Assignment-2 Report

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1 Dataset 1

1.1 KNN Classifier

1.1.1 K = 1

Table 1: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
1.0	0.9875	0.9916666666666667

1.1.2 K = 5

Table 2: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
0.9857142857142858	0.9875	0.9916666666666667

1.1.3 K = 9

Table 3: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
0.986904761904762	0.9875	0.9833333333333333

Conclusion: Since the validation accuracy values for all models are the same, let us use the training accuracy values to select the best model. So, based on the training accuracy values, the best configuration for the model is achieved for $K = 1$.

Table 4: Confusion matrix for the best configuration of the model on training and test data

Training Data	Test Data
$\begin{pmatrix} 280 & 0 & 0 \\ 0 & 274 & 0 \\ 0 & 0 & 286 \end{pmatrix}$	$\begin{pmatrix} 47 & 0 & 0 \\ 0 & 40 & 1 \\ 0 & 0 & 32 \end{pmatrix}$

Table 5: Precision, Recall, and F1 scores for training data

	Class 0	Class 1	Class 2
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F1	1.0	1.0	1.0

Table 6: Precision, Recall, and F1 scores for validation data

	Class 0	Class 1	Class 2
Precision	1.0	1.0	0.9647058823529412
Recall	0.9863013698630136	0.9764705882352941	1.0
F1	0.993103448275862	0.988095238095238	0.9820359281437125

Table 7: Precision, Recall, and F1 scores for test data

	Class 0	Class 1	Class 2
Precision	1.0	1.0	0.9696969696969697
Recall	1.0	0.975609756097561	1.0
F1	1.0	0.9876543209876543	0.9846153846153847

Table 8: Average Precision, Recall and F1 scores for Training, Validation, and Test data

	Average Precision	Average Recall	Average F1
Training	1.0	1.0	1.0
Validation	0.9882352941176471	0.9875906526994359	0.9877448715049374
Test	0.98989898989899	0.991869918699187	0.9907565685343463

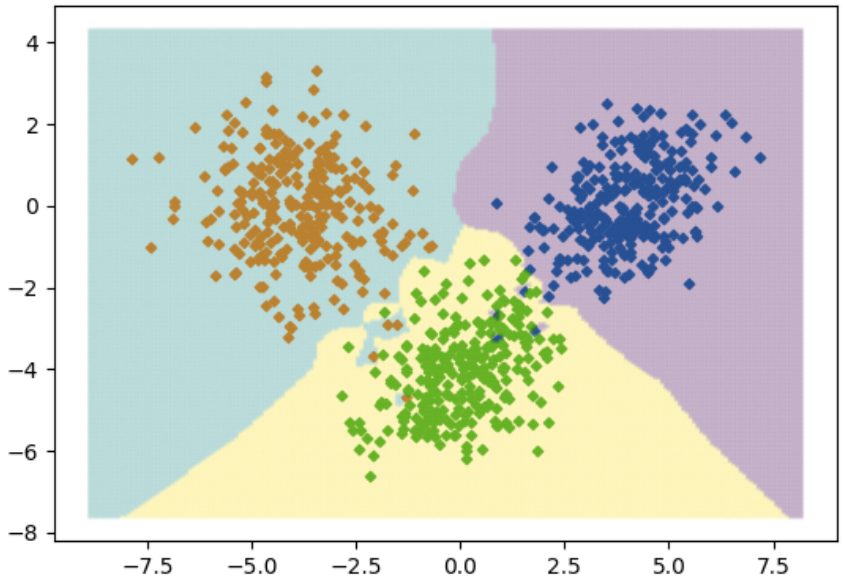

Figure 1: Decision Region Plot

1.2 Bayes Classifier

1.2.1 Covariance matrices for all the classes are the same

Table 9: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
0.9845238095238096	0.9833333333333333	0.9833333333333333

Table 10: Confusion matrix for training and test data

Training Data	Test Data
$\begin{pmatrix} 275 & 0 & 5 \\ 0 & 267 & 7 \\ 1 & 0 & 285 \end{pmatrix}$	$\begin{pmatrix} 47 & 0 & 0 \\ 0 & 39 & 2 \\ 0 & 0 & 32 \end{pmatrix}$

Table 11: Precision, Recall, and F1 scores for training data

	Class 0	Class 1	Class 2
Precision	0.9963768115942029	1.0	0.9595959595959596
Recall	0.9821428571428571	0.9744525547445255	0.9965034965034965
F1	0.9892086330935251	0.9870609981515711	0.9777015437392795

Table 12: Precision, Recall, and F1 scores for validation data

	Class 0	Class 1	Class 2
Precision	1.0	1.0	0.9534883720930233
Recall	0.9863013698630136	0.9647058823529412	1.0
F1	0.993103448275862	0.9820359281437125	0.9761904761904763

Table 13: Precision, Recall, and F1 scores for test data

	Class 0	Class 1	Class 2
Precision	1.0	1.0	0.9411764705882353
Recall	1.0	0.9512195121951219	1.0
F1	1.0	0.975	0.9696969696969697

Table 14: Average Precision, Recall and F1 scores for Training, Validation, and Test data

	Average Precision	Average Recall	Average F1
Training	0.9853242570633874	0.9843663027969596	0.9846570583281252
Validation	0.9844961240310077	0.983669084071985	0.9837766175366837
Test	0.9803921568627452	0.983739837398374	0.9815656565656566

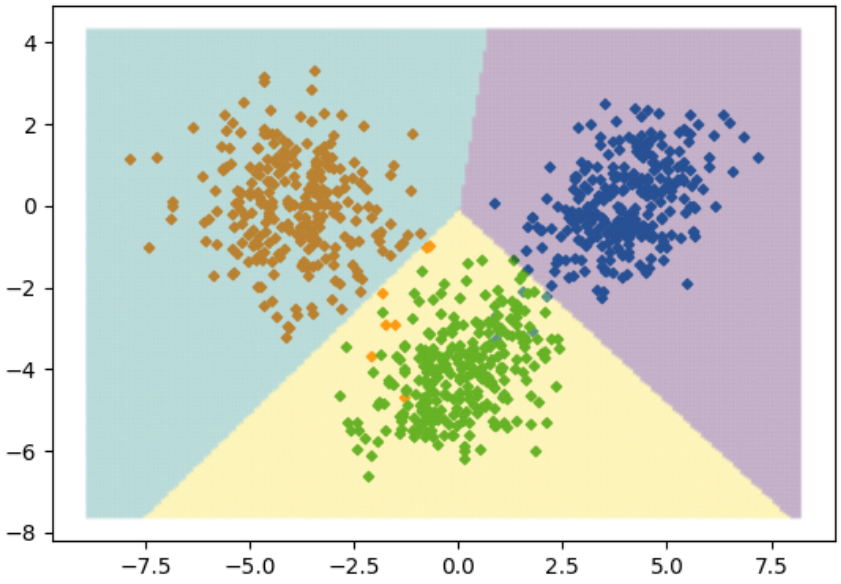

Figure 2: Decision Region Plot

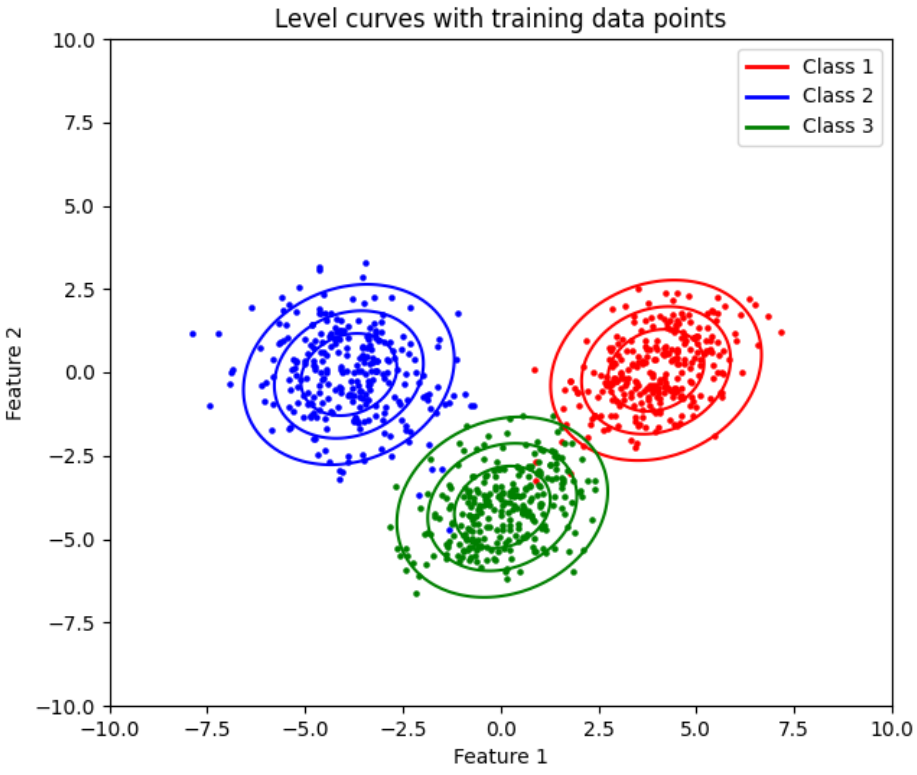

Figure 3: Level Curves Plot

1.2.2 Covariance matrices are different

Table 15: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
0.9833333333333333	0.9916666666666667	0.9916666666666667

Table 16: Confusion matrix for training and test data

Training Data	Test Data
$\begin{pmatrix} 275 & 0 & 5 \\ 0 & 270 & 4 \\ 2 & 3 & 281 \end{pmatrix}$	$\begin{pmatrix} 47 & 0 & 0 \\ 0 & 40 & 1 \\ 0 & 0 & 32 \end{pmatrix}$

Table 17: Precision, Recall, and F1 scores for training data

	Class 0	Class 1	Class 2
Precision	0.9927797833935018	0.989010989010989	0.9689655172413794
Recall	0.9821428571428571	0.9854014598540146	0.9825174825174825
F1	0.9874326750448832	0.9872029250457038	0.9756944444444444

Table 18: Precision, Recall, and F1 scores for validation data

	Class 0	Class 1	Class 2
Precision	1.0	1.0	0.9761904761904762
Recall	0.9863013698630136	0.9882352941176471	1.0
F1	0.993103448275862	0.9940828402366864	0.9879518072289156

Table 19: Precision, Recall, and F1 scores for test data

	Class 0	Class 1	Class 2
Precision	1.0	1.0	0.9696969696969697
Recall	1.0	0.975609756097561	1.0
F1	1.0	0.9876543209876543	0.9846153846153847

Table 20: Average Precision, Recall and F1 scores for Training, Validation, and Test data

	Average Precision	Average Recall	Average F1
Training	0.9835854298819567	0.9833539331714514	0.9834433481783439
Validation	0.9920634920634921	0.9915122213268869	0.9917126985804879
Test	0.98989898989899	0.991869918699187	0.9907565685343463

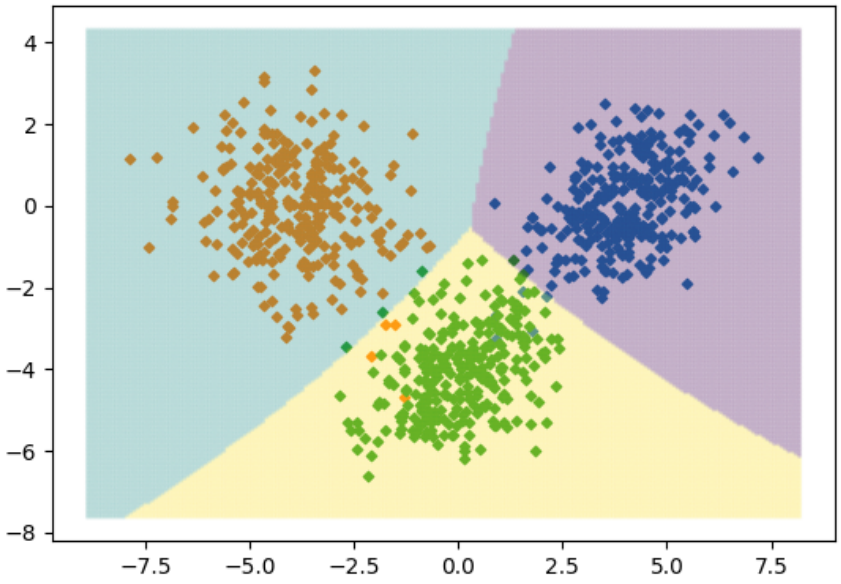

Figure 4: Decision Region Plot

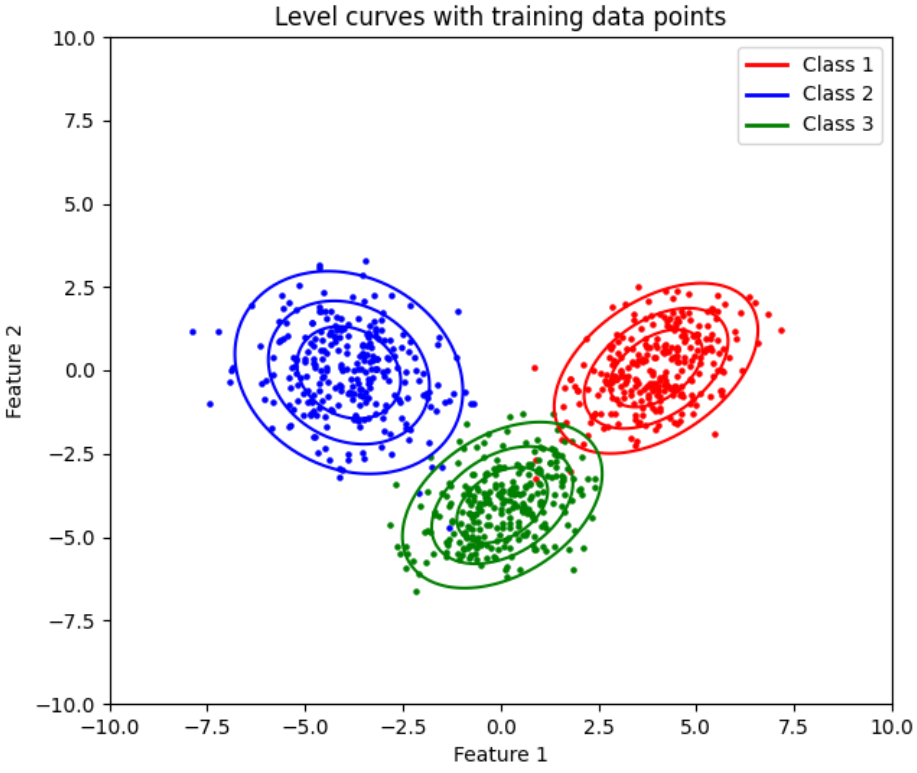

Figure 5: Level Curves Plot

2 Dataset 2

2.1 KNN Classifier

2.1.1 K = 1

Table 21: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
1.0	0.9119496855345912	0.975

2.1.2 K = 5

Table 22: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
0.9625668449197861	0.9371069182389937	0.9875

2.1.3 K = 9

Table 23: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
0.9572192513368984	0.9308176100628931	0.975

Conclusion: Based on the validation accuracy values, the best model for this classifier is achieved for $K = 5$.

Table 24: Confusion matrix for the best configuration of the model on training and test data

Training Data	Test Data
$\begin{pmatrix} 273 & 11 \\ 10 & 267 \end{pmatrix}$	$\begin{pmatrix} 34 & 0 \\ 1 & 45 \end{pmatrix}$

Table 25: Precision, Recall, and F1 scores for training data

	Class 0	Class 1
Precision	0.9646643109540636	0.960431654676259
Recall	0.9612676056338029	0.9638989169675091
F1	0.962962962962963	0.9621621621621621

Table 26: Precision, Recall, and F1 scores for validation data

	Class 0	Class 1
Precision	0.9186046511627907	0.958904109589041
Recall	0.9634146341463414	0.9090909090909091
F1	0.9404761904761905	0.9333333333333333

Table 27: Precision, Recall, and F1 scores for test data

	Class 0	Class 1
Precision	0.9714285714285714	1.0
Recall	1.0	0.9782608695652174
F1	0.9855072463768115	0.989010989010989

Table 28: Average Precision, Recall and F1 scores for Training, Validation, and Test data

	Average Precision	Average Recall	Average F1
Training	0.9625479828151613	0.962583261300656	0.9625625625625626
Validation	0.9387543803759159	0.9362527716186253	0.9369047619047619
Test	0.9857142857142858	0.9891304347826086	0.9872591176939003

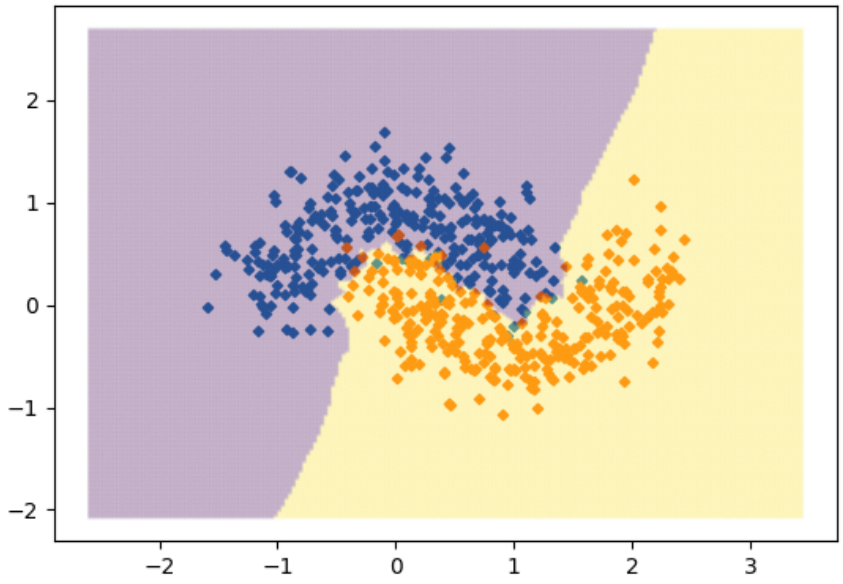

Figure 6: Decision Region Plot

2.2 Bayes Classifier

2.2.1 Covariance matrices for all the classes are the same

Table 29: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
0.8663101604278075	0.8238993710691824	0.9

Table 30: Confusion matrix for training and test data

Training Data	Test Data
$\begin{pmatrix} 249 & 35 \\ 40 & 237 \end{pmatrix}$	$\begin{pmatrix} 30 & 4 \\ 4 & 42 \end{pmatrix}$

Table 31: Precision, Recall, and F1 scores for training data

	Class 0	Class 1
Precision	0.8615916955017301	0.8713235294117647
Recall	0.8767605633802817	0.855595667870036
F1	0.8691099476439791	0.8633879781420765

Table 32: Precision, Recall, and F1 scores for validation data

	Class 0	Class 1
Precision	0.8375	0.810126582278481
Recall	0.8170731707317073	0.8311688311688312
F1	0.8271604938271605	0.8205128205128205

Table 33: Precision, Recall, and F1 scores for test data

	Class 0	Class 1
Precision	0.8823529411764706	0.9130434782608695
Recall	0.8823529411764706	0.9130434782608695
F1	0.8823529411764706	0.9130434782608695

Table 34: Average Precision, Recall and F1 scores for Training, Validation, and Test data

	Average Precision	Average Recall	Average F1
Training	0.8664576124567474	0.8661781156251589	0.8662489628930278
Validation	0.8238132911392405	0.8241210009502693	0.8238366571699904
Test	0.8976982097186701	0.8976982097186701	0.8976982097186701

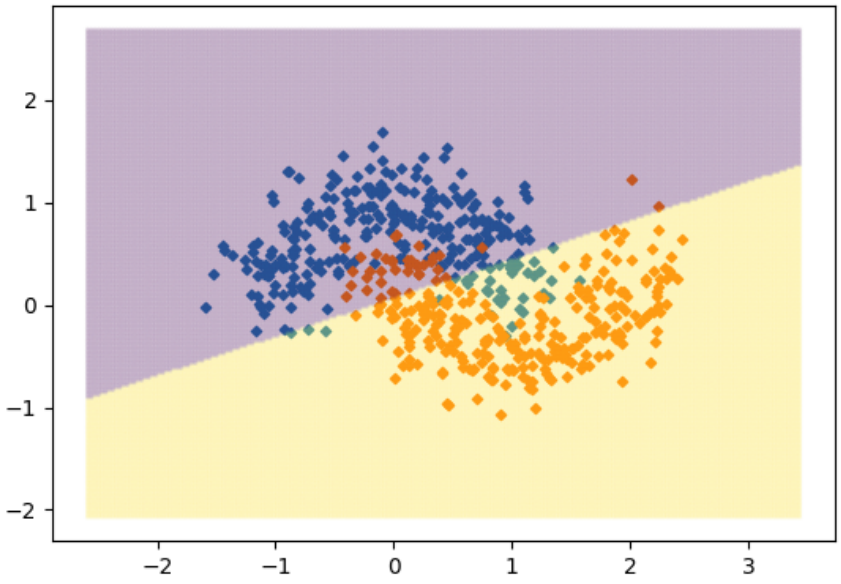

Figure 7: Decision Region Plot

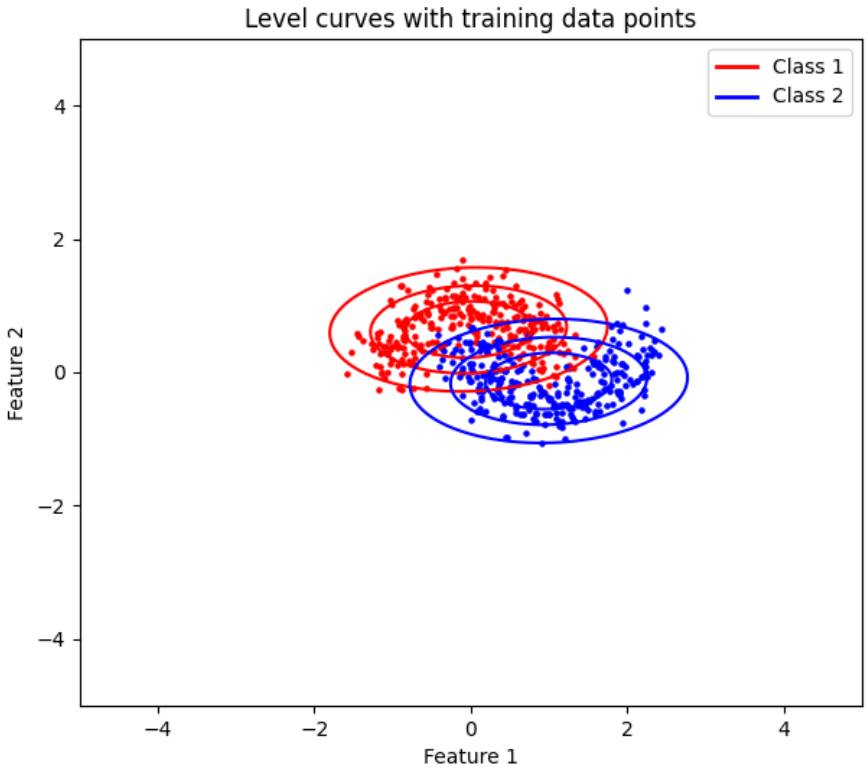

Figure 8: Level Curves Plot

2.2.2 Covariance matrices are different

Table 35: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
0.8645276292335116	0.8238993710691824	0.9

Table 36: Confusion matrix for training and test data

Training Data	Test Data
$\begin{pmatrix} 247 & 37 \\ 39 & 238 \end{pmatrix}$	$\begin{pmatrix} 30 & 4 \\ 4 & 42 \end{pmatrix}$

Table 37: Precision, Recall, and F1 scores for training data

	Class 0	Class 1
Precision	0.8636363636363636	0.8654545454545455
Recall	0.8636363636363636	0.8654545454545455
F1	0.8666666666666667	0.8623188405797101

Table 38: Precision, Recall, and F1 scores for validation data

	Class 0	Class 1
Precision	0.8375	0.810126582278481
Recall	0.8170731707317073	0.8311688311688312
F1	0.8271604938271605	0.8205128205128205

Table 39: Precision, Recall, and F1 scores for test data

	Class 0	Class 1
Precision	0.8823529411764706	0.9130434782608695
Recall	0.8823529411764706	0.9130434782608695
F1	0.8823529411764706	0.9130434782608695

Table 40: Average Precision, Recall and F1 scores for Training, Validation, and Test data

	Average Precision	Average Recall	Average F1
Training	0.8645454545454545	0.86446204301622	0.8644927536231883
Validation	0.8238132911392405	0.8241210009502693	0.8238366571699904
Test	0.8976982097186701	0.8976982097186701	0.8976982097186701

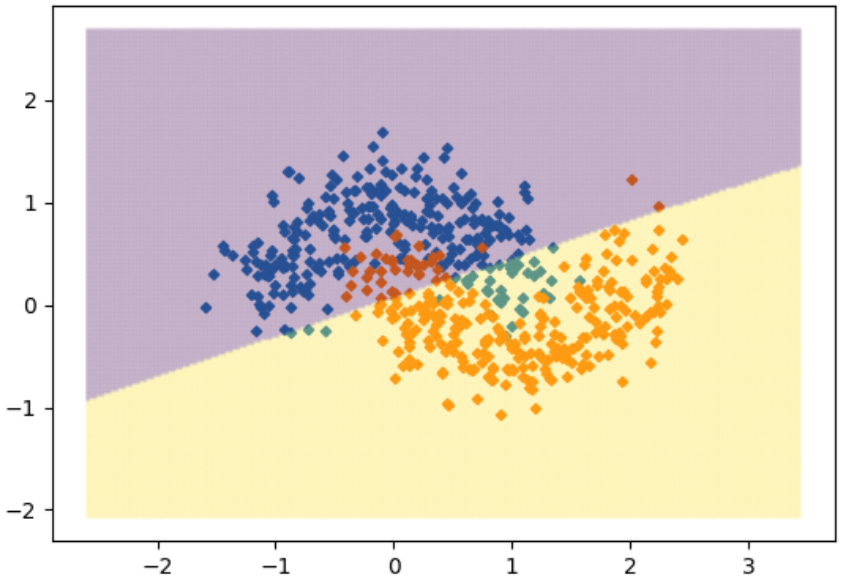

Figure 9: Decision Region Plot

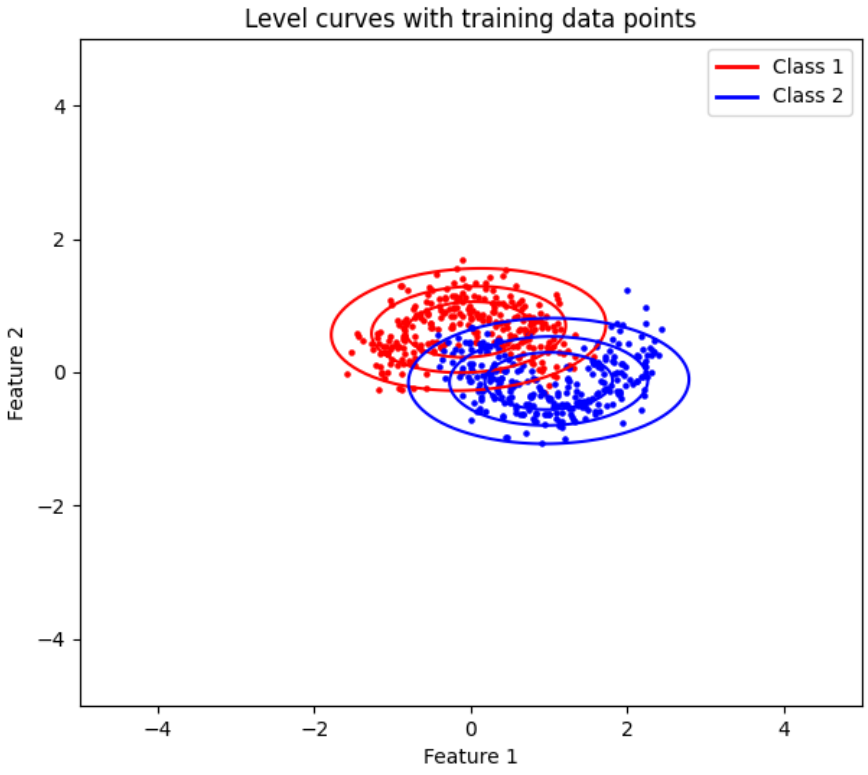

Figure 10: Level Curves Plot

2.3 Naive Bayes Classifier

2.3.1 Covariance matrices for all the classes are the same

Table 41: Classification accuracies on train, test, and validation data

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.87165775	0.9	0.82389937

Table 42: Confusion matrix for train and test data

Train Data	Test Data
$\begin{pmatrix} 251 & 33 \\ 39 & 238 \end{pmatrix}$	$\begin{pmatrix} 30 & 4 \\ 4 & 42 \end{pmatrix}$

Table 43: Precision, Recall and F1 scores for train data

	Precision	Recall	F1
Class 0	0.86551724	0.88380282	0.87456446
Class 1	0.87822878	0.85920578	0.86861314

Table 44: Precision, Recall and F1 scores for test data

	Precision	Recall	F1
Class 0	0.88235294	0.88235294	0.88235294
Class 1	0.91304348	0.91304348	0.91304348

Table 45: Precision, Recall and F1 scores for Validation data

	Precision	Recall	F1
Class 0	0.8375	0.81707317	0.82716049
Class 1	0.81012658	0.83116883	0.82051282

Table 46: Average Precision, Recall and F1 scores for Train, Test and Validation data

	Average Precision	Average Recall	Average F1
Train	0.87187301	0.87150429	0.87158879
Test	0.89769820	0.89769820	0.89769820
Validation	0.82381329	0.82412100	0.82383665

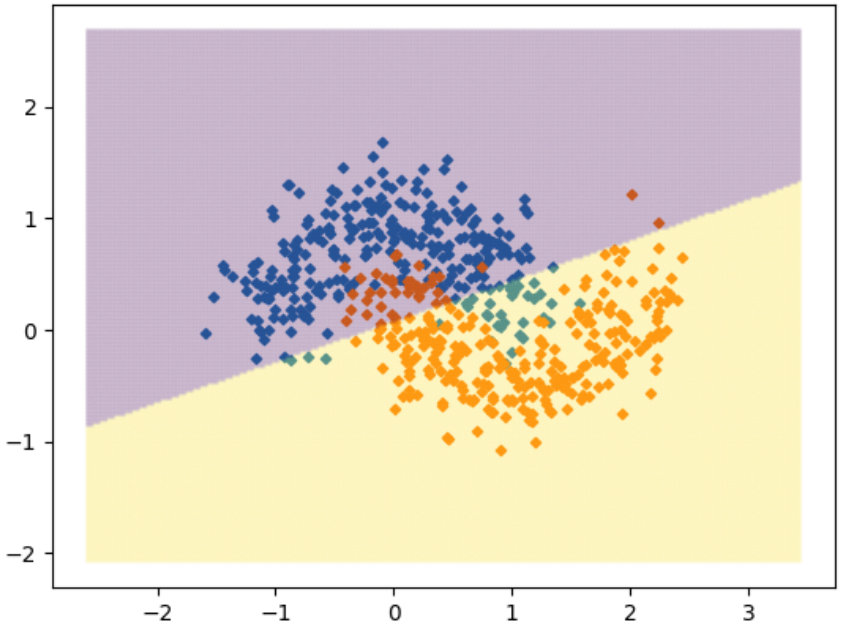

Figure 11: Decision Region Plot

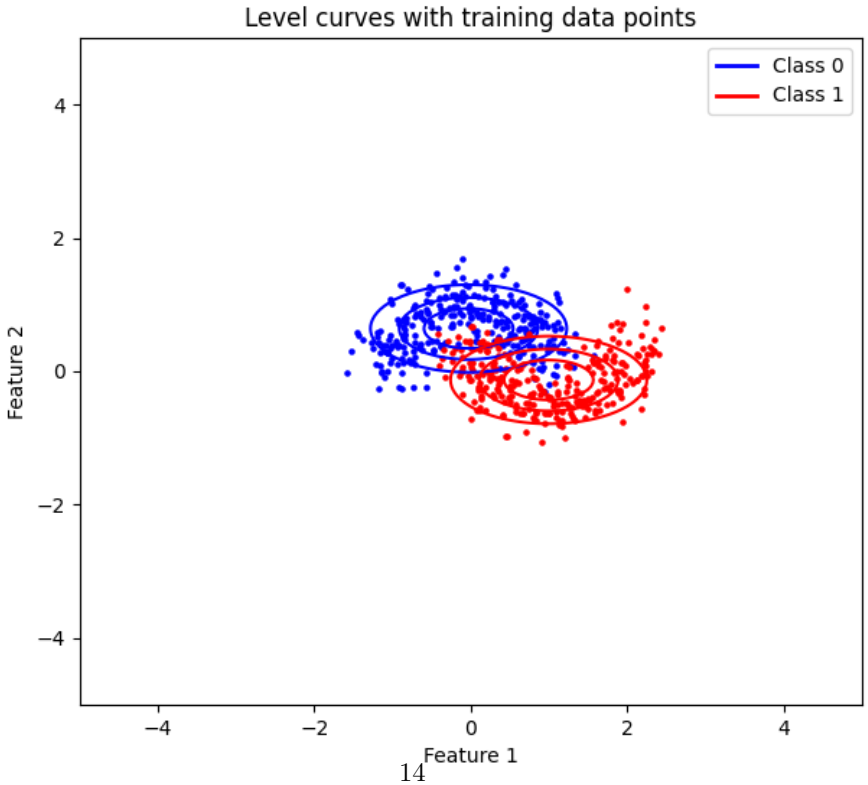

Figure 12: Level Curves Plot

2.3.2 Covariance matrices are different

Table 47: Classification accuracies on train, test, and validation data

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.86987522	0.9	0.82389937

Table 48: Confusion matrix for train and test data

Train Data	Test Data
$\begin{pmatrix} 250 & 34 \\ 39 & 238 \end{pmatrix}$	$\begin{pmatrix} 30 & 4 \\ 4 & 42 \end{pmatrix}$

Table 49: Precision, Recall and F1 scores for train data

	Precision	Recall	F1
Class 0	0.8650519	0.88028169	0.87260035
Class 1	0.875	0.85920578	0.86703097

Table 50: Precision, Recall and F1 scores for test data

	Precision	Recall	F1
Class 0	0.88235294	0.88235294	0.88235294
Class 1	0.91304348	0.91304348	0.91304348

Table 51: Precision, Recall and F1 scores for Validation data

	Precision	Recall	F1
Class 0	0.8375	0.81707317	0.82716049
Class 1	0.81012658	0.83116883	0.82051282

Table 52: Average Precision, Recall and F1 scores for Train, Test and Validation data

	Average Precision	Average Recall	Average F1
Train	0.87002595	0.86974373	0.86981565
Test	0.89769820	0.89769820	0.89769820
Validation	0.82381329	0.82412100	0.82383665

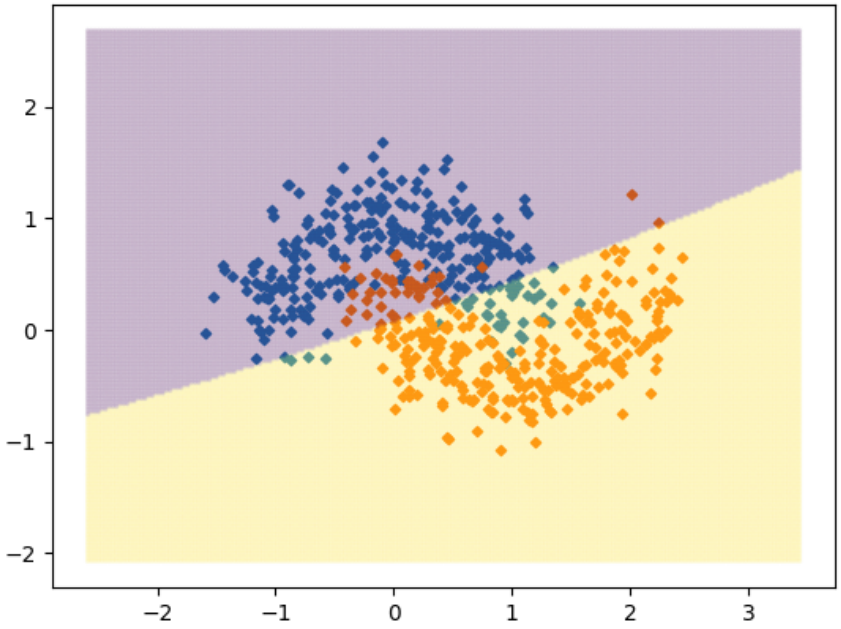

Figure 13: Decision Region Plot

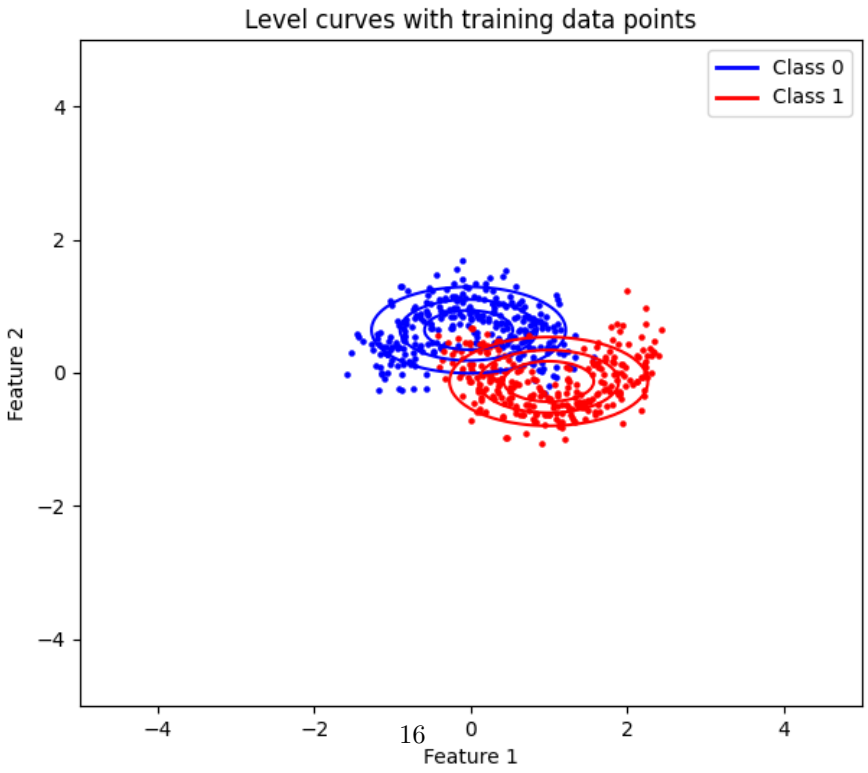

Figure 14: Level Curves Plot

2.4 GMM Classifier

2.4.1 Full covariance matrix

Table 53: Classification accuracies on train, test, and validation data for $Q = 4$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.95187165	0.975	0.93710691

Table 54: Classification accuracies on train, test, and validation data for $Q = 6$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.95721925	0.975	0.93710691

Table 55: Classification accuracies on train, test, and validation data for $Q = 8$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.96078431	0.975	0.93081761

Table 56: Classification accuracies on train, test, and validation data for $Q = 10$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.95900178	0.9625	0.94339622

Conclusion: Validation accuracy is highest for $Q = 10$ and is therefore the best configuration.

Table 57: Confusion matrix for train and test data for the best configuration($Q = 10$)

Train Data	Test Data
$\begin{pmatrix} 274 & 10 \\ 13 & 264 \end{pmatrix}$	$\begin{pmatrix} 33 & 1 \\ 2 & 44 \end{pmatrix}$

Table 58: Precision, Recall and F1 scores for train data for the best configuration($Q = 10$)

	Precision	Recall	F1
Class 0	0.95470383	0.96478873	0.95971979
Class 1	0.96350365	0.95306859	0.95825771

Table 59: Precision, Recall and F1 scores for test data for the best configuration($Q = 10$)

	Precision	Recall	F1
Class 0	0.94285714	0.97058824	0.95652174
Class 1	0.97777778	0.95652174	0.96703297

Table 60: Precision, Recall and F1 scores for Validation data for the best configuration($Q = 10$)

	Precision	Recall	F1
Class 0	0.92941176	0.96341463	0.94610778
Class 1	0.95945946	0.92207792	0.94039735

Table 61: Average Precision, Recall and F1 scores for Train, Test and Validation data for the best configuration($Q = 10$)

	Average Precision	Average Recall	Average F1
Train	0.95910374	0.95892866	0.95898875
Test	0.96031746	0.96355498	0.96177735
Validation	0.94443561	0.94274627	0.94325256

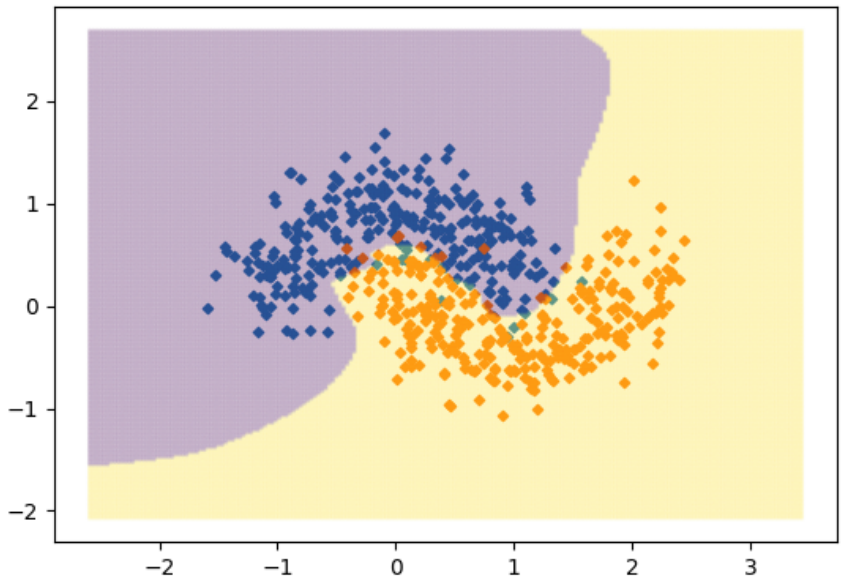

Figure 15: Decision Region Plot

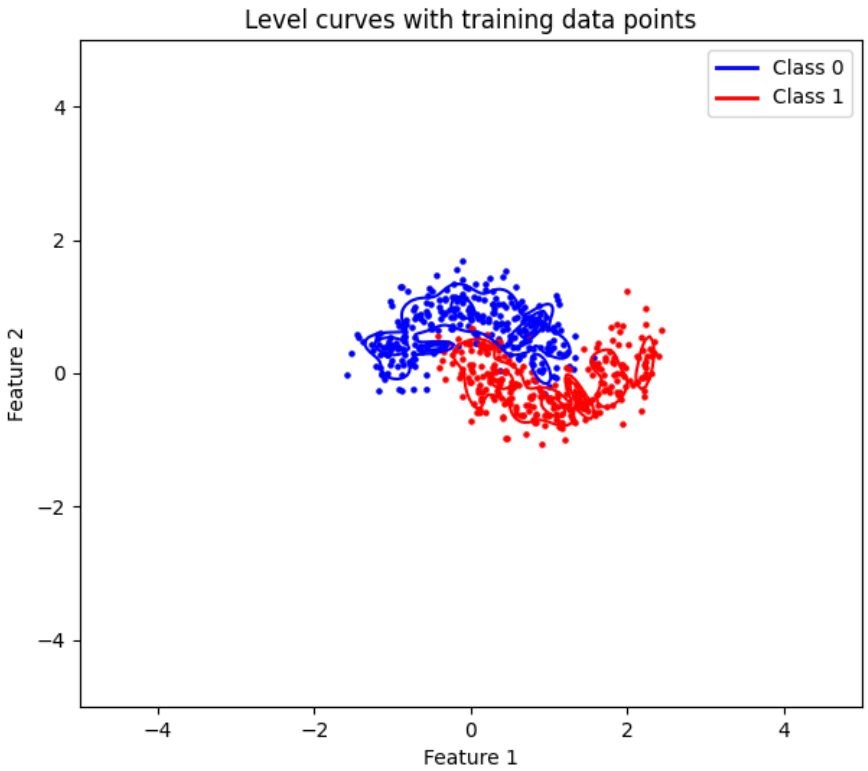

Figure 16: Level Curves Plot

2.4.2 Diagonal Covariance Matrix

Table 62: Classification accuracies on train, test, and validation data for $Q = 4$

Train Accuracy	Test Accuracy	Validation Accuracy
0.95187165	0.975	0.93081761

Table 63: Classification accuracies on train, test, and validation data for $Q = 6$

Train Accuracy	Test Accuracy	Validation Accuracy
0.95543672	0.975	0.93710691

Table 64: Classification accuracies on train, test, and validation data for $Q = 8$

Train Accuracy	Test Accuracy	Validation Accuracy
0.95543672	0.975	0.94339622

Table 65: Classification accuracies on train, test, and validation data for $Q = 10$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.95721925	0.9625	0.93081761

Conclusion: Validation accuracy is highest for $Q = 8$ and is therefore the best configuration.

Table 66: Confusion matrix for train and test data for the best configuration($Q = 8$)

Train Data	Test Data
$\begin{pmatrix} 272 & 12 \\ 13 & 264 \end{pmatrix}$	$\begin{pmatrix} 34 & 0 \\ 2 & 44 \end{pmatrix}$

Table 67: Precision, Recall and F1 scores for train data for the best configuration($Q = 8$)

	Precision	Recall	F1
Class 0	0.95438596	0.95774648	0.95606327
Class 1	0.95652174	0.95306859	0.95479204

Table 68: Precision, Recall and F1 scores for test data for the best configuration($Q = 8$)

	Precision	Recall	F1
Class 0	0.94444444	1	0.97142857
Class 1	1	0.95652174	0.97777778

Table 69: Precision, Recall and F1 scores for Validation data for the best configuration($Q = 8$)

	Precision	Recall	F1
Class 0	0.92941176	0.96341463	0.94610778
Class 1	0.95945946	0.92207792	0.94039735

Table 70: Average Precision, Recall and F1 scores for Train, Test and Validation data for the best configuration($Q = 8$)

	Average Precision	Average Recall	Average F1
Train	0.95545385	0.95540753	0.95542765
Test	0.97222222	0.97826086	0.97460317
Validation	0.94443561	0.94274627	0.94325256

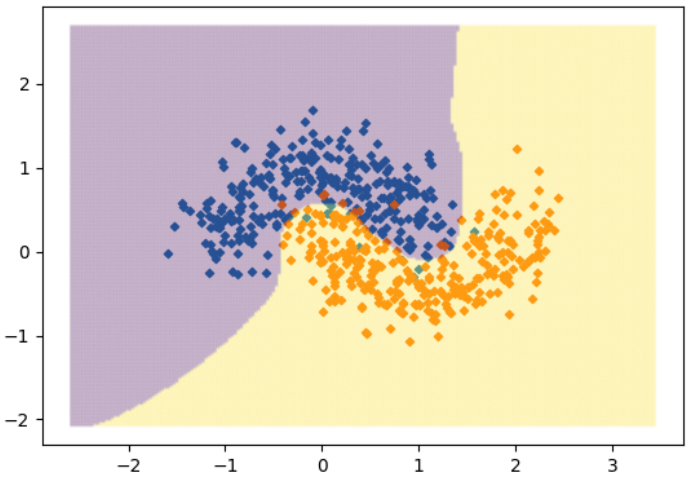

Figure 17: Decision Region Plot

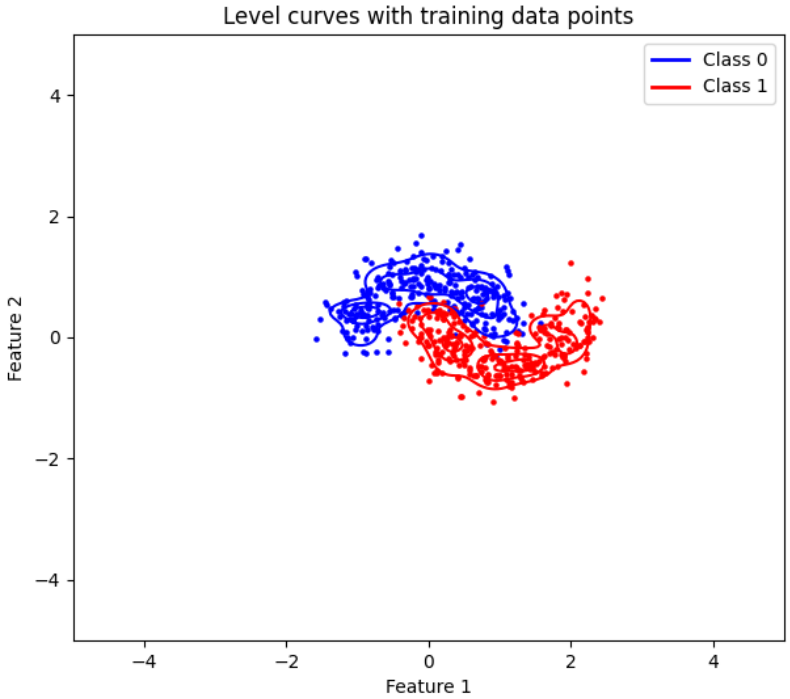

Figure 18: Level Curves Plot

3 Dataset 3

3.1 KNN Classifier

3.1.1 K = 1

3.1.2 K = 9

3.1.3 K = 15

Conclusion: Based on the validation accuracy values, the best model for this classifier is achieved for $K = 15$.

Table 71: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
1.0	0.466	0.488

Table 72: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
0.6865	0.538	0.536

Table 73: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
0.6395	0.548	0.53

Table 74: Confusion matrix for the best configuration of the model on training and test data

Training Data	Test Data
$\begin{pmatrix} 292 & 11 & 19 & 49 & 29 \\ 93 & 146 & 31 & 36 & 94 \\ 47 & 11 & 253 & 52 & 37 \\ 38 & 7 & 11 & 307 & 37 \\ 33 & 17 & 13 & 56 & 281 \end{pmatrix}$	$\begin{pmatrix} 62 & 1 & 8 & 19 & 10 \\ 25 & 22 & 14 & 10 & 29 \\ 10 & 1 & 58 & 15 & 16 \\ 18 & 3 & 5 & 65 & 9 \\ 9 & 12 & 5 & 16 & 58 \end{pmatrix}$

Table 75: Precision, Recall, and F1 scores for training data

	Class 0	Class 1	Class 2	Class 3	Class 4
Precision	0.5805	0.7604	0.7737	0.614	0.5878
Recall	0.73	0.365	0.6325	0.7675	0.7025
F1	0.6467	0.4932	0.6960	0.6822	0.6400

Table 76: Precision, Recall, and F1 scores for validation data

	Class 0	Class 1	Class 2	Class 3	Class 4
Precision	0.5175	0.6458	0.6627	0.5071	0.5
Recall	0.59	0.31	0.57	0.71	0.56
F1	0.5514	0.4189	0.6129	0.5916	0.5283

Table 77: Precision, Recall, and F1 scores for test data

	Class 0	Class 1	Class 2	Class 3	Class 4
Precision	0.5	0.5641	0.6444	0.52	0.4754
Recall	0.62	0.22	0.58	0.65	0.58
F1	0.5535	0.3165	0.6105	0.5777	0.5225

Table 78: Average Precision, Recall and F1 scores for Training, Validation, and Test data

	Average Precision	Average Recall	Average F1
Training	0.6632999959744049	0.6395000000000001	0.631660139522905
Validation	0.5666621495599464	0.5479999999999999	0.5406385134686736
Test	0.5407913689225164	0.53	0.5161889614502261

3.2 Bayes Classifier

Table 79: Classification accuracies on training, validation, and test data

Training Accuracy	**Validation Accuracy**	**Test Accuracy**
0.739	0.56	0.564

Table 80: Confusion matrix for training and test data

Training Data	Test Data
$\begin{pmatrix} 313 & 10 & 17 & 38 & 22 \\ 42 & 255 & 20 & 31 & 52 \\ 39 & 12 & 284 & 43 & 22 \\ 30 & 7 & 10 & 333 & 20 \\ 33 & 22 & 14 & 38 & 293 \end{pmatrix}$	$\begin{pmatrix} 51 & 19 & 5 & 16 & 9 \\ 15 & 54 & 8 & 3 & 20 \\ 9 & 2 & 63 & 16 & 10 \\ 10 & 5 & 11 & 65 & 9 \\ 22 & 10 & 4 & 15 & 49 \end{pmatrix}$

Table 81: Precision, Recall, and F1 scores for training data

	Class 0	Class 1	Class 2	Class 3	Class 4
Precision	0.6849	0.8333	0.8231	0.6894	0.7163
Recall	0.7825	0.6375	0.71	0.8325	0.7325
F1	0.7304	0.7223	0.7624	0.7542	0.7243

Table 82: Precision, Recall, and F1 scores for validation data

	Class 0	Class 1	Class 2	Class 3	Class 4
Precision	0.4791	0.6355	0.6419	0.5075	0.5595
Recall	0.46	0.68	0.52	0.67	0.47
F1	0.4693	0.6570	0.5745	0.5775	0.5108

Table 83: Precision, Recall, and F1 scores for test data

	Class 0	Class 1	Class 2	Class 3	Class 4
Precision	0.4766	0.6	0.6923	0.5652	0.5051
Recall	0.51	0.54	0.63	0.65	0.49
F1	0.4927	0.5684	0.6596	0.6046	0.4974

Table 84: Average Precision, Recall and F1 scores for Training, Validation, and Test data

	Average Precision	Average Recall	Average F1
Training	0.7494491365481659	0.739	0.7387697445850048
Validation	0.5647511122199596	0.5599999999999999	0.5578867986985948
Test	0.5678630473611979	0.5640000000000001	0.5645947262838076

3.3 Naive Bayes Classifier

Table 85: Classification accuracies on train, test, and validation data

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.55977988	0.58116232	0.58517034

Table 86: Confusion matrix for train and test data

Train Data	Test Data
$\begin{pmatrix} 222 & 22 & 44 & 49 & 62 \\ 69 & 178 & 31 & 17 & 105 \\ 51 & 19 & 230 & 55 & 45 \\ 73 & 6 & 29 & 237 & 55 \\ 44 & 37 & 23 & 44 & 252 \end{pmatrix}$	$\begin{pmatrix} 63 & 4 & 8 & 12 & 12 \\ 13 & 42 & 12 & 5 & 28 \\ 15 & 1 & 59 & 12 & 13 \\ 14 & 1 & 11 & 62 & 12 \\ 10 & 6 & 8 & 12 & 64 \end{pmatrix}$

Table 87: Precision, Recall and F1 scores for train data

	Precision	Recall	F1
Class 0	0.48366013	0.55639098	0.51748252
Class 1	0.67938931	0.445	0.53776435
Class 2	0.6442577	0.575	0.60766182
Class 3	0.58955224	0.5925	0.59102244
Class 4	0.48554913	0.63	0.5484222

Table 88: Precision, Recall and F1 scores for test data

	Precision	Recall	F1
Class 0	0.54782609	0.63636364	0.58878505
Class 1	0.77777778	0.42	0.54545455
Class 2	0.60204082	0.59	0.5959596
Class 3	0.60194175	0.62	0.61083744
Class 4	0.49612403	0.64	0.55895197

Table 89: Precision, Recall and F1 scores for Validation data

	Precision	Recall	F1
Class 0	0.50442478	0.57575758	0.53773585
Class 1	0.79104478	0.53	0.63473054
Class 2	0.5754717	0.61	0.59223301
Class 3	0.57	0.57	0.57
Class 4	0.56637168	0.64	0.60093897

Table 90: Average Precision, Recall and F1 scores for Train, Test and Validation data

	Average Precision	Average Recall	Average F1
Train	0.57648170	0.55977819	0.56047066
Test	0.60514209	0.58127272	0.57999771
Validation	0.60146258	0.58515151	0.58712767

3.4 GMM Classifier

3.4.1 Full Covariance Matrix

Table 91: Classification accuracies on train, test, and validation data for $Q = 2$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.846	0.562	0.52

Table 92: Classification accuracies on train, test, and validation data for $Q = 3$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.908	0.486	0.486

Table 93: Classification accuracies on train, test, and validation data for $Q = 4$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.9525	0.47	0.478

Table 94: Classification accuracies on train, test, and validation data for $Q = 5$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.9615	0.464	0.41

Conclusion: Validation accuracy is highest for $Q = 2$ and is therefore the best configuration.

Table 95: Confusion matrix for train and test data for the best configuration($Q = 2$)

Train Data	Test Data
$\begin{pmatrix} 357 & 8 & 10 & 20 & 5 \\ 22 & 308 & 7 & 26 & 37 \\ 24 & 9 & 322 & 23 & 22 \\ 15 & 1 & 9 & 369 & 6 \\ 12 & 18 & 6 & 28 & 336 \end{pmatrix}$	$\begin{pmatrix} 52 & 14 & 6 & 12 & 16 \\ 10 & 62 & 8 & 3 & 17 \\ 11 & 7 & 60 & 10 & 12 \\ 9 & 9 & 8 & 59 & 15 \\ 16 & 15 & 8 & 13 & 48 \end{pmatrix}$

Table 96: Precision, Recall and F1 scores for train data for the best configuration($Q = 2$)

	Precision	Recall	F1
Class 0	0.83023256	0.8925	0.86024096
Class 1	0.89534884	0.77	0.82795699
Class 2	0.90960452	0.805	0.85411141
Class 3	0.79184549	0.9225	0.852194
Class 4	0.82758621	0.84	0.8337469

Table 97: Precision, Recall and F1 scores for test data for the best configuration($Q = 2$)

	Precision	Recall	F1
Class 0	0.53061224	0.52	0.52525253
Class 1	0.57943925	0.62	0.59903382
Class 2	0.66666667	0.6	0.63157895
Class 3	0.60824742	0.59	0.59898477
Class 4	0.44444444	0.48	0.46153846

Table 98: Precision, Recall and F1 scores for Validation data for the best configuration($Q = 2$)

	Precision	Recall	F1
Class 0	0.46236559	0.43	0.44559585
Class 1	0.58474576	0.69	0.63302752
Class 2	0.57142857	0.52	0.54450262
Class 3	0.55769231	0.58	0.56862745
Class 4	0.40425532	0.38	0.39175258

Table 99: Average Precision, Recall and F1 scores for Train, Test and Validation data for the best configuration($Q = 2$)

	Average Precision	Average Recall	Average F1
Train	0.85092352	0.846	0.84565005
Test	0.56588200	0.562	0.56327770
Validation	0.51609751	0.519	0.51670120

3.4.2 Diagonal Covariance Matrix

Table 100: Classification accuracies on train, test, and validation data for $Q = 2$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.572	0.54	0.526

Table 101: Classification accuracies on train, test, and validation data for $Q = 3$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.59	0.588	0.538

Table 102: Classification accuracies on train, test, and validation data for $Q = 4$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.6135	0.568	0.558

Table 103: Classification accuracies on train, test, and validation data for $Q = 5$

Train Accuracy	**Test Accuracy**	**Validation Accuracy**
0.636	0.56	0.56

Conclusion: Validation accuracy is highest for $Q = 5$ and is therefore the best configuration.

Table 104: Confusion matrix for train and test data for the best configuration($Q = 5$)

Train Data	Test Data
$\begin{pmatrix} 252 & 19 & 36 & 59 & 34 \\ 51 & 208 & 23 & 26 & 92 \\ 46 & 23 & 258 & 36 & 37 \\ 42 & 11 & 21 & 293 & 33 \\ 37 & 46 & 16 & 40 & 261 \end{pmatrix}$	$\begin{pmatrix} 46 & 8 & 11 & 21 & 14 \\ 12 & 53 & 8 & 5 & 22 \\ 18 & 5 & 56 & 13 & 8 \\ 13 & 3 & 13 & 65 & 6 \\ 8 & 12 & 4 & 16 & 60 \end{pmatrix}$

Table 105: Precision, Recall and F1 scores for train data for the best configuration($Q = 5$)

	Precision	Recall	F1
Class 0	0.58878505	0.63	0.60869565
Class 1	0.67752443	0.52	0.5884017
Class 2	0.72881356	0.645	0.68435013
Class 3	0.64537445	0.7325	0.68618267
Class 4	0.57111597	0.6525	0.60910152

Table 106: Precision, Recall and F1 scores for test data for the best configuration($Q = 5$)

	Precision	Recall	F1
Class 0	0.4742268	0.46	0.46700508
Class 1	0.65432099	0.53	0.58563536
Class 2	0.60869565	0.56	0.58333333
Class 3	0.54166667	0.65	0.59090909
Class 4	0.54545455	0.6	0.57142857

Table 107: Precision, Recall and F1 scores for Validation data for the best configuration($Q = 5$)

	Precision	Recall	F1
Class 0	0.52688172	0.49	0.50777202
Class 1	0.56818182	0.5	0.53191489
Class 2	0.68	0.68	0.68
Class 3	0.51785714	0.58	0.54716981
Class 4	0.51401869	0.55	0.53140097

Table 108: Average Precision, Recall and F1 scores for Train, Test and Validation data for the best configuration($Q = 5$)

	Average Precision	Average Recall	Average F1
Train	0.64232269	0.636	0.63534633
Test	0.56487293	0.56	0.55966228
Validation	0.56138787	0.56	0.55965153