Group 28 - Report for Assignment 2 - Classification Models

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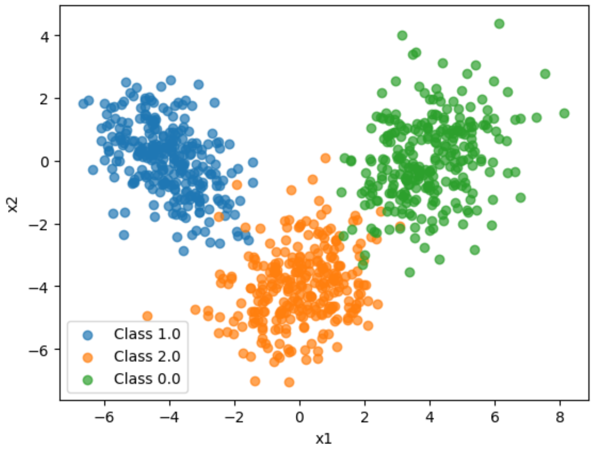
Contents

1 Dataset 1

This is a 3-class 2 dimensional linearly separable dataset.

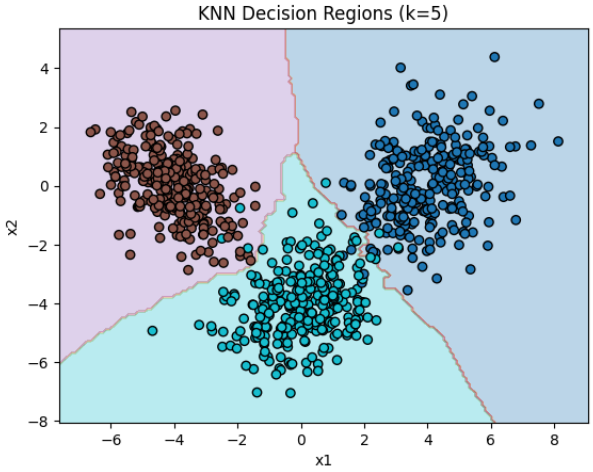


1.1 K-Nearest Neighbours Classifier

K	Train Accuracy	Validation Accuracy	Test Accuracy
1	100.00	97.92	95.83
5	98.57	98.33	97.50
9	97.74	98.33	95.83

We see that the best fit for the data is obtained for k = 5 model, it gives the best performance (most accuracy in test data).

1.1.1 Decision Region of Best Model

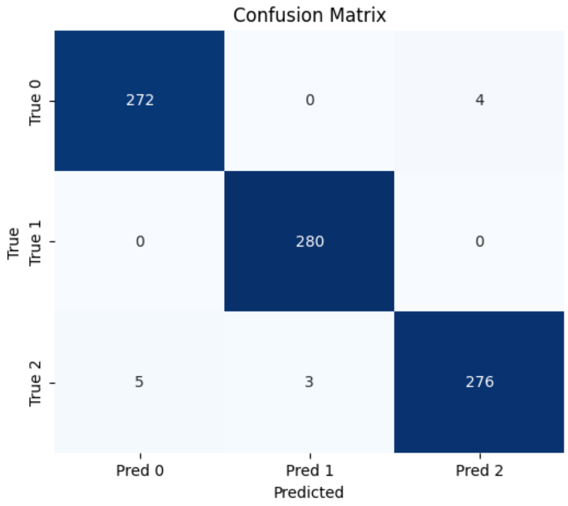


1.1.2 Performance Metrics

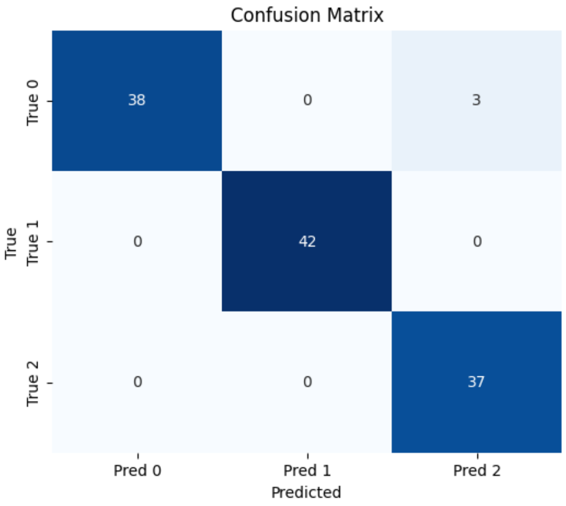
Accuracy for best performing model (k = 5):

Train Data Accuracy: 98.57%
Test Data Accuracy: 97.50%

Confusion Matrix:



Train Dataset



Test Dataset

For the test dataset predictions:

- Class 0
  - Precision: 1.000
  - Recall: 0.927
  - F1 Score: 0.962
- Class 1
  - Precision: 1.000
  - Recall: 1.000
  - F1 Score: 1.000
- Class 2
  - Precision: 0.925
  - Recall: 1.000
  - F1 Score: 0.961

Average Precision: 0.975
Average Recall: 0.976
Average F1 Score: 0.974

1.2 Bayes Classifier - Gaussian

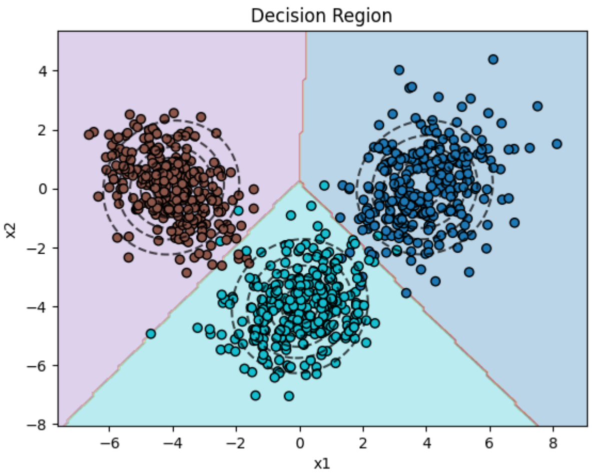
1.2.1 Accuracy of each model

Type	Train Accuracy	Validation Accuracy	Test Accuracy
Same Cov. Matrix	98.10	98.33	95.00
Diff. Cov. Matrix	98.21	98.33	95.00

The model with different covariance matrices for different classes has a better fit on training data, although performance on validation and test datasets are the same.

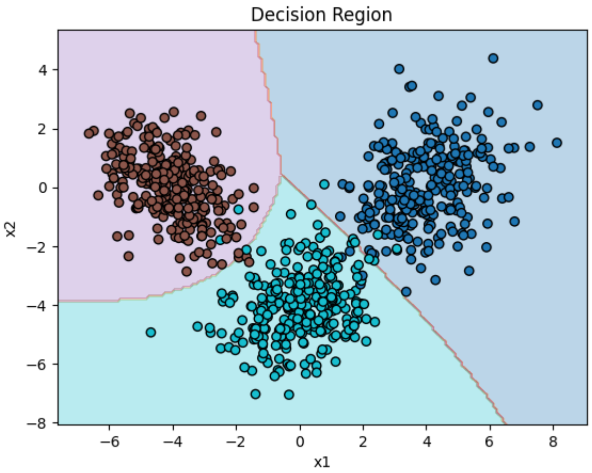
1.2.2 Decision Regions

Same Covariance Matrix for all classes:



The decision boundaries are linear.

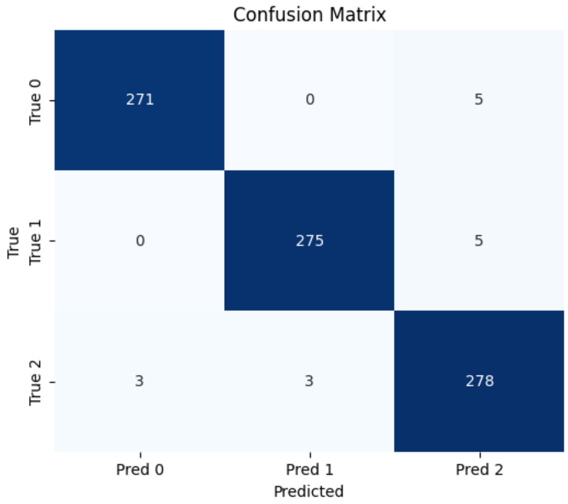
Different Covariance Matrix for each class:



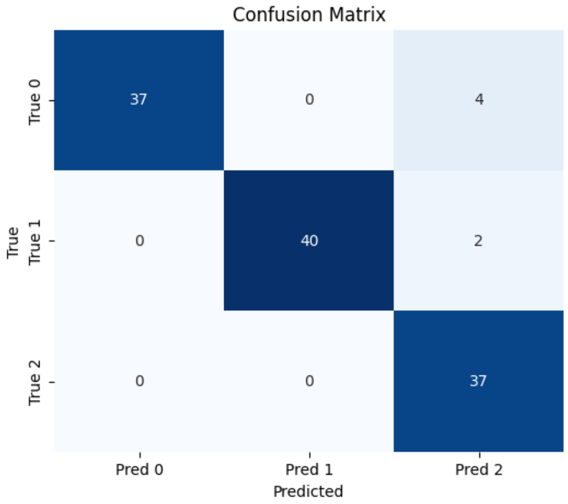
The decision boundaries are quadratic.

1.2.3 Performance Metrics

1.2.3.1 a. Same Cov. Matrix for all classes Confusion Matrix:



Train Dataset



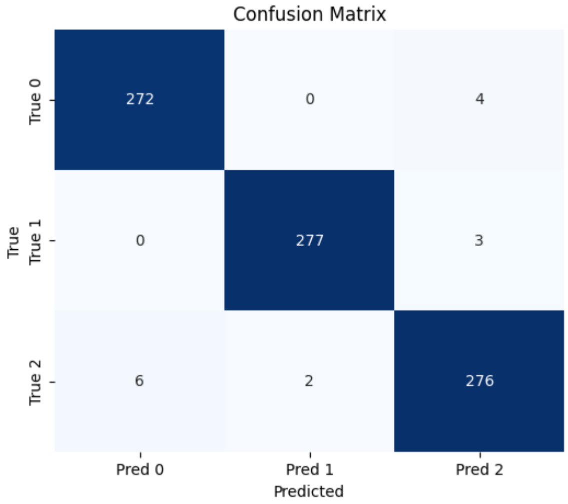
Test Dataset

For the test dataset:

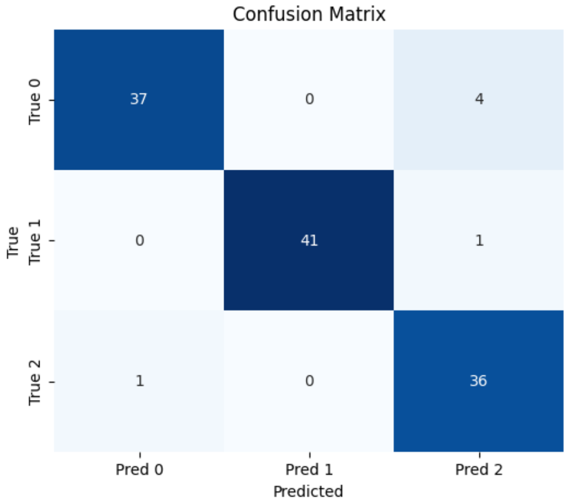
- **Class 0**
  - Precision: 1.000
  - Recall: 0.902
  - F1 Score: 0.949
- **Class 1**
  - Precision: 1.000
  - Recall: 0.952
  - F1 Score: 0.976
- **Class 2**
  - Precision: 0.860
  - Recall: 1.000
  - F1 Score: 0.925

Average Precision: 0.953
Average Recall: 0.952
Average F1 Score: 0.950

1.2.3.2 b. Diff Cov. Matrix for each class Confusion Matrix:



Train Dataset



Test Dataset

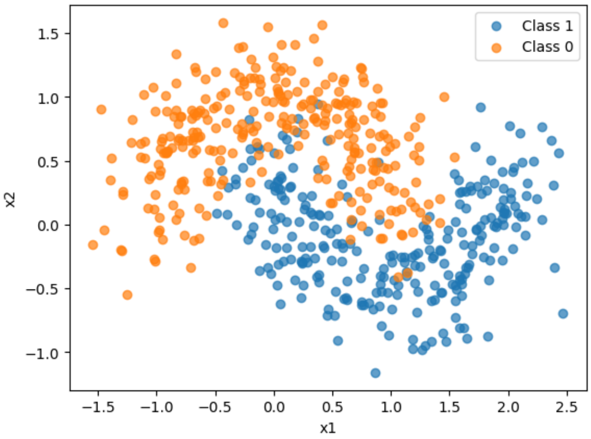
For the test dataset:

- **Class 0**
  - Precision: 0.974
  - Recall: 0.902
  - F1 Score: 0.937
- **Class 1**
  - Precision: 1.000
  - Recall: 0.976
  - F1 Score: 0.988
- **Class 2**
  - Precision: 0.878
  - Recall: 0.973
  - F1 Score: 0.923

Average Precision: 0.951
Average Recall: 0.951
Average F1 Score: 0.949

2 Dataset 2

2-Class 2 Dimensional Non-linearly separable dataset

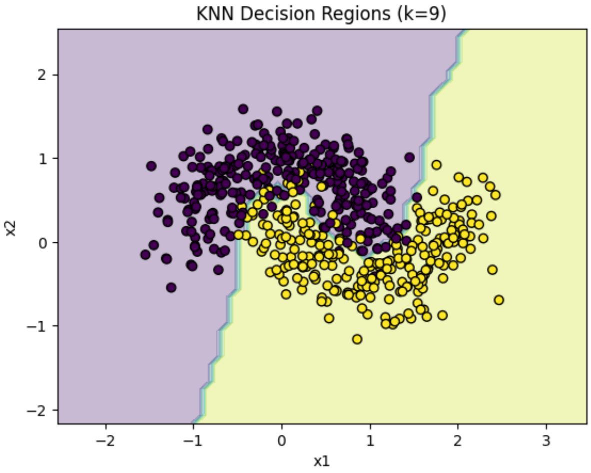


2.1 K-Nearest Neighbours Classifier

K	Train Accuracy	Validation Accuracy	Test Accuracy
1	100.00	94.34	93.75
5	94.12	95.60	100.00
9	94.30	96.23	97.50

We see that the best fit for the data is obtained for k = 9 model, it gives the best performance (most accuracy in test data).

2.1.1 Decision Region of Best Model

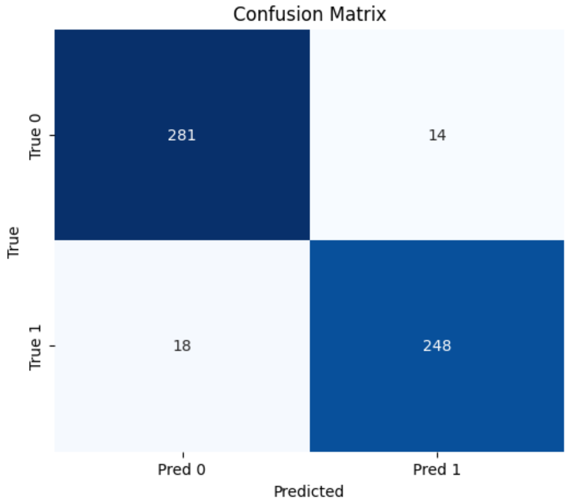


2.1.2 Performance Metrics

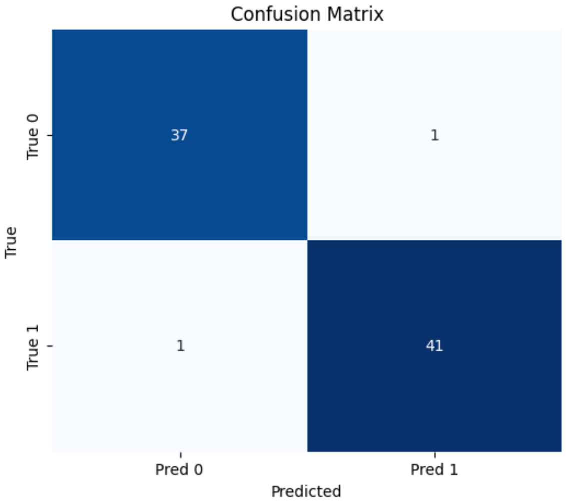
Accuracy for best performing model (k = 9):

Train Data Accuracy: 94.30%
Test Data Accuracy: 97.50%

Confusion Matrix:



Train Dataset



Test Dataset

For the test dataset predictions:

- **Class 0**
  - Precision: 0.974
  - Recall: 0.974
  - F1 Score: 0.974
- **Class 1**
  - Precision: 0.976
  - Recall: 0.976
  - F1 Score: 0.976

Average Precision: 0.975
Average Recall: 0.975
Average F1 Score: 0.975

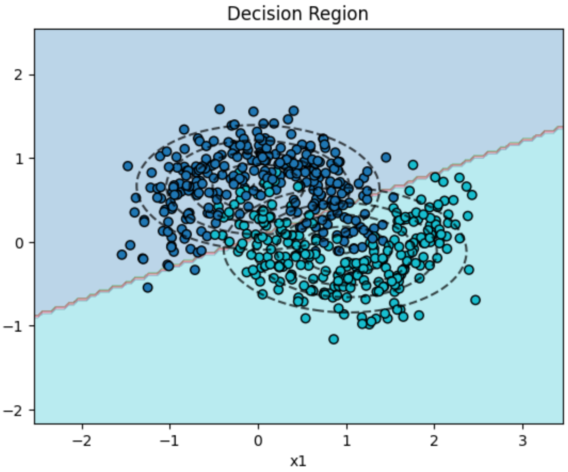
2.2 Bayes Classifier - Gaussian

2.2.1 Accuracy of each model

Type	Train Accuracy	Validation Accuracy	Test Accuracy
Same Cov. Matrix	85.03	85.54	86.25
Diff. Cov. Matrix	84.85	84.91	86.25

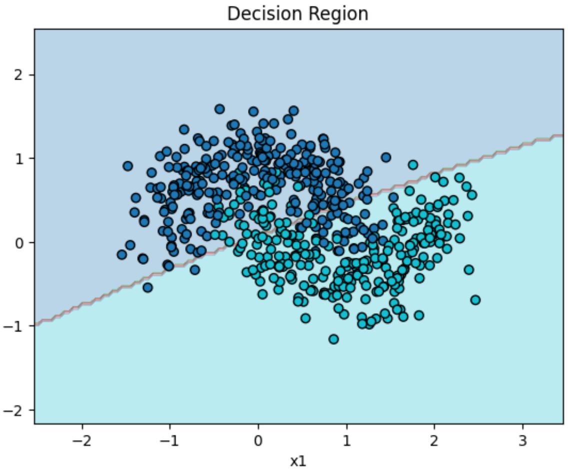
2.2.2 Decision Regions

Same Covariance Matrix for all classes:



The decision boundaries are linear.

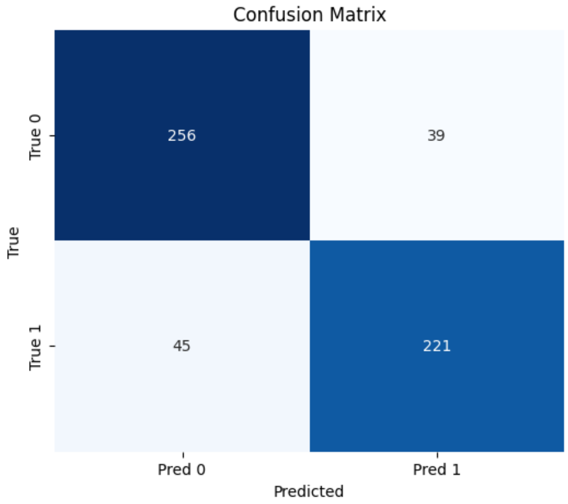
Different Covariance Matrix for each class:



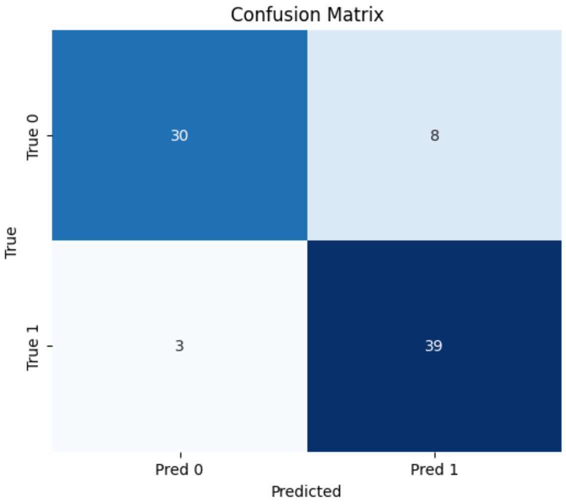
The decision boundaries are quadratic, still looks very similar to above case.

2.2.3 Performance Metrics

2.2.3.1 a. Same Cov. Matrix for all classes Confusion Matrix:



Train Dataset



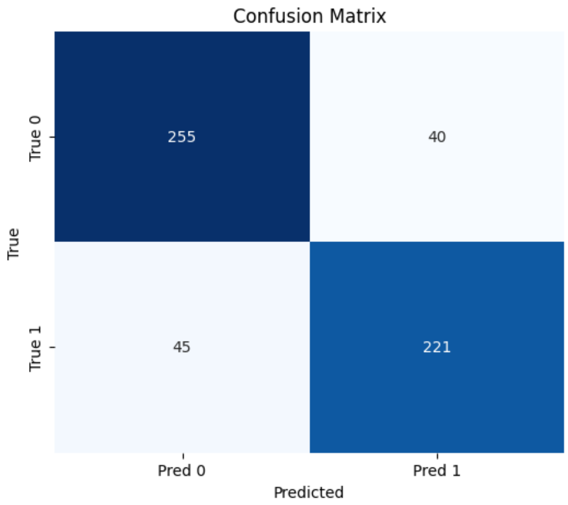
Test Dataset

For the test dataset:

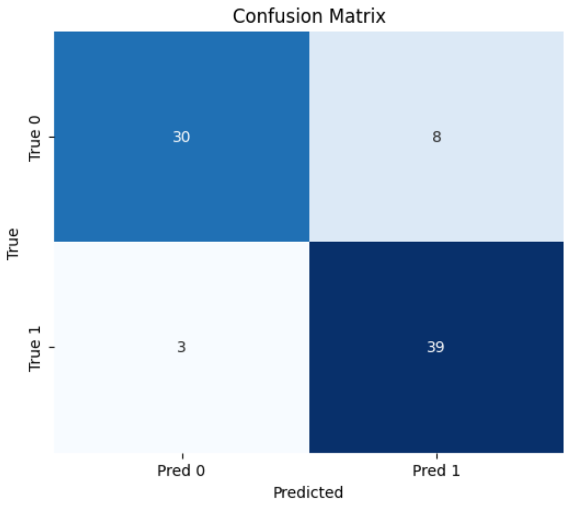
- **Class 0**
  - Precision: 0.909
  - Recall: 0.789
  - F1 Score: 0.845
- **Class 1**
  - Precision: 0.830
  - Recall: 0.929
  - F1 Score: 0.876

Average Precision: 0.869
Average Recall: 0.859
Average F1 Score: 0.861

2.2.3.2 b. Diff Cov. Matrix for each class Confusion Matrix:



Train Dataset



Test Dataset

For the test dataset:

- **Class 0**
  - Precision: 0.909
  - Recall: 0.789
  - F1 Score: 0.845
- **Class 1**
  - Precision: 0.830
  - Recall: 0.929
  - F1 Score: 0.876

Average Precision: 0.869
Average Recall: 0.859
Average F1 Score: 0.861

2.3 Naive-Bayes classifier with a Gaussian distribution for every class

2.3.1 Accuracy for same covariance matrices for all the classes

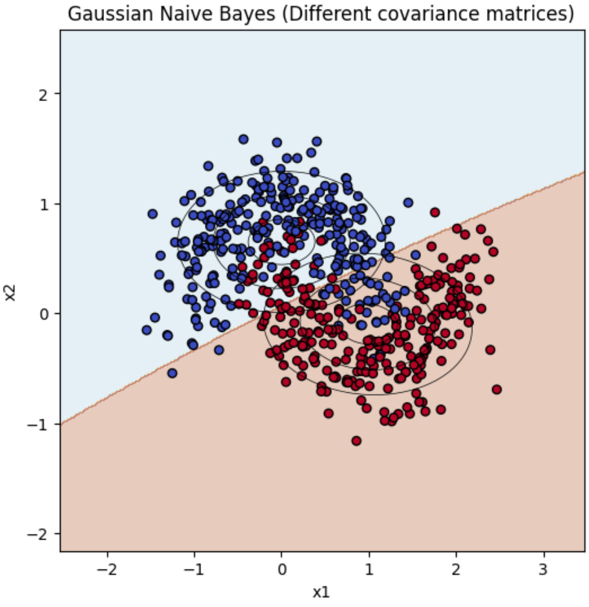
Train Accuracy	Validation Accuracy	Test Accuracy
84.5	85.5	86.2

2.3.2 Accuracy for different covariance matrices

Train Accuracy	Validation Accuracy	Test Accuracy
85.0	85.5	86.2

We see that both the models perform equally good, but the model with different covariance matrices for different classes has a better fit on training data. So let us choose the model with different covariance matrices for different classes as the best model.

2.3.3 Decision Region of Best Model

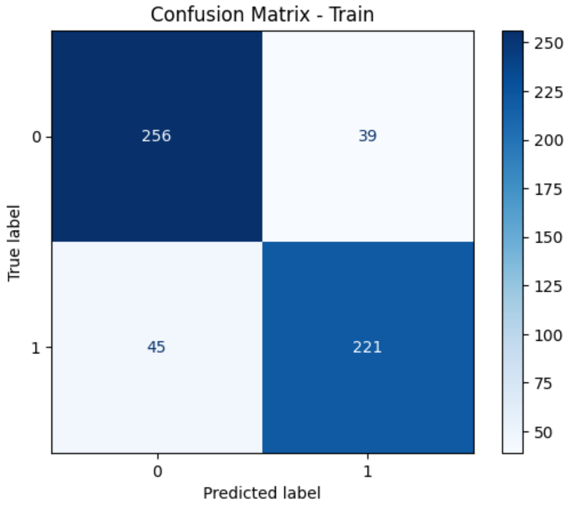


2.3.4 Performance Metrics

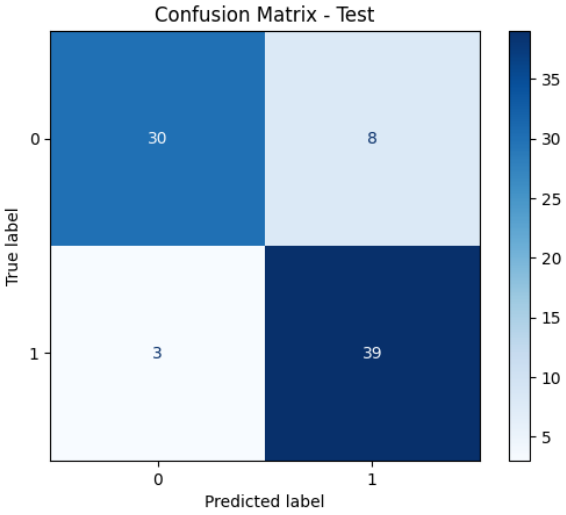
Accuracy for best performing model (different covariance matrices):

Train Data Accuracy: 85%
Validation Data Accuracy: 85.5%
Test Data Accuracy: 86.2%

Confusion Matrix:



Train Dataset



Test Dataset

For the test dataset predictions:

- Class 0
  - Precision: 0.91
  - Recall: 0.79
  - F1 Score: 0.84
- Class 1
  - Precision: 0.83
  - Recall: 0.86
  - F1 Score: 0.86

Average Precision: 0.87
Average Recall: 0.86
Average F1 Score: 0.86

2.4 GMM based classifier

2.4.1 Accuracy with Q = 4

Covariance_type	Train Accuracy	Validation Accuracy	Test Accuracy
Full cov	93.4	95.0	97.5
Diag cov	92.5	94.3	97.5

2.4.2 Accuracy with Q = 6

Covariance_type	Train Accuracy	Validation Accuracy	Test Accuracy
Full cov	93.9	95.0	97.5
Diag cov	92.5	94.3	97.5

2.4.3 Accuracy with Q = 8

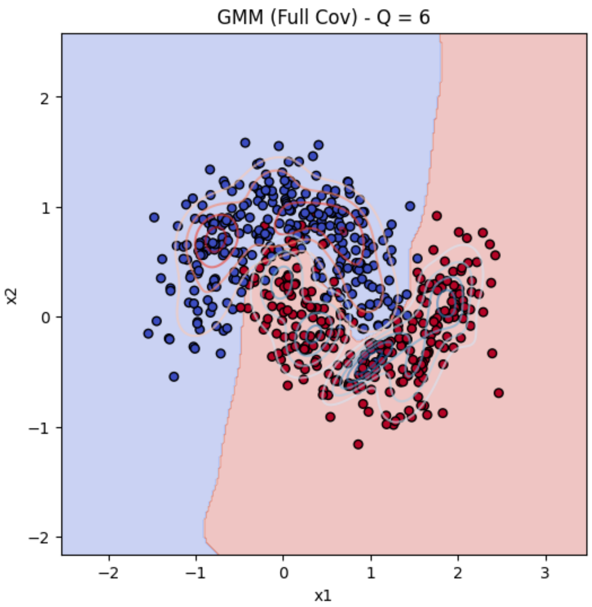
Covariance_type	Train Accuracy	Validation Accuracy	Test Accuracy
Full cov	93.8	94.3	97.5
Diag cov	92.5	94.3	97.5

2.4.4 Accuracy with Q = 10

Covariance_type	Train Accuracy	Validation Accuracy	Test Accuracy
Full cov	93.8	95.0	97.5
Diag cov	92.5	94.3	97.5

We see that the best fit for the data is obtained for Q = 6 (covariance_type = 'full') model, although all the model perform more or less equally better, this model is slightly best among them.

2.4.5 Decision Region of Best Model

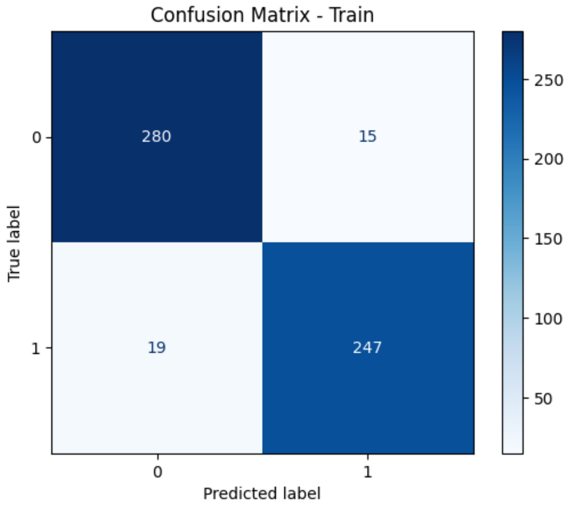


2.4.6 Performance Metrics

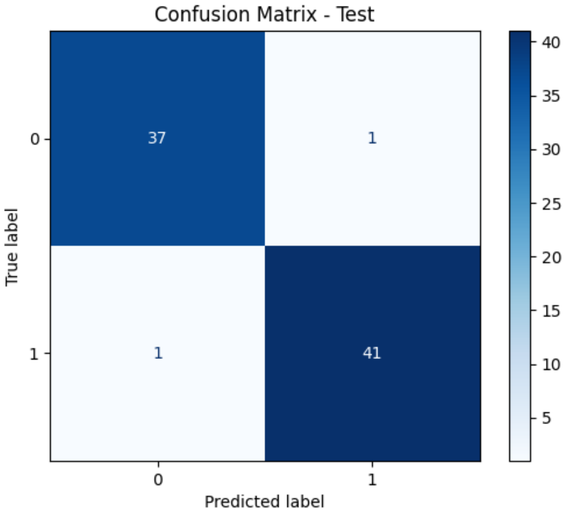
Accuracy for best performing model:

Train Data Accuracy: 93.9%
Validation Data Accuracy: 95.0%
Test Data Accuracy: 97.5%

Confusion Matrix:



Train Dataset



Test Dataset

For the test dataset predictions:

- Class 0

  - Precision: 0.974
  - Recall: 0.974
  - F1 Score: 0.974

- Class 1
  - Precision: 0.976
  - Recall: 0.976
  - F1 Score: 0.976

Average Precision: 0.975
Average Recall: 0.975
Average F1 Score: 0.975

3 Dataset 3

Image data set (Dimension of feature vector: 36) for 5 classes

3.1 K-Nearest Neighbours Classifier

K	Train Accuracy	Validation Accuracy	Test Accuracy
1	100.00	41.40	44.40
9	66.95	45.00	49.80
15	61.50	48.60	49.40

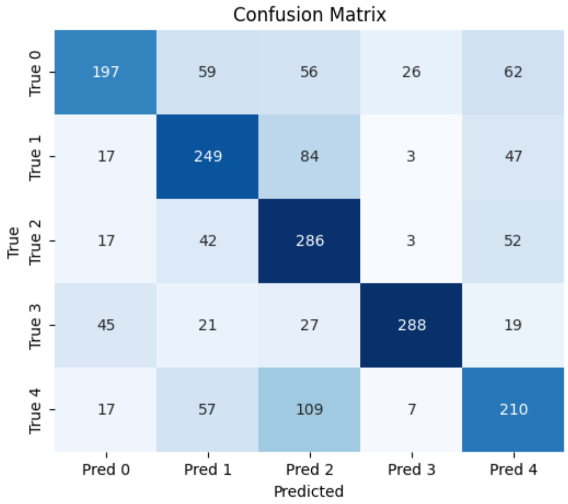
We see that the best fit for the data is obtained for k = 15 model, it gives the best performance (most accuracy in test data).

3.1.1 Performance Metrics

Accuracy for best performing model (k = 15):

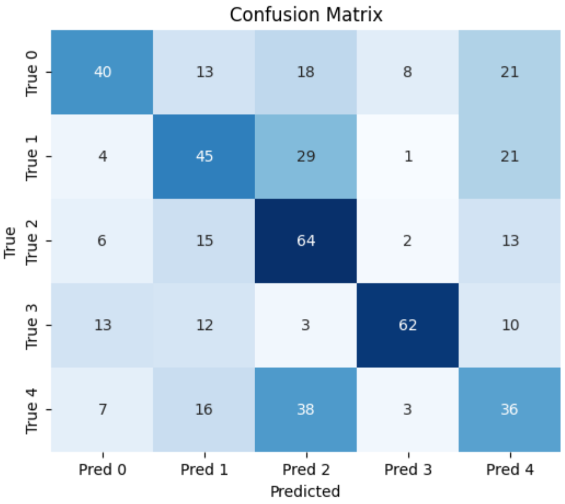
Train Data Accuracy: 48.60%
Test Data Accuracy: 49.40%

Confusion Matrix:



	Pred 0	Pred 1	Pred 2	Pred 3	Pred 4
True 0	197	59	56	26	62
True 1	17	249	84	3	47
True 2	17	42	286	3	52
True 3	45	21	27	288	19
True 4	17	57	109	7	210

Train Dataset



	Pred 0	Pred 1	Pred 2	Pred 3	Pred 4
True 0	40	13	18	8	21
True 1	4	45	29	1	21
True 2	6	15	64	2	13
True 3	13	12	3	62	10
True 4	7	16	38	3	36

Test Dataset

For the test dataset predictions:

- **Class 0**
  - Precision: 0.571
  - Recall: 0.400
  - F1 Score: 0.471

- **Class 1**
  - Precision: 0.446
  - Recall: 0.450
  - F1 Score: 0.448
- **Class 2**
  - Precision: 0.421
  - Recall: 0.640
  - F1 Score: 0.508
- **Class 3**
  - Precision: 0.816
  - Recall: 0.620
  - F1 Score: 0.705
- **Class 4**
  - Precision: 0.356
  - Recall: 0.360
  - F1 Score: 0.358

Average Precision: 0.522
Average Recall: 0.494
Average F1 Score: 0.498

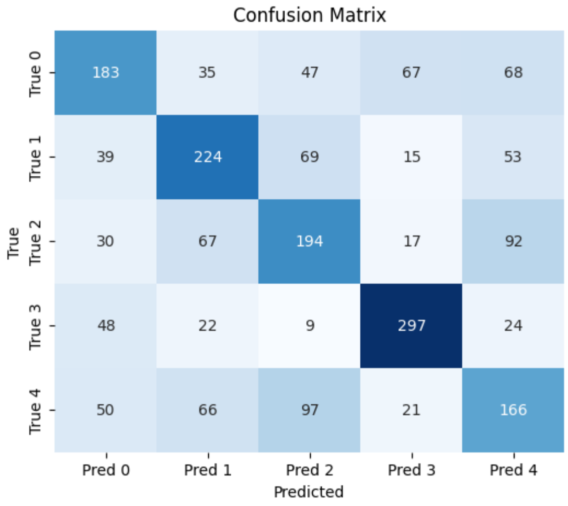
3.2 Bayes Classifier - Gaussian

3.2.1 Accuracy of each model

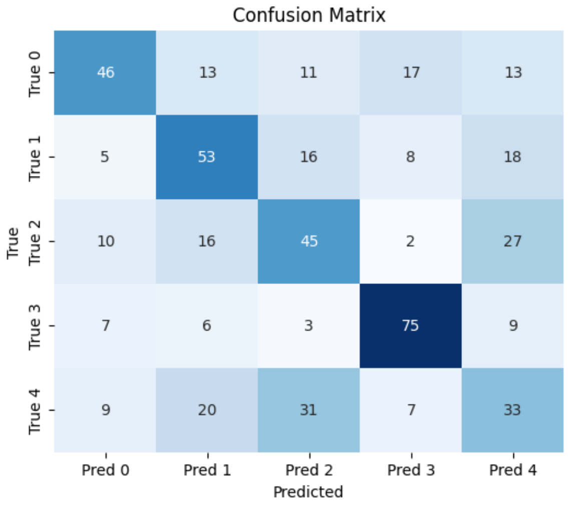
Type	Train Accuracy	Validation Accuracy	Test Accuracy
Same Cov. Matrix	53.20	49.00	50.40
Diff. Cov. Matrix	62.45	41.80	41.00

3.2.2 Performance Metrics

3.2.2.1 a. Same Cov. Matrix for all classes Confusion Matrix:



Train Dataset



Test Dataset

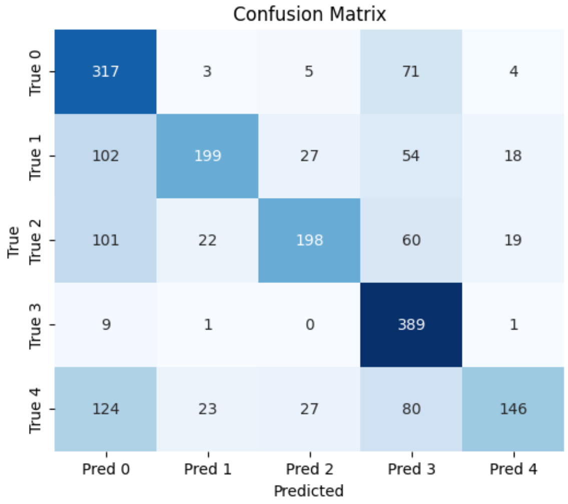
For the test dataset:

- **Class 0**
  - Precision: 0.597
  - Recall: 0.460
  - F1 Score: 0.520
- **Class 1**
  - Precision: 0.491
  - Recall: 0.530
  - F1 Score: 0.510
- **Class 2**
  - Precision: 0.425
  - Recall: 0.450
  - F1 Score: 0.437

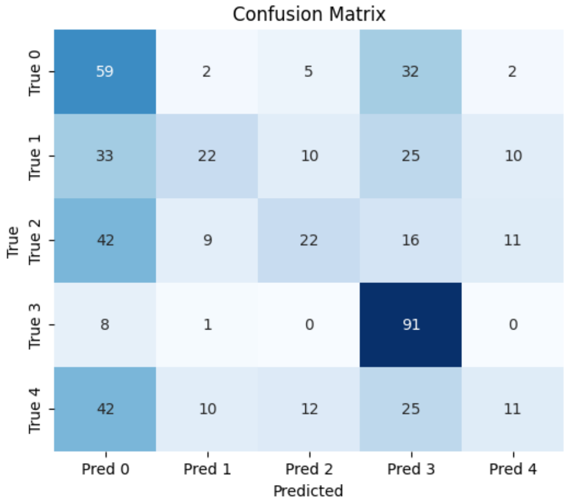
- **Class 3**
  - Precision: 0.688
  - Recall: 0.750
  - F1 Score: 0.718
- **Class 4**
  - Precision: 0.330
  - Recall: 0.330
  - F1 Score: 0.330

Average Precision: 0.506
Average Recall: 0.504
Average F1 Score: 0.503

3.2.2.2 b. Diff Cov. Matrix for each class Confusion Matrix:



Train Dataset



Test Dataset

For the test dataset:

- **Class 0**
  - Precision: 0.321
  - Recall: 0.590
  - F1 Score: 0.415
- **Class 1**
  - Precision: 0.500
  - Recall: 0.220
  - F1 Score: 0.306
- **Class 2**

  - Precision: 0.449
  - Recall: 0.220
  - F1 Score: 0.295

- **Class 3**
  - Precision: 0.481
  - Recall: 0.910
  - F1 Score: 0.630

- **Class 4**
  - Precision: 0.324
  - Recall: 0.110
  - F1 Score: 0.164

Average Precision: 0.415
Average Recall: 0.410
Average F1 Score: 0.362

3.3 Naive-Bayes classifier with a Gaussian distribution for every class

3.3.1 Accuracy for same covariance matrices for all the classes

Train Accuracy	Validation Accuracy	Test Accuracy
53.4	47.4	49.8

3.3.2 Accuracy for different covariance matrices

Train Accuracy	Validation Accuracy	Test Accuracy
73.0	46.6	51.4

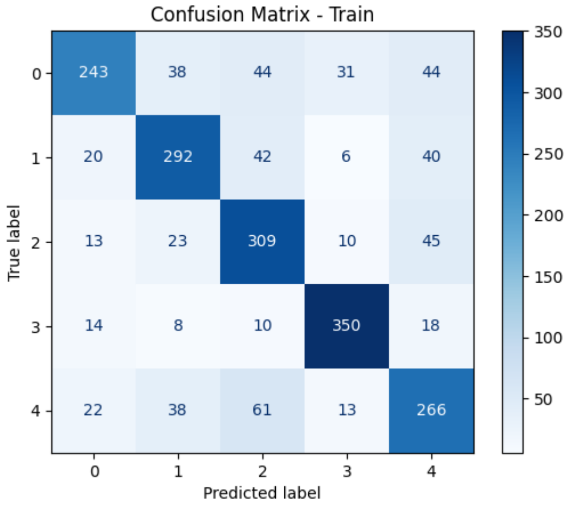
We see that model with different covariance matrices for different classes has a better accuracy on testing data with less difference in validation accuracy with that of other one, and also fits the training data better. So let us choose the model with different covariance matrices for different classes as the best model.

3.3.3 Performance Metrics

Accuracy for best performing model (different covariance matrices):

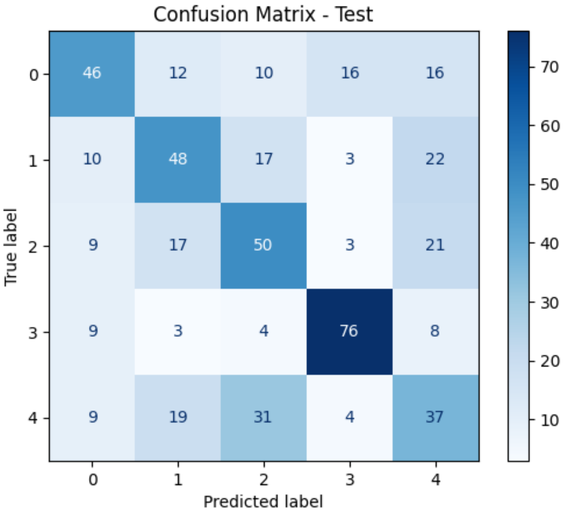
Train Data Accuracy: 73%
Validation Data Accuracy: 46.6%
Test Data Accuracy: 51.4%

Confusion Matrix:



True label \ Predicted label	0	1	2	3	4
0	243	38	44	31	44
1	20	292	42	6	40
2	13	23	309	10	45
3	14	8	10	350	18
4	22	38	61	13	266

Train Dataset



True label \ Predicted label	0	1	2	3	4
0	46	12	10	16	16
1	10	48	17	3	22
2	9	17	50	3	21
3	9	3	4	76	8
4	9	19	31	4	37

Test Dataset

For the test dataset predictions:

- Class 0
  - Precision: 0.554
  - Recall: 0.46
  - F1 Score: 0.50
- Class 1
  - Precision: 0.485
  - Recall: 0.48
  - F1 Score: 0.482
- Class 2
  - Precision: 0.446
  - Recall: 0.5
  - F1 Score: 0.472
- Class 3
  - Precision: 0.745
  - Recall: 0.76
  - F1 Score: 0.752
- Class 4
  - Precision: 0.356
  - Recall: 0.37
  - F1 Score: 0.363

Average Precision: 0.52
Average Recall: 0.51
Average F1 Score: 0.51

3.4 GMM based classifier

3.4.1 Accuracy with Q = 2

Covariance_type	Train Accuracy	Validation Accuracy	Test Accuracy
Full cov	85.2	47.2	49.0
Diag cov	54.4	49.6	46.0

3.4.2 Accuracy with Q = 3

Covariance_type	Train Accuracy	Validation Accuracy	Test Accuracy
Full cov	92.1	44.4	44.8
Diag cov	54.4	49.6	46.0

3.4.3 Accuracy with Q = 4

Covariance_type	Train Accuracy	Validation Accuracy	Test Accuracy
Full cov	95.4	45.8	44.6
Diag cov	54.4	49.6	46.0

3.4.4 Accuracy with Q = 5

Covariance_type	Train Accuracy	Validation Accuracy	Test Accuracy
Full cov	97.8	41.6	40.8
Diag cov	54.4	49.6	46.0

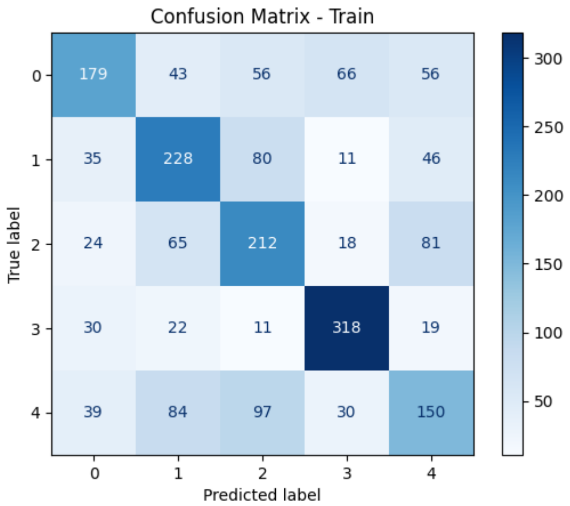
We see that all the models with (covariance type : diagonal) perform equally good (from validation data accuracy). Among them, we can choose any one, We choose the model for Q = 2 (covariance_type = 'diag').

3.4.5 Performance Metrics

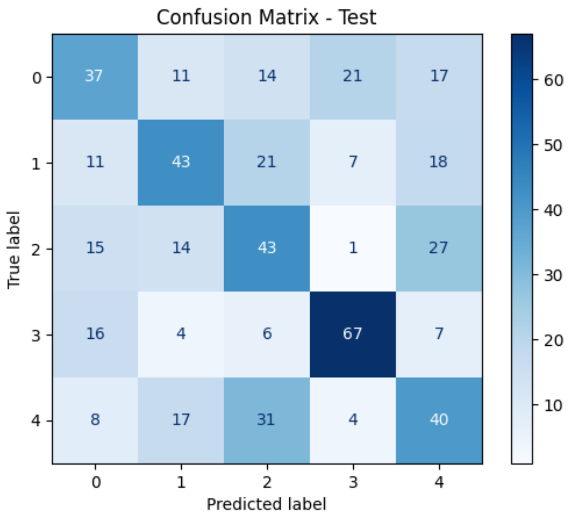
Accuracy for best performing model:

Train Data Accuracy: 54.4%
Validation Data Accuracy: 49.6%
Test Data Accuracy: 46%

Confusion Matrix:



Train Dataset



Test Dataset

For the test dataset predictions:

- Class 0
  - Precision: 0.425
  - Recall: 0.37
  - F1 Score: 0.96
- Class 1
  - Precision: 0.483
  - Recall: 0.43
  - F1 Score: 0.455
- Class 2
  - Precision: 0.374
  - Recall: 0.43
  - F1 Score: 0.4
- Class 3
  - Precision: 0.67
  - Recall: 0.67
  - F1 Score: 0.67
- Class 4
  - Precision: 0.37
  - Recall: 0.4
  - F1 Score: 0.38

Average Precision: 0.464
Average Recall: 0.46
Average F1 Score: 0.461