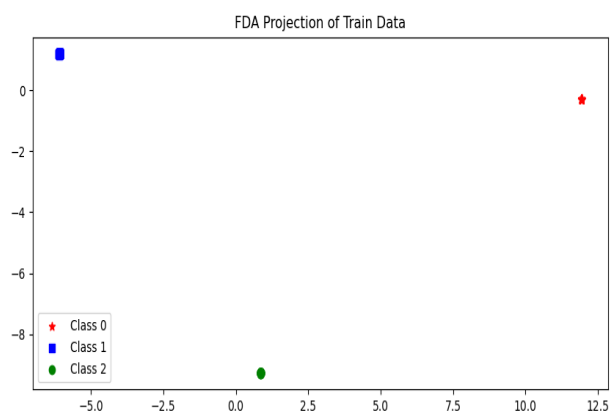
```
PCA applied: 90% variance retained
PCA applied: 52 components retained
LDA Train Accuracy after PCA: 0.980
LDA Test Accuracy after PCA: 0.960
```

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===== PCA =====
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```
PCA applied: 2 components retained
LDA Train Accuracy after PCA: 0.907
LDA Test Accuracy after PCA: 0.917
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PCA Projection of MNIST Digits (0,1,2)



```

python3 -u ~/home/anveshan-khanna/Desktop/SML/Assignment 2
anveshan-khanna@linux-ubuntu:~/Desktop/SML/Assignment 2
LDA Train Accuracy: 1.000
LDA Test Accuracy: 0.870
QDA Train Accuracy: 1.000
QDA Test Accuracy: 0.983

===== FDA =====

LDA Train Accuracy after FDA: 1.000
LDA Test Accuracy after FDA: 0.867
QDA Train Accuracy after FDA: 1.000
QDA Test Accuracy after FDA: 0.767

===== PCA =====

PCA applied: 95% variance retained
PCA applied: 81 components retained
LDA Train Accuracy after PCA: 0.997
LDA Test Accuracy after PCA: 0.943
QDA Train Accuracy after PCA: 1.000
QDA Test Accuracy after PCA: 0.897

===== PCA =====

PCA applied: 90% variance retained
PCA applied: 50 components retained
LDA Train Accuracy after PCA: 0.993
LDA Test Accuracy after PCA: 0.960
QDA Train Accuracy after PCA: 1.000
QDA Test Accuracy after PCA: 0.917

===== PCA =====

PCA applied: 2 components retained
LDA Train Accuracy after PCA: 0.923
LDA Test Accuracy after PCA: 0.907
QDA Train Accuracy after PCA: 0.950
QDA Test Accuracy after PCA: 0.920

```

Sample output containing PCA+QDA accuracies also