2015

CS669: Pattern Recognition

GROUP-13
IIT Mandi
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INTRODUCTION –

In pattern recognition, machine learning and statistics, classification is the problem of identifying to which of a set of categories (sub-populations) a new observation belongs, on the basis of a training set of data containing observations (or instances) whose category membership is known.

Problem Statement:

- **Data types provided –**
  - Artificial Dataset
    - Linearly Separable Data
      It has three classes. Each example has 2 attributes.
    - Non Linearly Separable Data
      - Ring
        It has two classes. Each example has 2 attributes. In this, there is a ring with a central mass.
      - Spiral
        It has two classes. Each example has 2 attributes.
      - Interlock
        It has two classes. Each example has 2 attributes.
  - Real World Dataset
    - Image data:
      It has three classes. Each image is a super vector having 828 dimensions.
    - Speech data:
      It has three classes. Each example has 2 attributes. The real world data sets correspond to the formant frequencies F1 and F2 for vowel utterances.
- **Classifiers to be used –**
  1) Bayes classifier using unimodal Gaussian distribution on Dataset-1(a) and Dataset-2.
  2) Bayes classifier using GMM on Dataset-2. GMM is built using the K-means clustering to initialize the parameters.
  3) Build Bayes classifier using unimodal Gaussian distribution on the 1- dimensional representation of Dataset-1(a) and Dataset-2(a) obtained using PCA.
  4) Build Bayes classifier using unimodal Gaussian distribution and GMM on the reduced dimensional representations of Dataset-2 obtained using PCA.
  5) Fisher linear discriminant analysis (FDA) based classifier on Dataset-1 and Dataset-2. Use both Bayes classifier using unimodal Gaussian and GMM.
  6) Perceptron-based classifier on Dataset-1.
  7) SVM-based classifier using (a) linear kernel, (b) polynomial kernel and (c) Gaussian/RBF kernel on Dataset-1 and Dataset-2
  8) SVM-based classifier using (a) linear kernel, (b) polynomial kernel and (c) Gaussian/RBF kernel on the reduced dimensional representations of Dataset-2 obtained using PCA.
- **Learning Objective –**
  1) Observe performance Accuracy and Confusion Matrix from different classifiers for the provided data sets.
  2) Conclude inferences from these observations.
- In the report, k represents number of clusters.

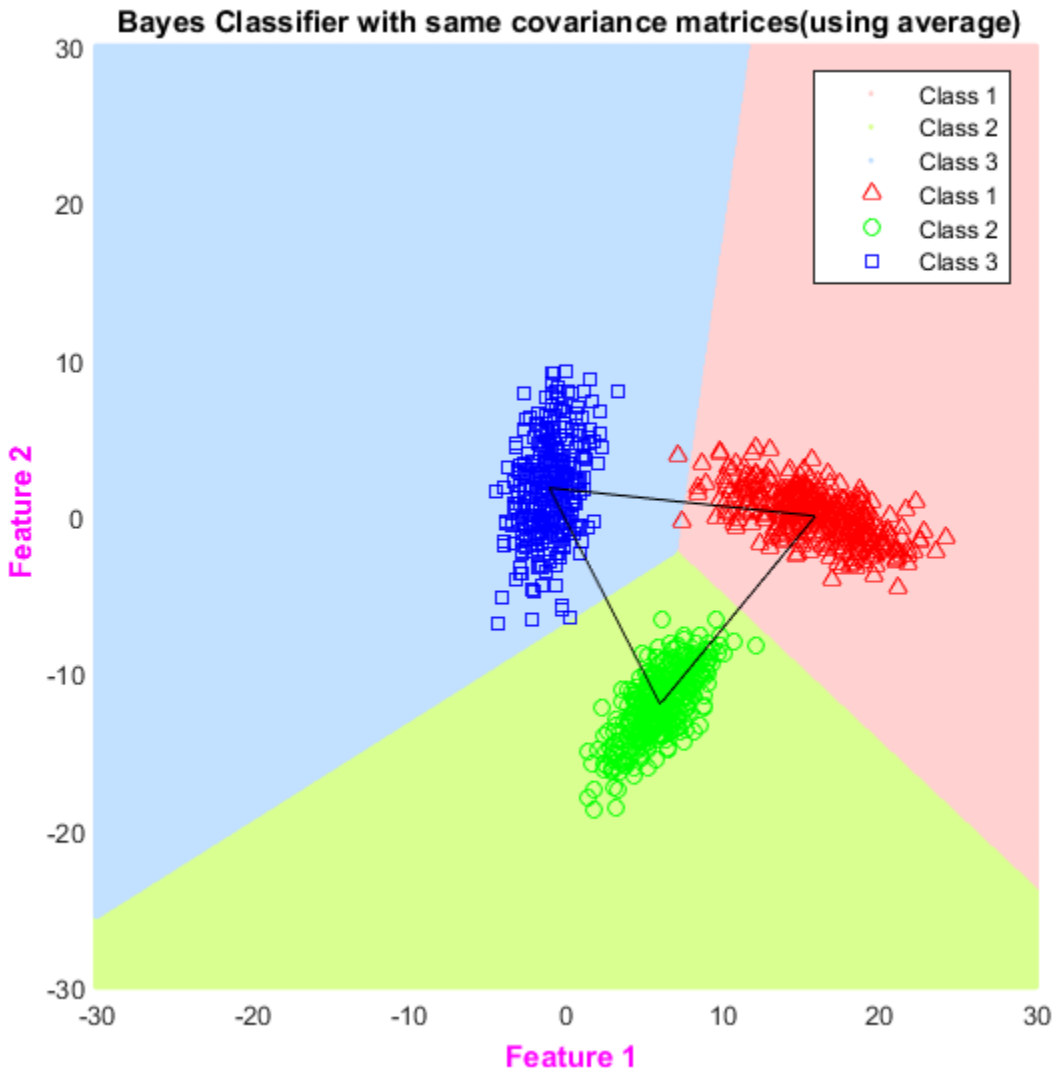
I. Bayes Classifier using Unimodal Gaussian Distribution–

1. For Dataset 1(a)-

A. On actual Dimensions -

a) Same covariance matrices (by taking average)

- *Decision region plot for all the classes together with the training data superposed –*



- *Confusion Matrix based on performance for test data-*

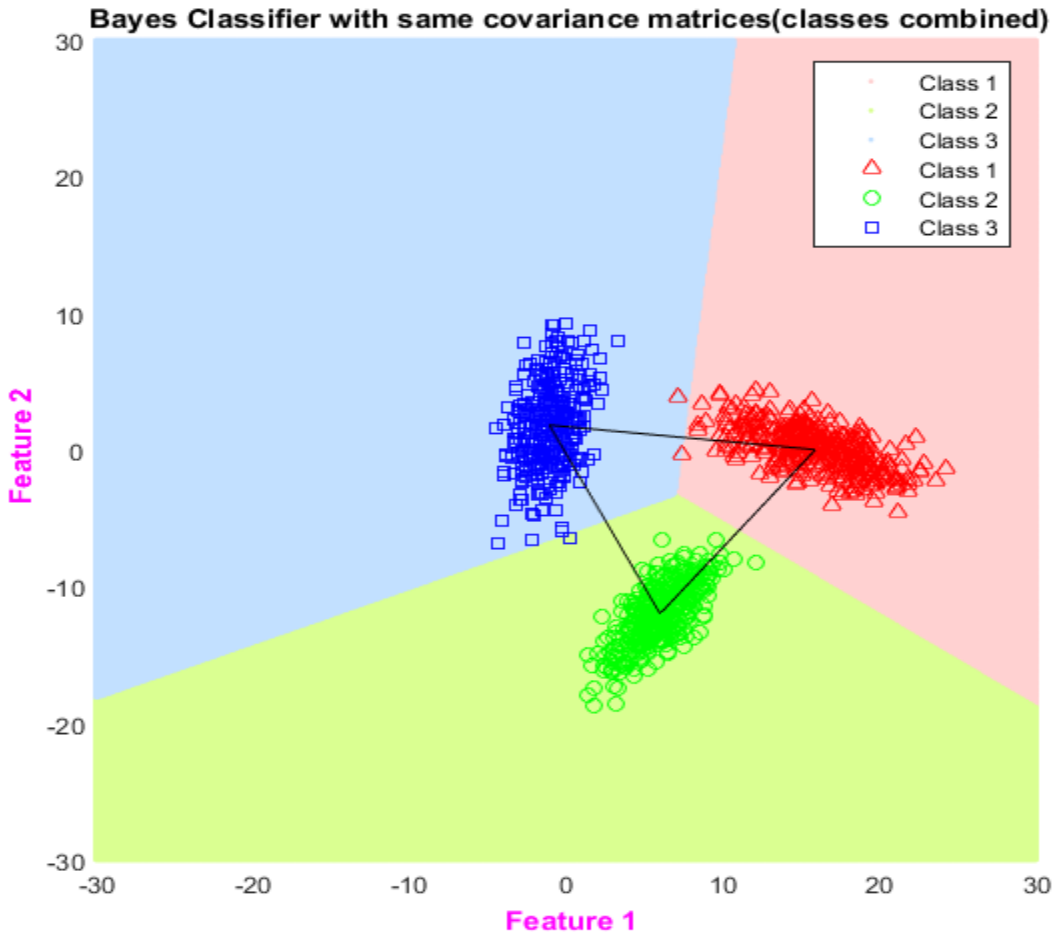
Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	124	0	1
Class 2	0	125	0
Class 3	0	0	125

- *Classification accuracy on test data –*

Overall Accuracy – 99.7333
Classifier Accuracy for class 1 – 99.2
Classifier Accuracy for class 2 – 100.0
Classifier Accuracy for class 3 – 100.0

b) Same covariance matrices (from training data of all classes combined)

- *Decision region plot for all the classes together with the training data superposed -*



- *Confusion Matrix based on performance for test data-*

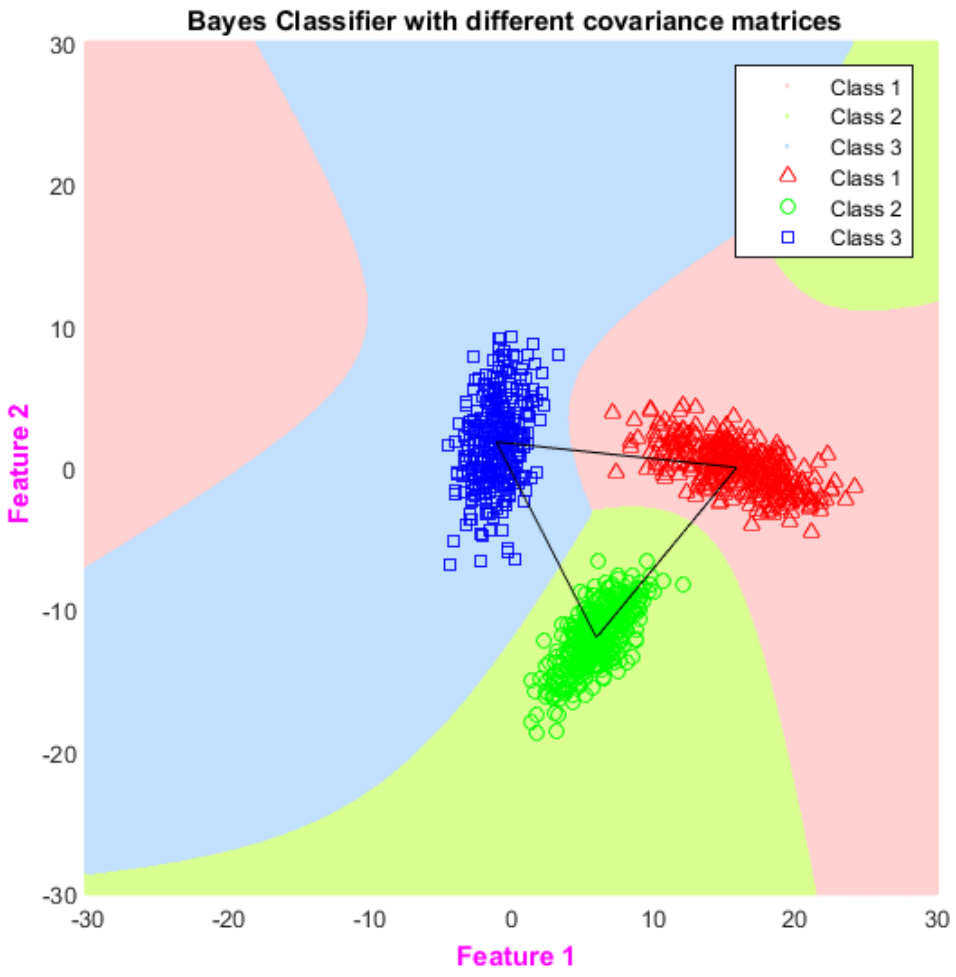
Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	124	0	1
Class 2	0	125	0
Class 3	0	0	125

- *Classification accuracy on test data –*

Overall Accuracy – 99.7333
Classifier Accuracy for class 1 – 99.2
Classifier Accuracy for class 2 – 100.0
Classifier Accuracy for class 3 – 100.0

c) Covariance matrix for each class is different

- *Decision region plot for all the classes together with the training data superposed -*



- *Confusion Matrix based on performance for test data-*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	125	0	0
Class 2	0	125	0
Class 3	0	0	125

- *Classification accuracy on test data –*

Overall Accuracy - 100.0
Classifier Accuracy for class 1 - 100.0
Classifier Accuracy for class 2 - 100.0
Classifier Accuracy for class 3 - 100.0

B. On reduced Dimensions using Principal Component Analysis (PCA)-

This dataset has three classes. This data has two dimensions originally, after application of PCA the dimension was reduced to one.

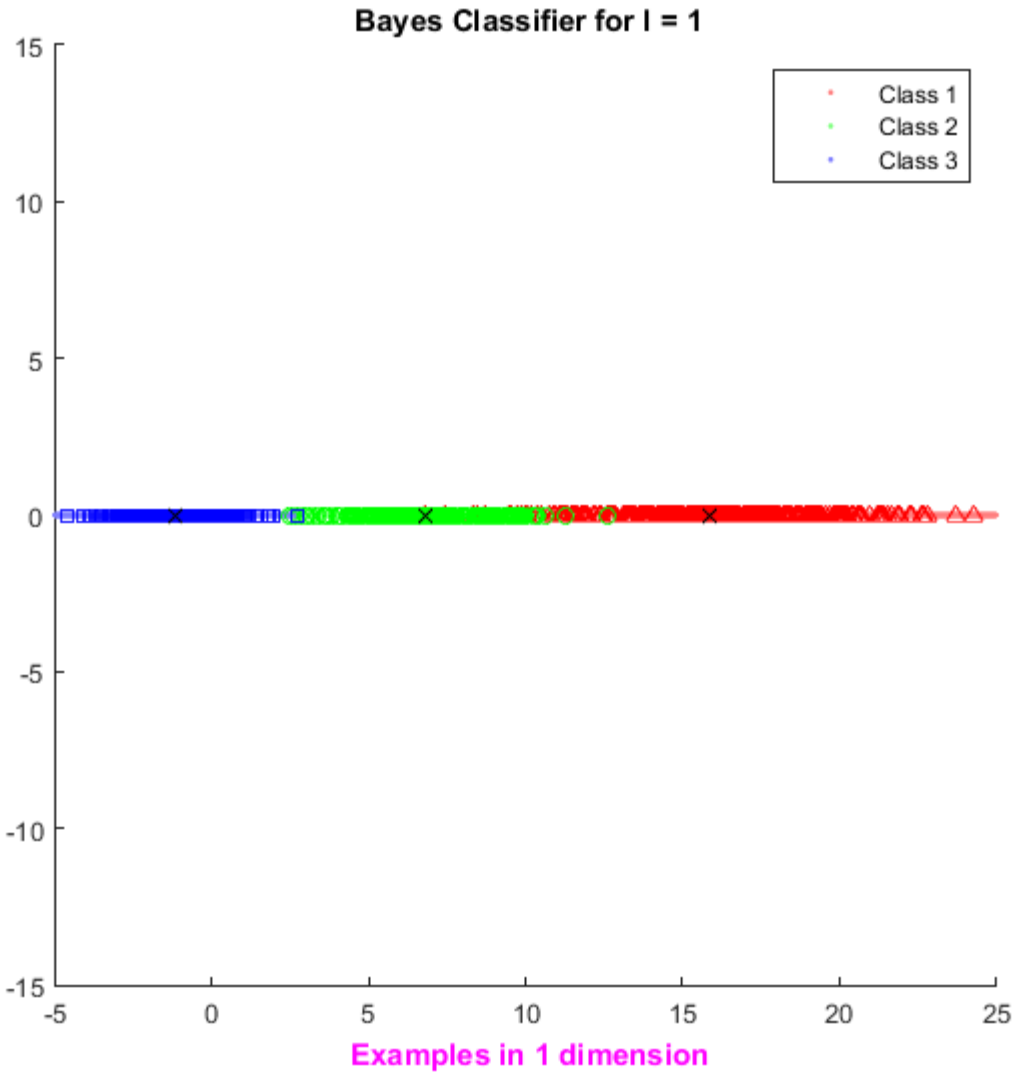
- **Dimension reduction to 1**

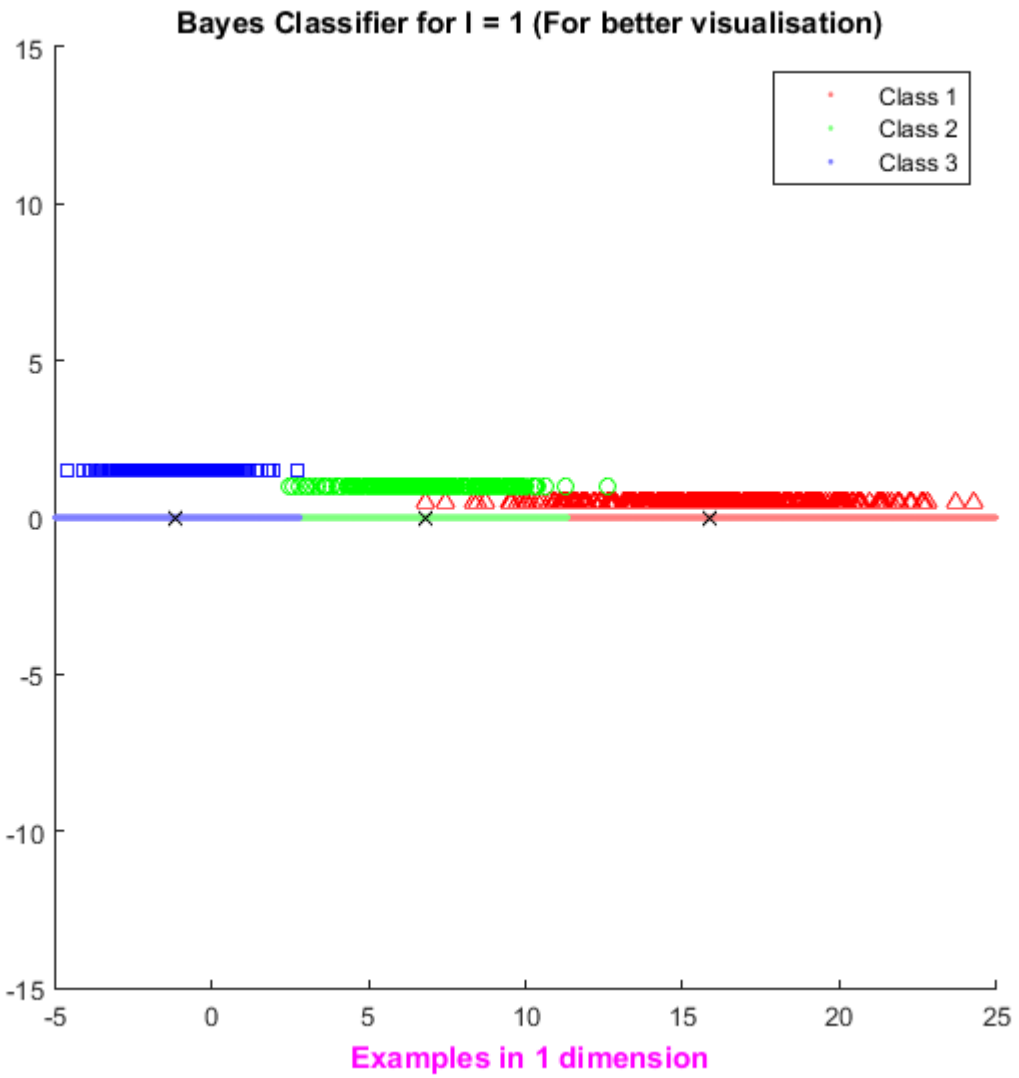
- *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	111	14	0
Class 2	0	125	0
Class 3	0	0	125

- *Classification accuracy on test data*

Overall Accuracy: 96.266667
Class 1 Accuracy: 88.800000
Class 2 Accuracy: 100.000000
Class 3 Accuracy: 100.000000


Bayes Classifier for l = 1
Class 1
Class 2
Class 3
15
10
5
0
-5
-10
-15
-5
0
5
10
15
20
25
Examples in 1 dimension



C. <u>On reduced Dimensions using Fisher Discriminant Analysis (FDA)-</u>

- *<u>Confusion Matrix based on performance for test data-</u>*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	125	0	0
Class 2	0	125	0
Class 3	0	0	125

- *<u>Classification accuracy on test data –</u>*

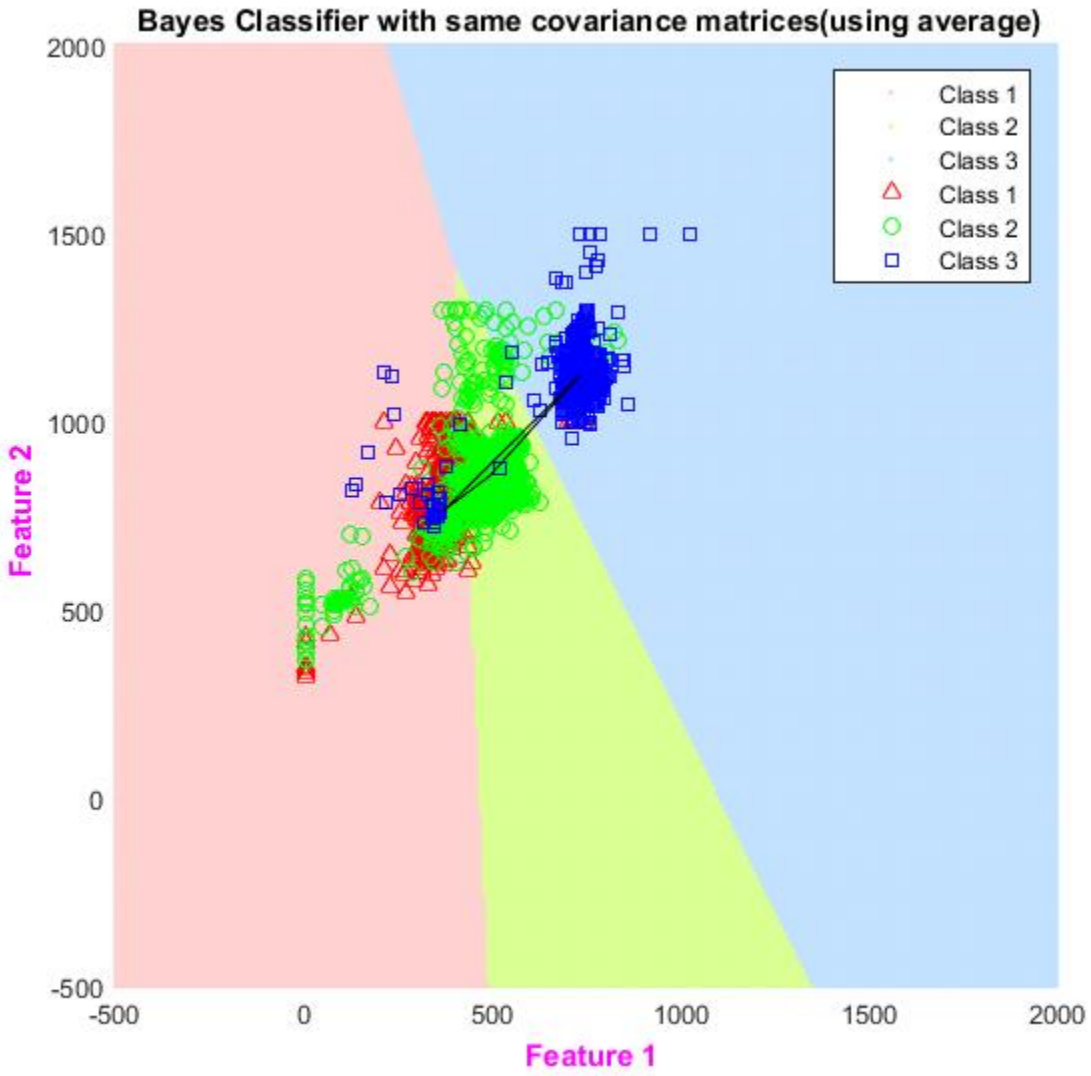
Overall Accuracy - 100.0
Classifier Accuracy for class 1 - 100.0
Classifier Accuracy for class 2 - 100.0
Classifier Accuracy for class 3 - 100.0

2. For Dataset 2(a)-

A. On actual Dimensions -

a) Same covariance matrices (by taking average)

- *Decision region plot for all the classes together with the training data superposed -*



- *Confusion Matrix based on performance for test data-*

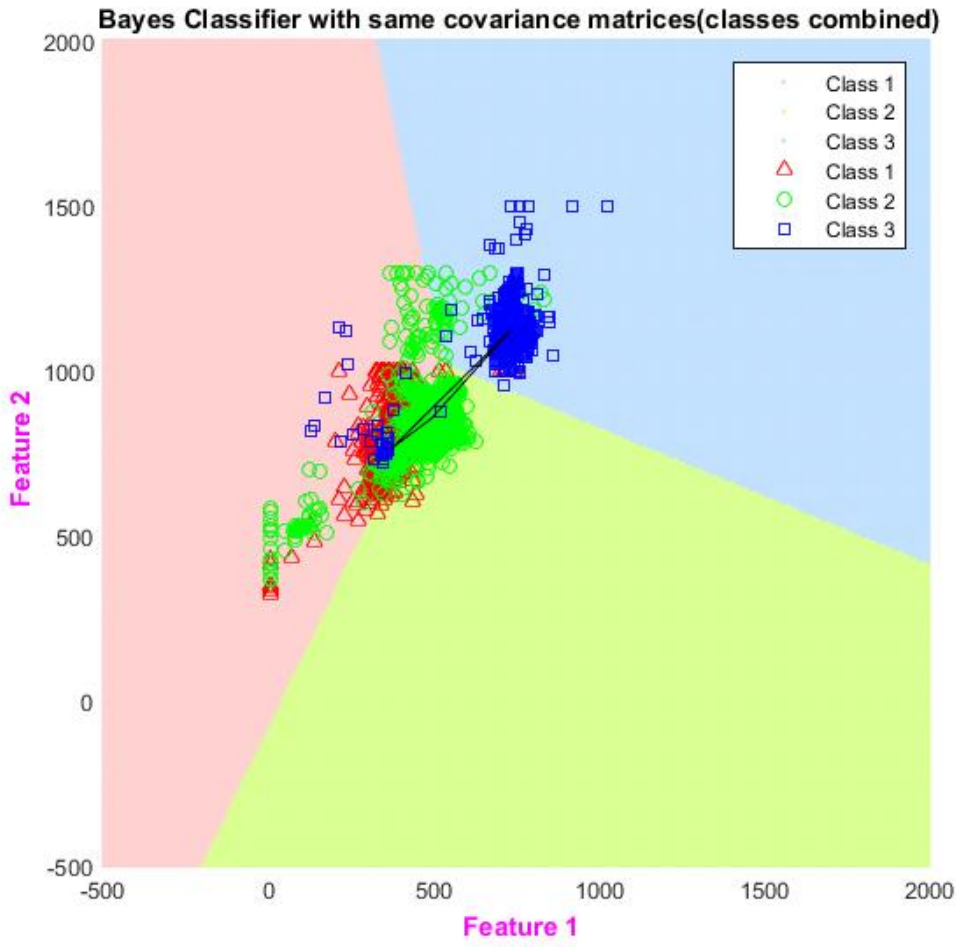
Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	602	13	7
Class 2	197	397	20
Class 3	26	5	510

- *Classification accuracy on test data –*

Overall Accuracy – 84.9184
Classifier Accuracy for class 1 – 96.7846
Classifier Accuracy for class 2 – 64.6580
Classifier Accuracy for class 3 – 94.2699

b) Same covariance matrices (from training data of all classes combined)

- *Decision region plot for all the classes together with the training data superposed -*



- *Confusion Matrix based on performance for test data-*

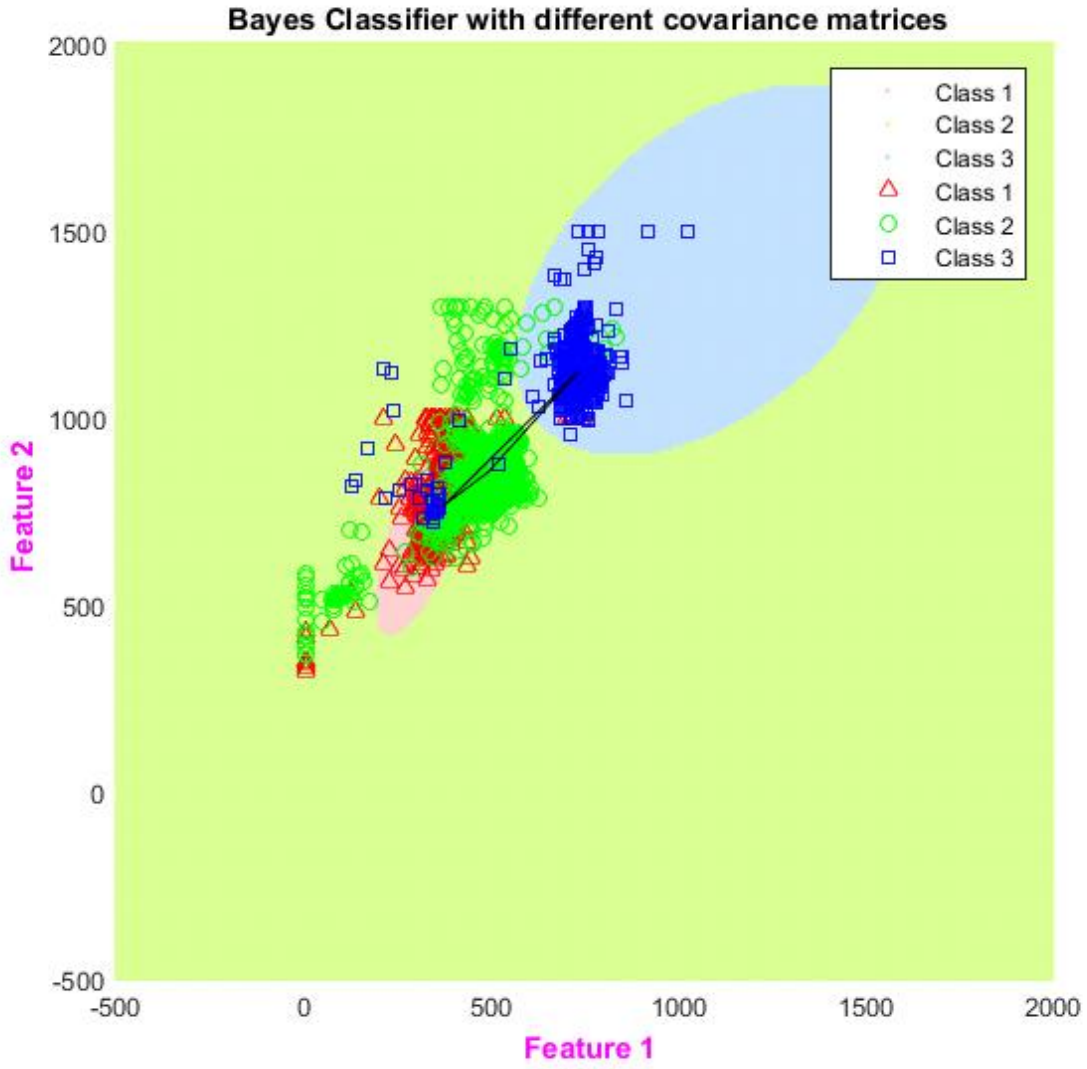
Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	544	71	7
Class 2	261	332	21
Class 3	30	1	510

- *Classification accuracy on test data –*

Overall Accuracy – 77.9966
Classifier Accuracy for class 1 – 87.4598
Classifier Accuracy for class 2 – 54.0717
Classifier Accuracy for class 3 – 94.2699

c) Covariance matrix for each class is different

- *Decision region plot for all the classes together with the training data superposed -*



- *Confusion Matrix based on performance for test data-*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	531	84	7
Class 2	203	406	5
Class 3	13	19	509

- *Classification accuracy on test data –*

Overall Accuracy – 81.3731
Classifier Accuracy for class 1 – 85.3698
Classifier Accuracy for class 2 – 66.1238
Classifier Accuracy for class 3 – 94.0850

B. On reduced Dimensions using Principal Component Analysis (PCA)-

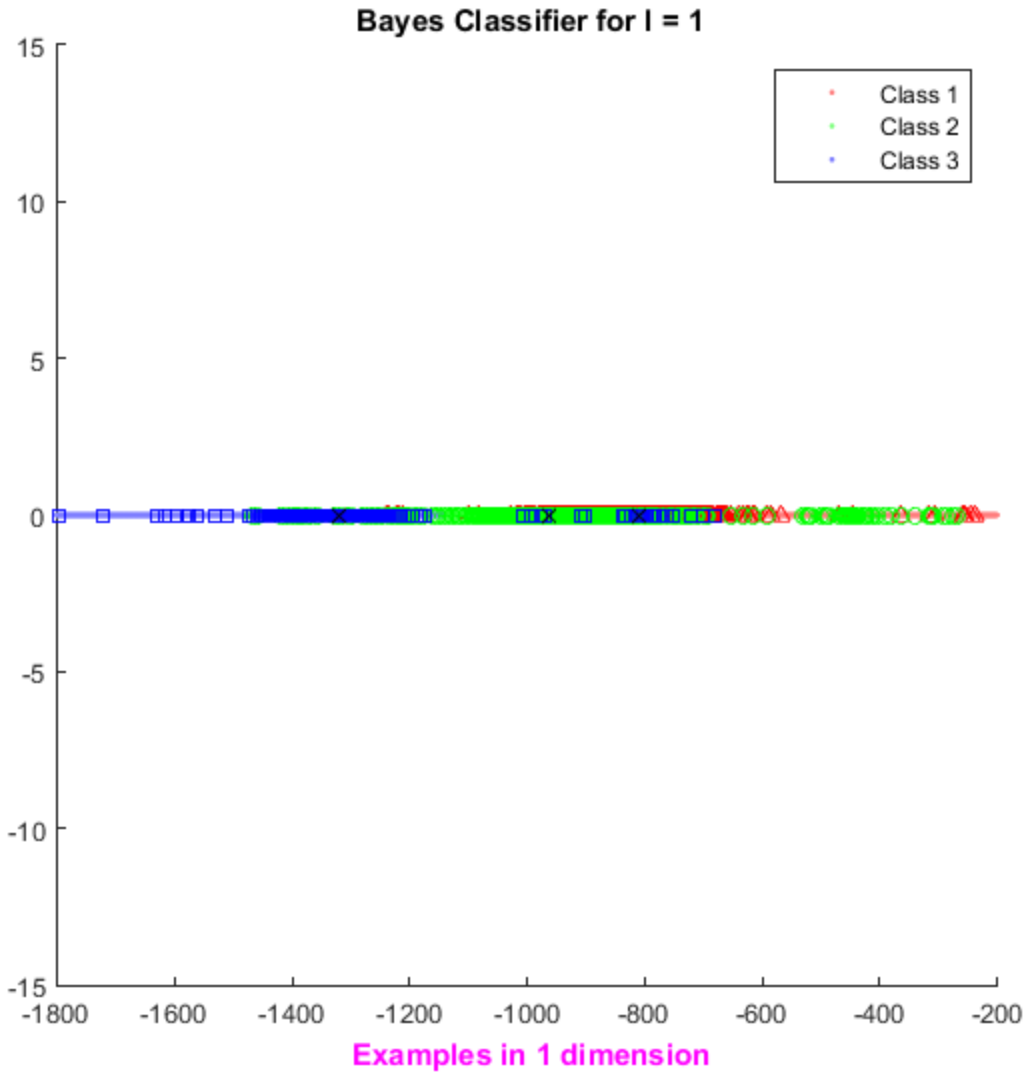
This dataset has three classes. This data has two dimensions originally, after application of PCA the dimension was reduced to one.

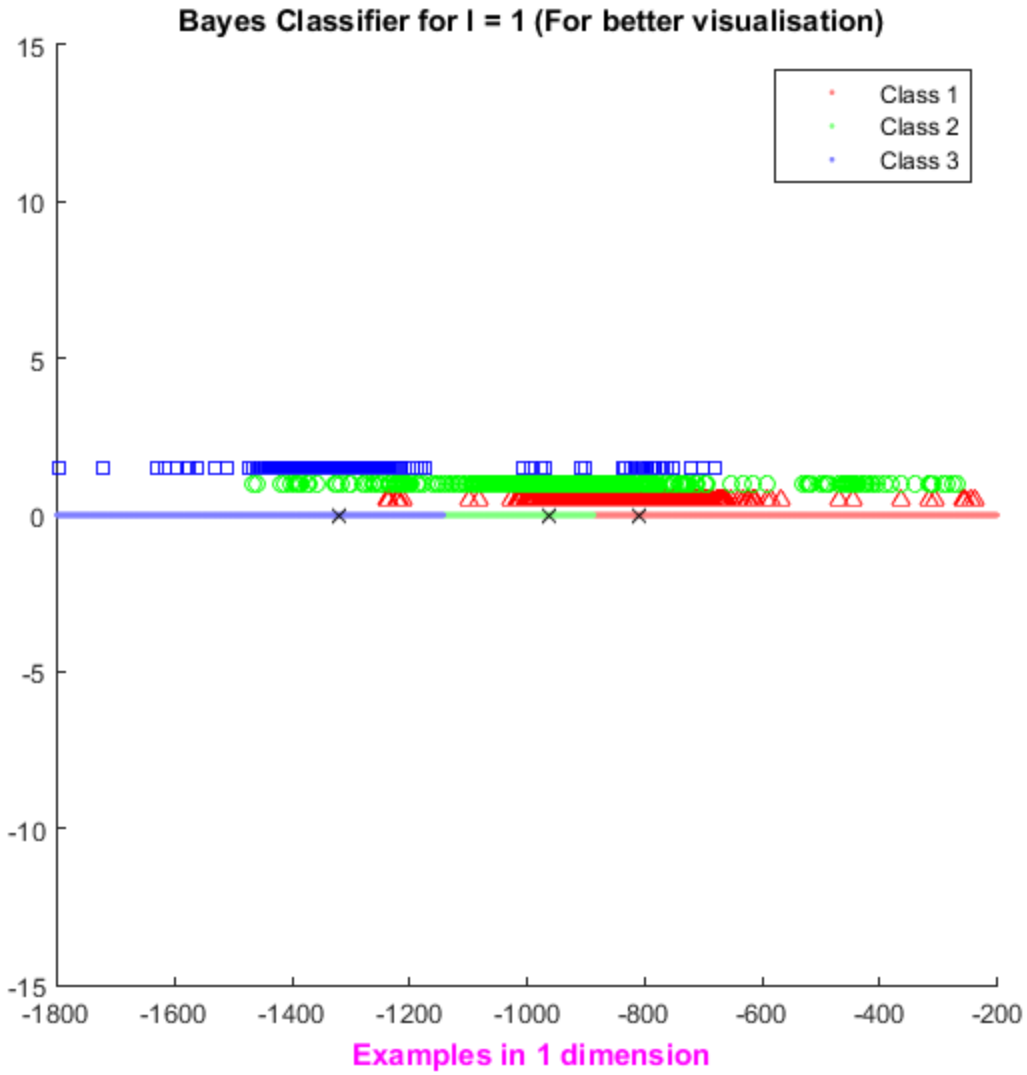
- **Dimension reduction to 1**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	570	45	7
Class 2	172	398	44
Class 3	24	5	512

  - *Classification accuracy on test data*

Overall Accuracy: 83.286438
Class 1 Accuracy: 91.639871
Class 2 Accuracy: 64.820847
Class 3 Accuracy: 94.639556


Bayes Classifier for l = 1
Class 1
Class 2
Class 3
15
10
5
0
-5
-10
-15
-1800
-1600
-1400
-1200
-1000
-800
-600
-400
-200
Examples in 1 dimension



C. On reduced Dimensions using Fisher Discriminant Analysis (FDA)-

- *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	510	108	4
Class 2	33	559	22
Class 3	12	20	509

- *Classification accuracy on test data*

Overall Accuracy: 88.801351
Class 1 Accuracy: 81.993569
Class 2 Accuracy: 91.042345
Class 3 Accuracy: 94.085028

3. For Dataset 2(b)-

A. On reduced Dimensions using Principal Component Analysis (PCA)-

This dataset has three classes. This data has 828(in the form of a super vector) dimensions originally, after application of PCA the dimension was reduced to one and two.

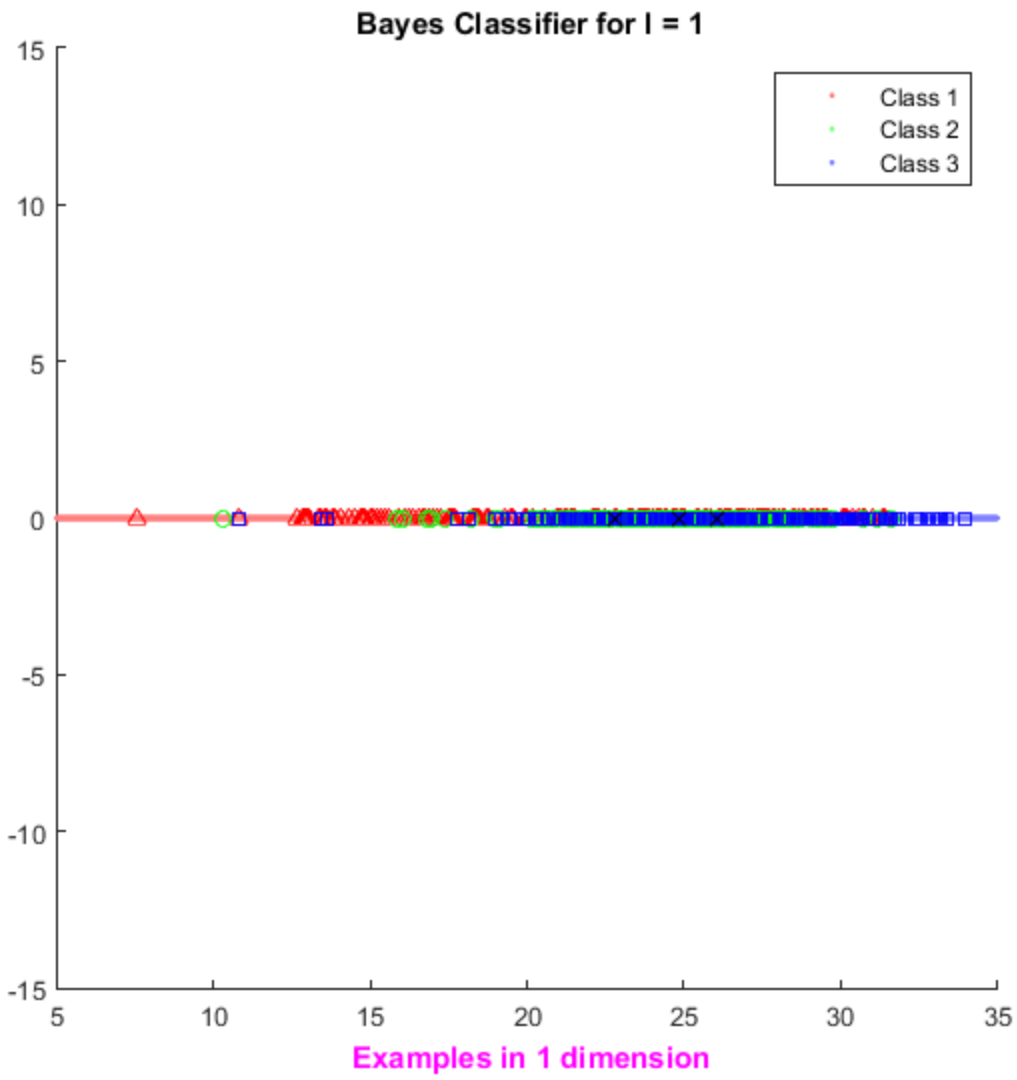
- **Dimension reduction to 1**

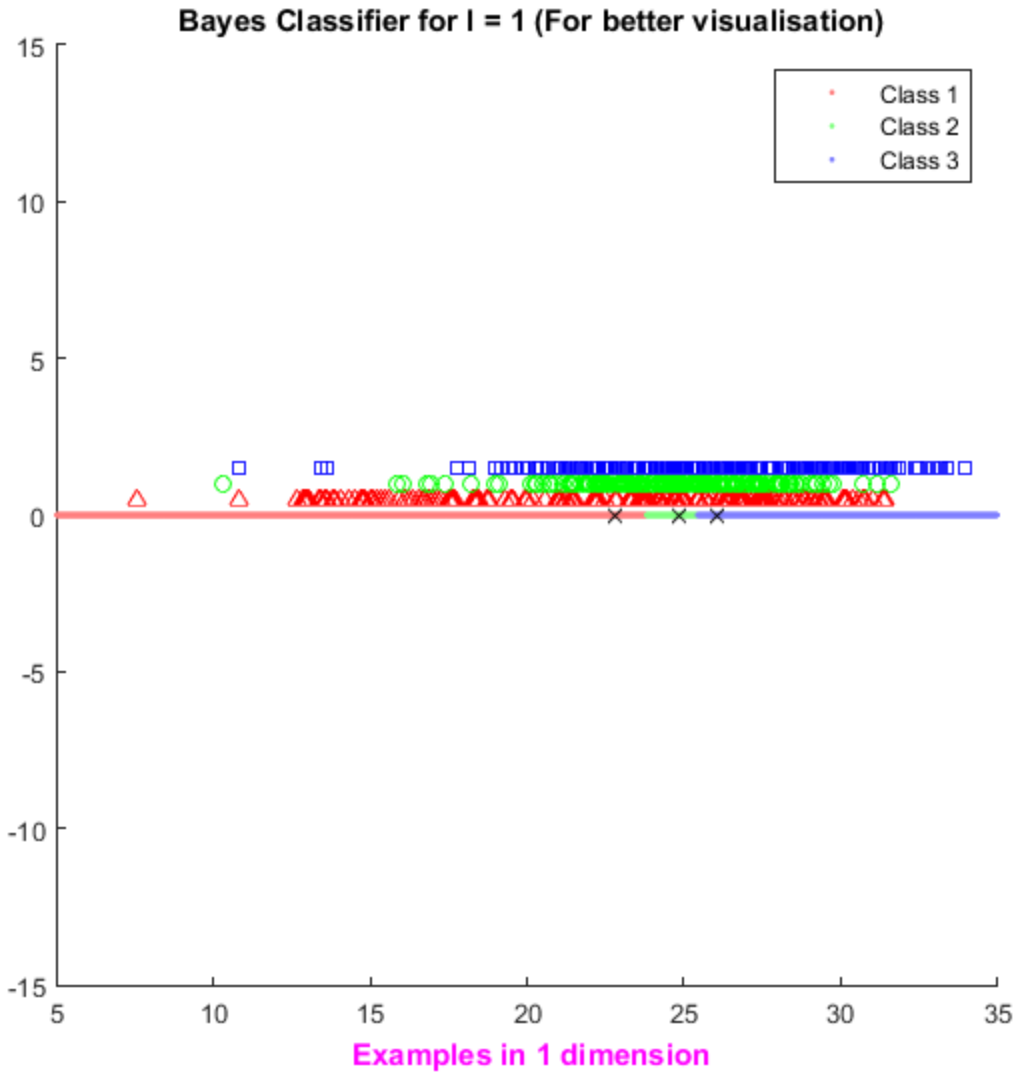
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	12	6	47
Class 2	26	18	29
Class 3	27	14	48

  - *Classification accuracy on test data*

Overall Accuracy: 34.361233
Class 1 Accuracy: 18.461538
Class 2 Accuracy: 24.657534
Class 3 Accuracy: 53.932584


Bayes Classifier for l = 1
Class 1
Class 2
Class 3
15
10
5
0
-5
-10
-15
5
10
15
20
25
30
35
Examples in 1 dimension

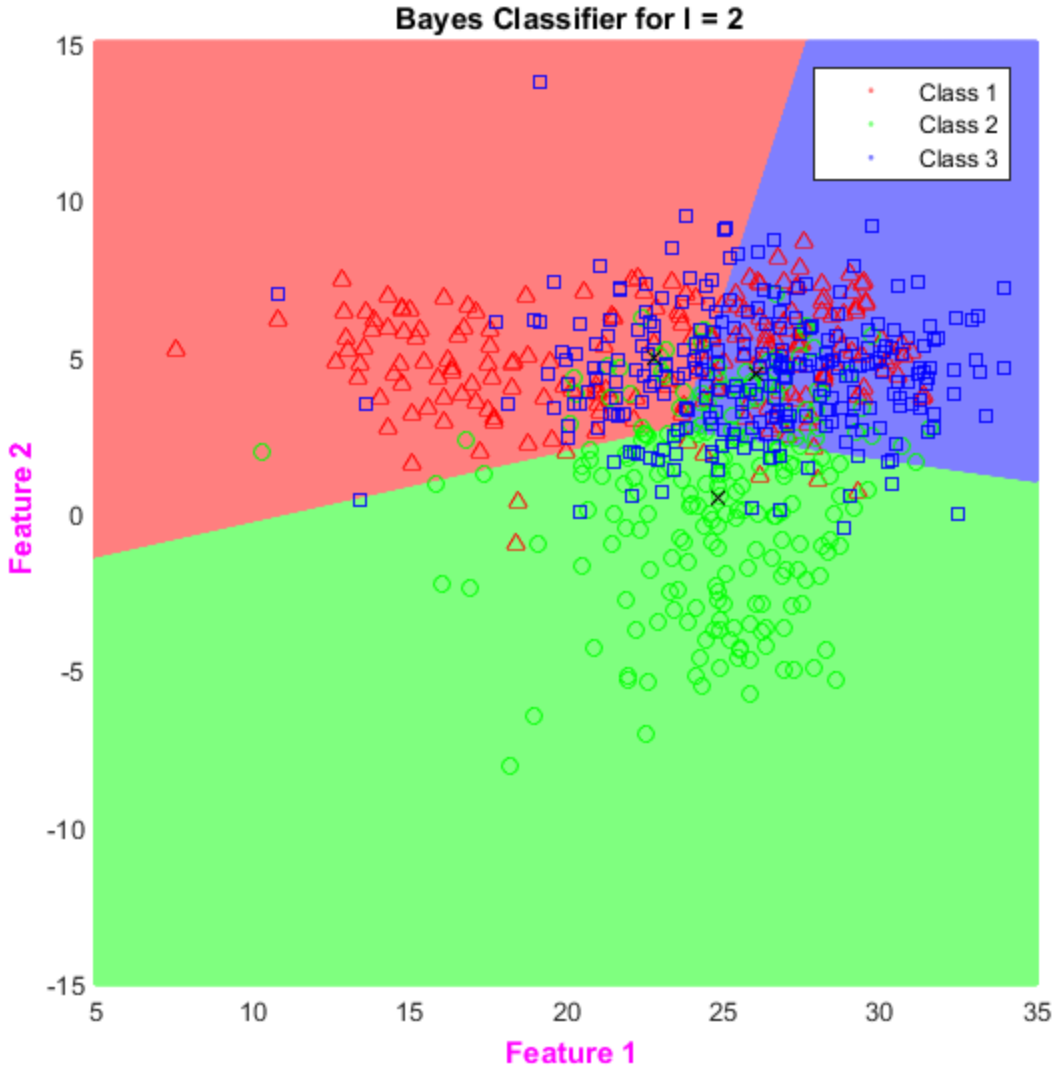


- **Dimension reduction to 2**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	13	4	48
Class 2	12	42	19
Class 3	30	11	48

  - *Classification accuracy on test data*

Overall Accuracy: 45.374449
Class 1 Accuracy: 20.000000
Class 2 Accuracy: 57.534247
Class 3 Accuracy: 53.932584



B. On reduced Dimensions using Fisher Discriminant Analysis (FDA)-

- *Confusion Matrix based on performance for test data*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	13	34	18
Class 2	10	38	25
Class 3	17	17	55

- *Classification accuracy on test data*

Overall Accuracy: 46.696035
Class 1 Accuracy: 20.000000
Class 2 Accuracy: 52.054795
Class 3 Accuracy: 61.797753

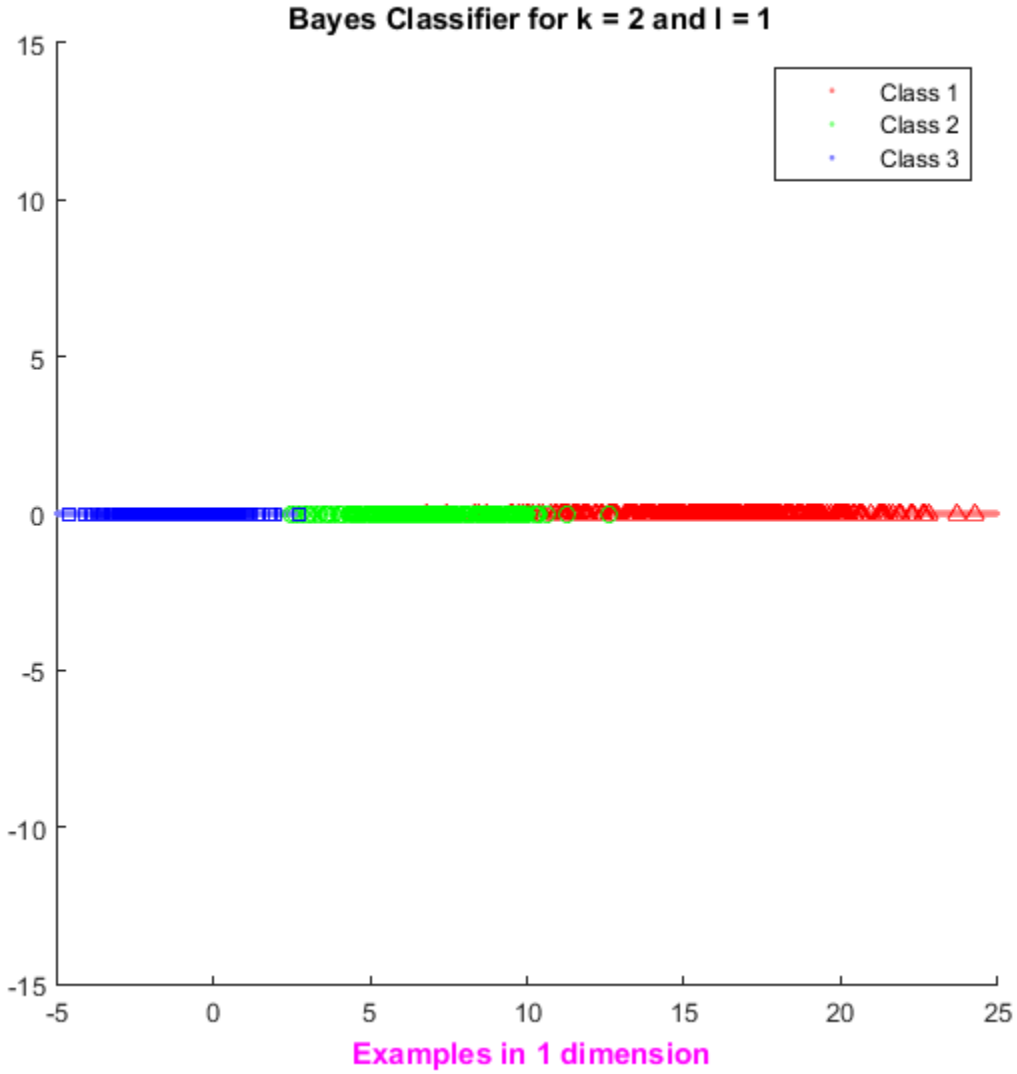
II. Bayes Classifier using Gaussian Mixture Model(GMM) Distribution–

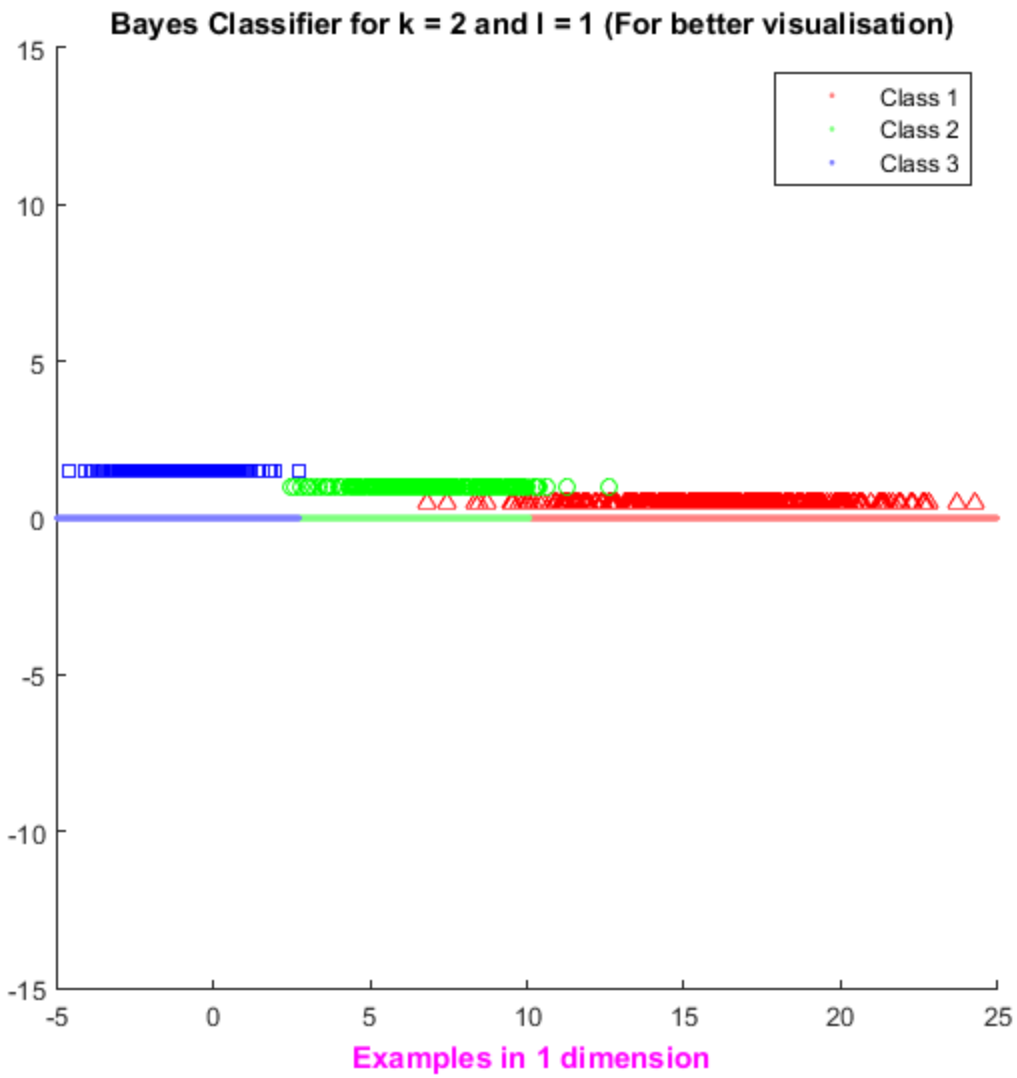
1. For Dataset 1(a)-

A. On reduced Dimensions using Principal Component Analysis (PCA)-

This dataset has three classes. This data has two dimensions originally, after application of PCA the dimension was reduced to one.
K - Number of clusters.

- **K = 2 and dimension reduction to 1**





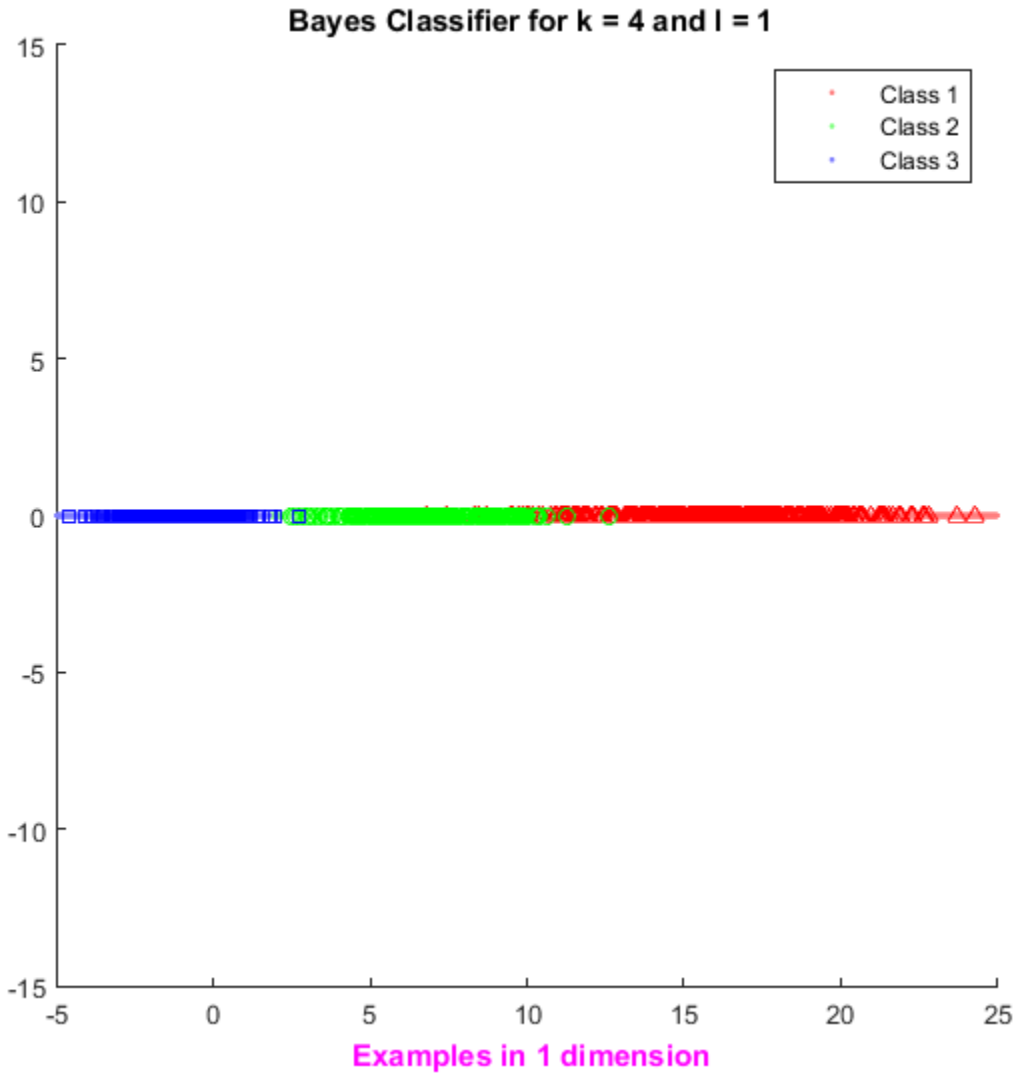
- *Confusion Matrix based on performance for test data*

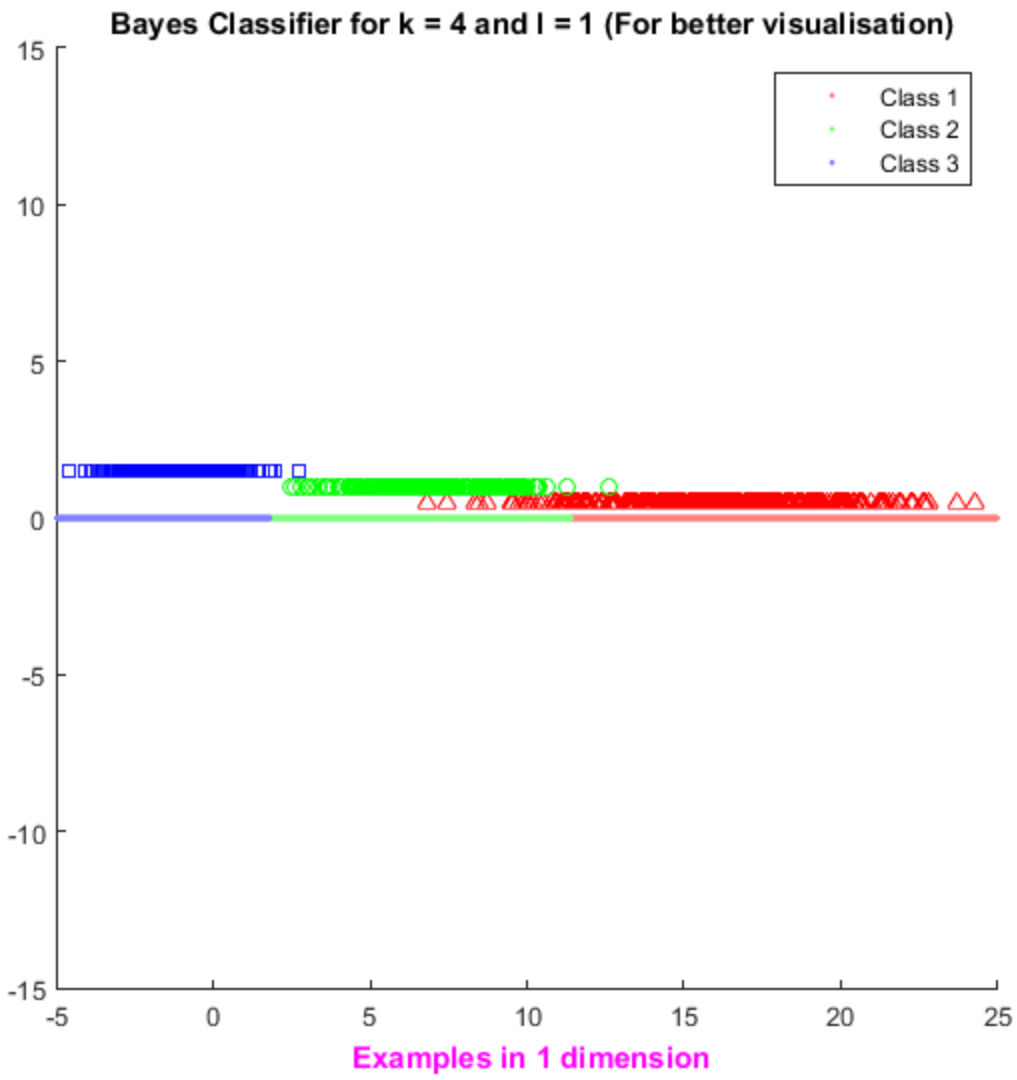
Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	120	5	0
Class 2	3	122	0
Class 3	0	0	125

- *Classification accuracy on test data*

Overall Accuracy: 97.866667
Class 1 Accuracy: 96.000000
Class 2 Accuracy: 97.600000
Class 3 Accuracy: 100.000000

- **K = 4 and dimension reduction to 1**





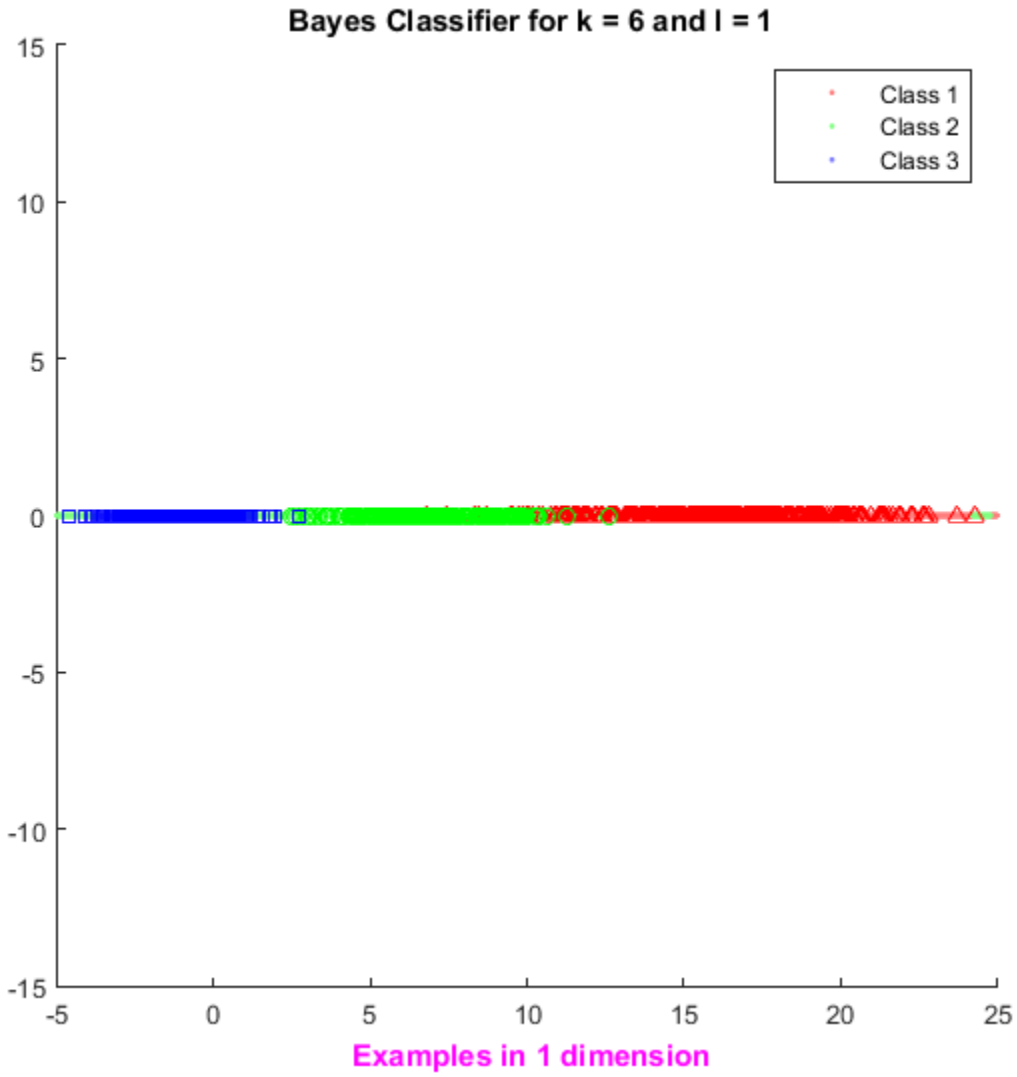
- *Confusion Matrix based on performance for test data*

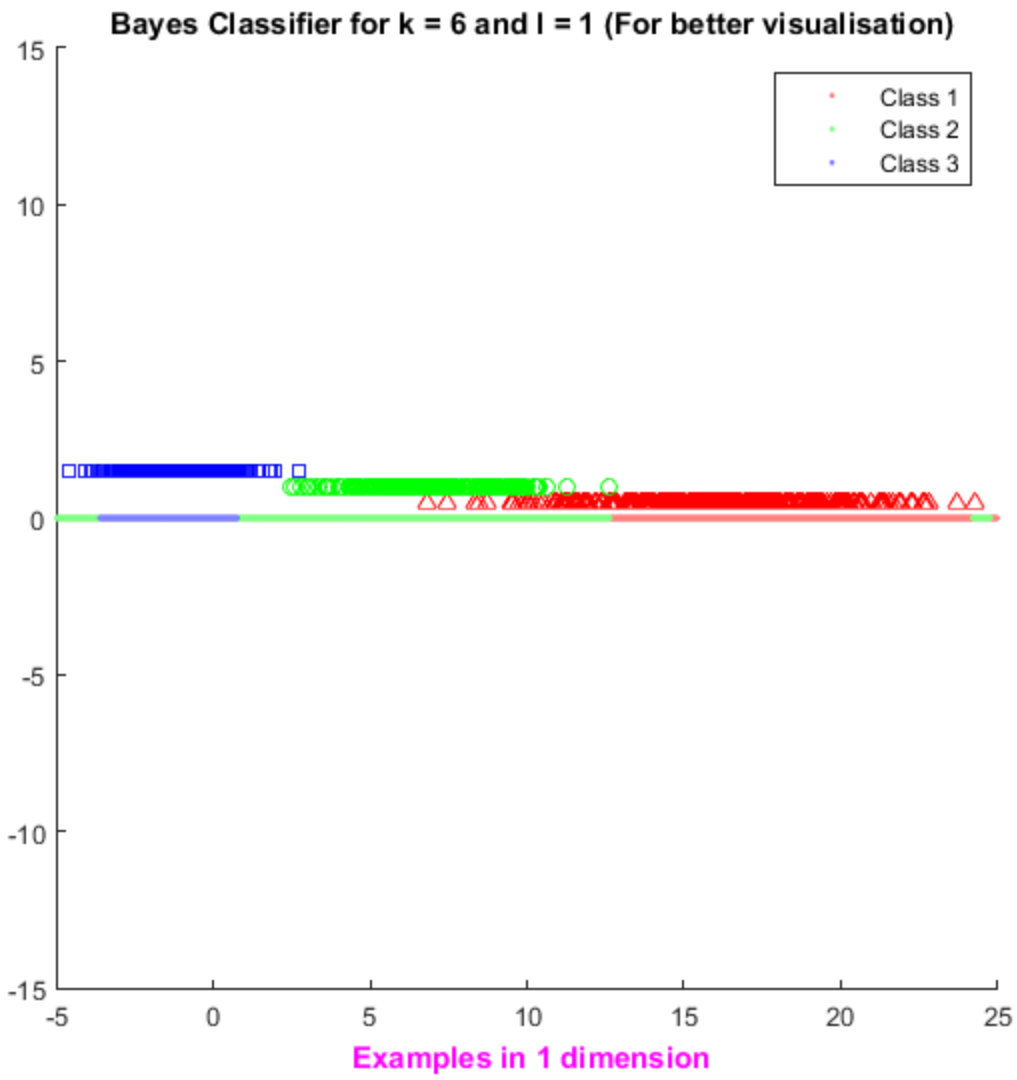
Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	111	14	0
Class 2	0	125	0
Class 3	0	0	125

- *Classification accuracy on test data*

Overall Accuracy: 96.266667
Class 1 Accuracy: 88.800000
Class 2 Accuracy: 100.000000
Class 3 Accuracy: 100.000000

- **K = 6 and dimension reduction to 1**





- *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	99	26	0
Class 2	0	125	0
Class 3	0	7	118

- *Classification accuracy on test data*

Overall Accuracy: 91.200000
Class 1 Accuracy: 79.200000
Class 2 Accuracy: 100.000000
Class 3 Accuracy: 94.400000

B. On reduced Dimensions using Fisher Discriminant Analysis (FDA)-

- **K = 2**

  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	125	0	0
Class 2	0	125	0
Class 3	0	0	125

  - *Classification accuracy on test data*

Overall Accuracy: 100.00000
Class 1 Accuracy: 100.00000
Class 2 Accuracy: 100.000000
Class 3 Accuracy: 100.00000

- **K = 4**

  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	125	0	0
Class 2	0	125	0
Class 3	0	0	125

  - *Classification accuracy on test data*

Overall Accuracy: 100.00000
Class 1 Accuracy: 100.00000
Class 2 Accuracy: 100.000000
Class 3 Accuracy: 100.00000

- **K = 6**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	125	0	0
Class 2	0	125	0
Class 3	0	0	125

  - *Classification accuracy on test data*

Overall Accuracy: 100.00000
Class 1 Accuracy: 100.00000
Class 2 Accuracy: 100.000000
Class 3 Accuracy: 100.00000

- **K = 8**
  - *Confusion Matrix based on performance for test data*

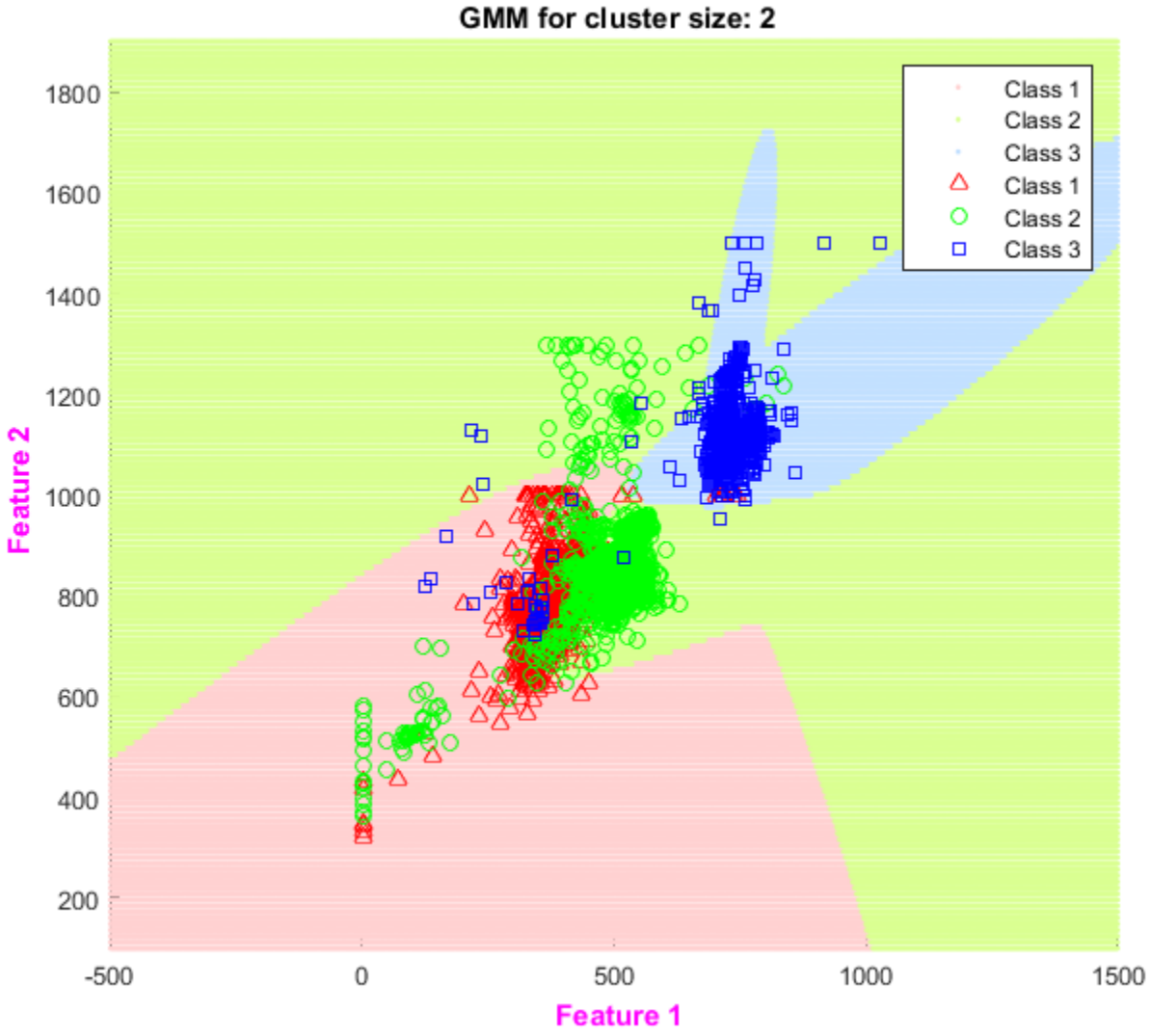
Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	125	0	0
Class 2	0	125	0
Class 3	0	0	125

  - *Classification accuracy on test data*

Overall Accuracy: 100.00000
Class 1 Accuracy: 100.00000
Class 2 Accuracy: 100.000000
Class 3 Accuracy: 100.00000

2. For Dataset 2(a)-

A. *On actual Dimensions*



*Decision region plot for all the **real world speech data** of 3 classes together with the training data superposed for cluster size **2***

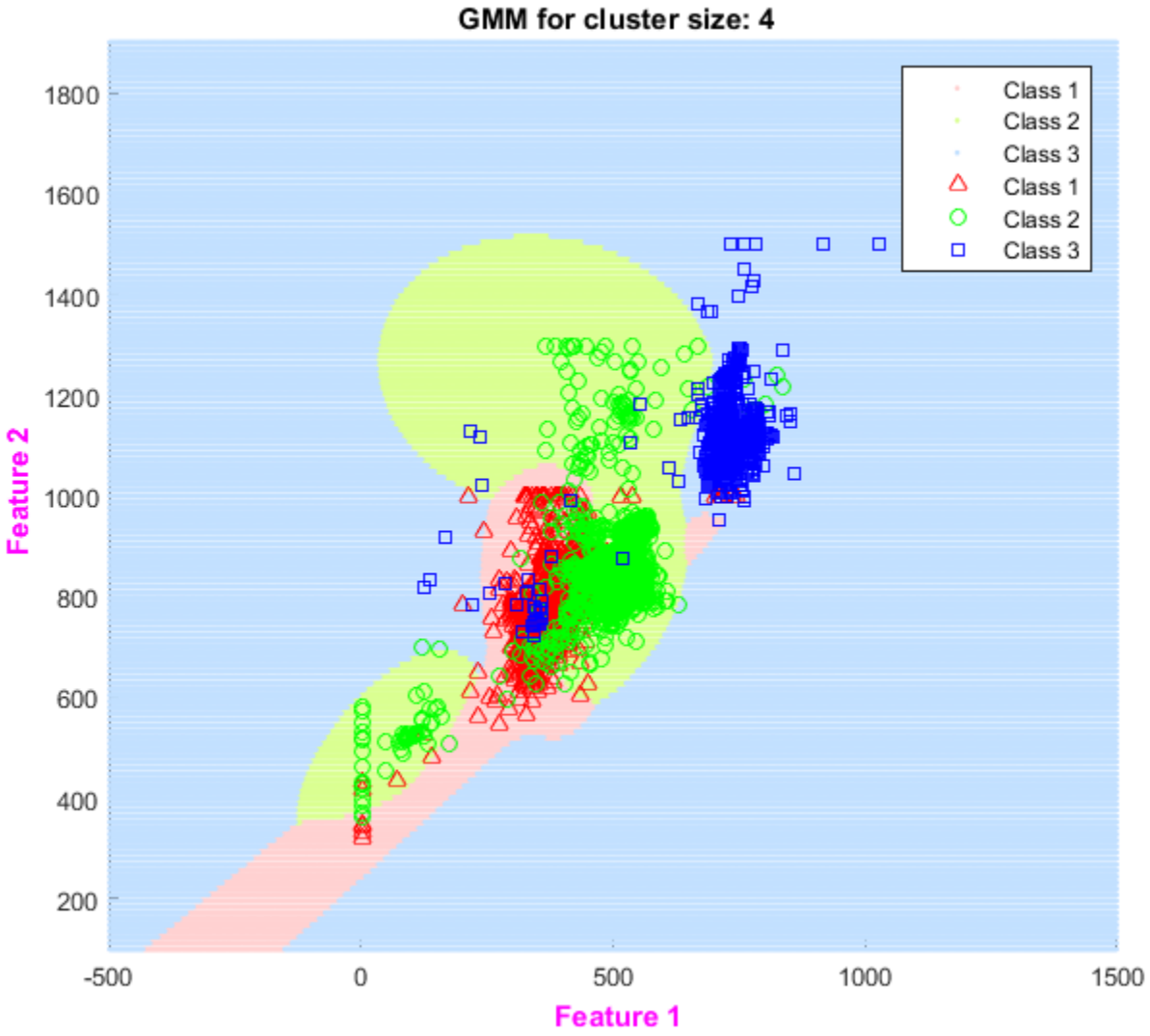
- *Confusion Matrix based on performance for test data-*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	583	32	7
Class 2	135	477	2
Class 3	24	16	501

- *Classification accuracy on test data –*

Overall Accuracy – 87.8447
Classifier Accuracy for class 1 – 93.7299
Classifier Accuracy for class 2 – 77.6873
Classifier Accuracy for class 3 – 92.6063

*Decision region plot for all the **real world speech data** of 3 classes together with the training data superposed for cluster size **2***



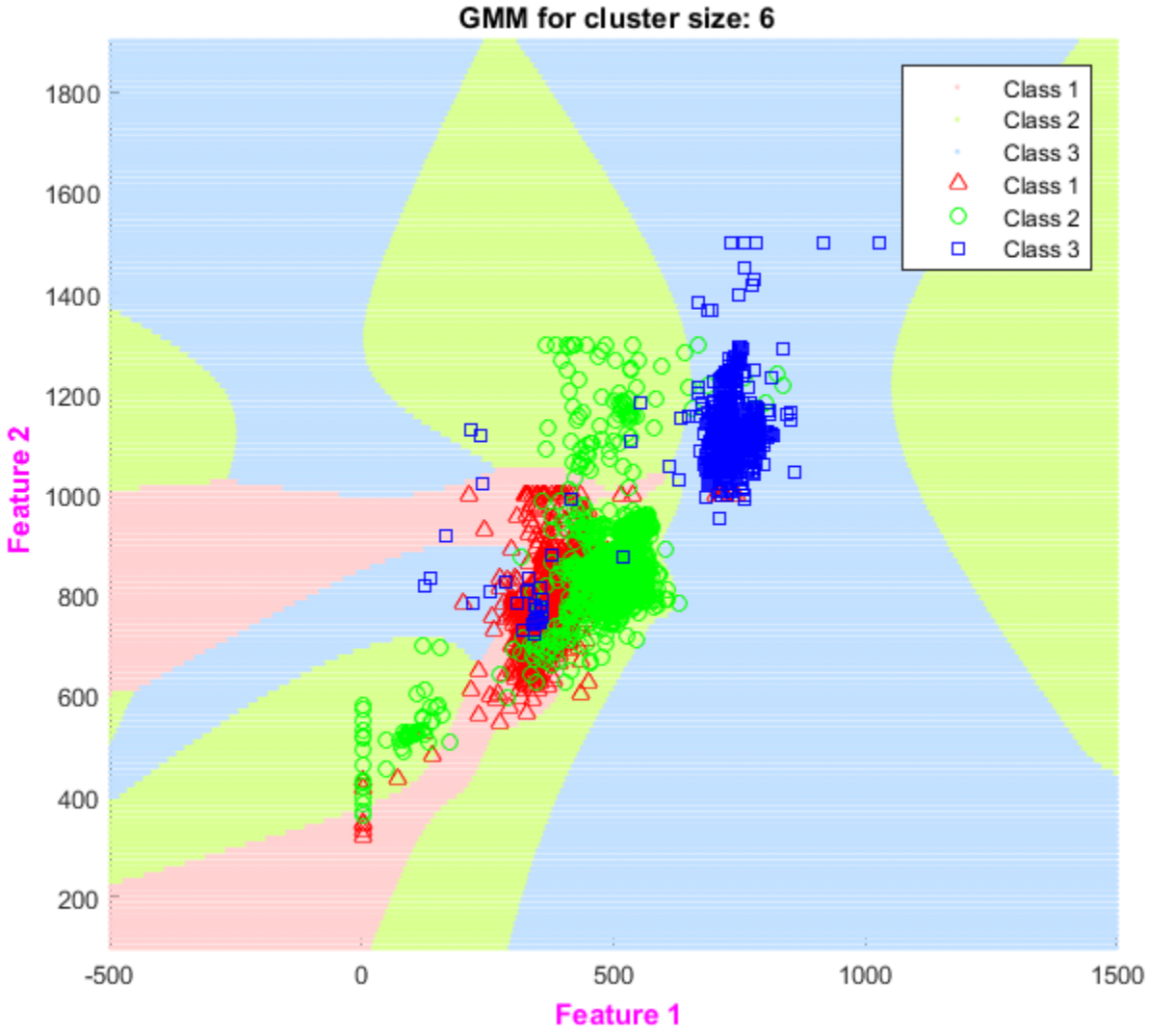
- *Confusion Matrix based on performance for test data-*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	572	38	12
Class 2	236	375	3
Class 3	16	13	512

- *Classification accuracy on test data –*

Overall Accuracy – 82.1047
Classifier Accuracy for class 1 – 91.9614
Classifier Accuracy for class 2 – 61.0749
Classifier Accuracy for class 3 – 94.6396

*Decision region plot for all the **real world speech data** of 3 classes together with the training data superposed for cluster size **6***



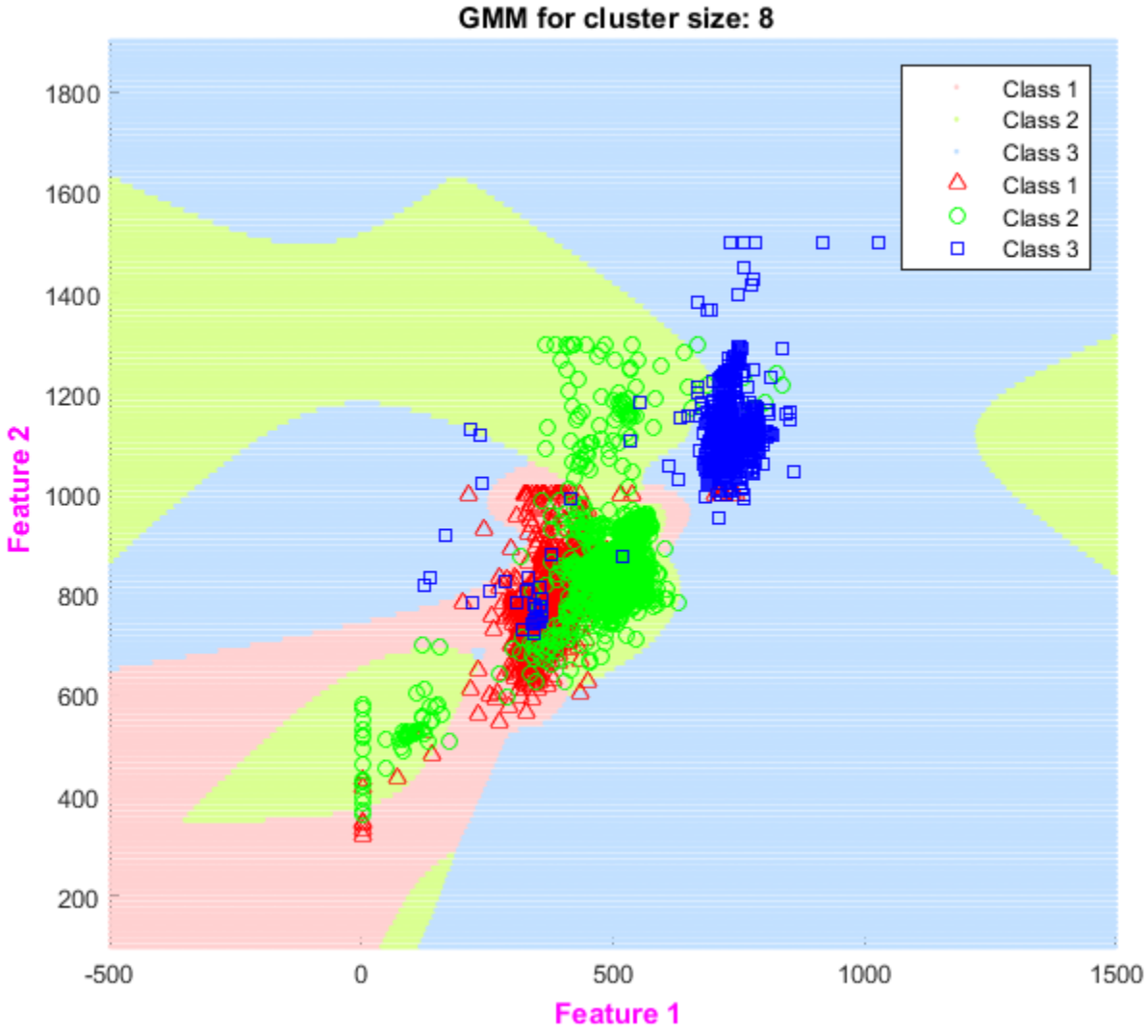
- *Confusion Matrix based on performance for test data-*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	548	37	37
Class 2	209	402	3
Class 3	23	7	511

- *Classification accuracy on test data –*

Overall Accuracy – 82.2172
Classifier Accuracy for class 1 – 88.1029
Classifier Accuracy for class 2 – 64.4723
Classifier Accuracy for class 3 – 94.4547

*Decision region plot for all the **real world speech data** of 3 classes together with the training data superposed for cluster size **8***



- *Confusion Matrix based on performance for test data-*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	575	38	9
Class 2	195	418	1
Class 3	15	13	513

- *Classification accuracy on test data –*

Overall Accuracy – 84.7496
Classifier Accuracy for class 1 – 92.4437
Classifier Accuracy for class 2 – 68.0782
Classifier Accuracy for class 3 – 94.8244

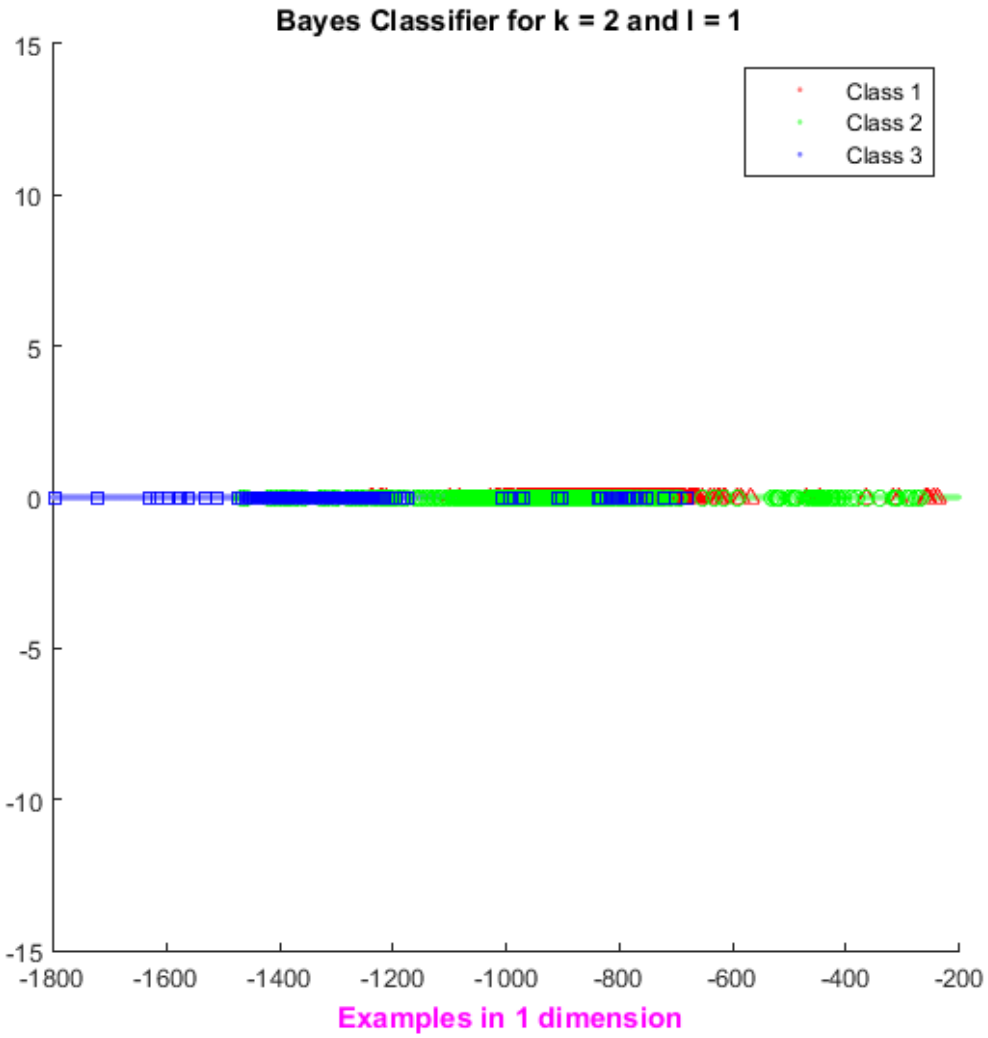
B. On reduced Dimensions using Principal Component Analysis (PCA)-

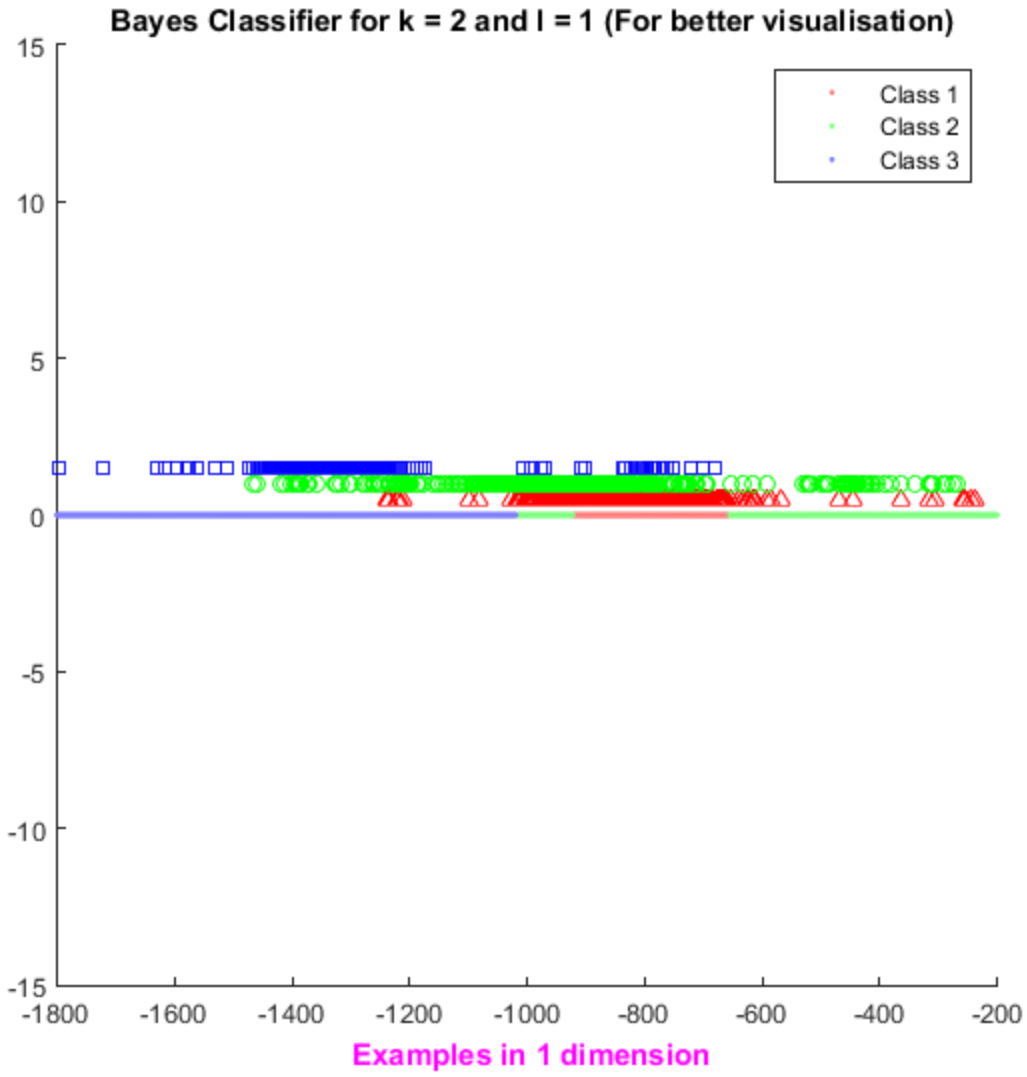
- **K = 2 and dimension reduction to 1**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	534	74	14
Class 2	271	282	61
Class 3	25	0	516

  - *Classification accuracy on test data*

Overall Accuracy: 74.957794
Class 1 Accuracy: 85.852090
Class 2 Accuracy: 45.928339
Class 3 Accuracy: 95.378928


Bayes Classifier for k = 2 and l = 1
Class 1
Class 2
Class 3
15
10
5
0
-5
-10
-15
-1800
-1600
-1400
-1200
-1000
-800
-600
-400
-200
Examples in 1 dimension

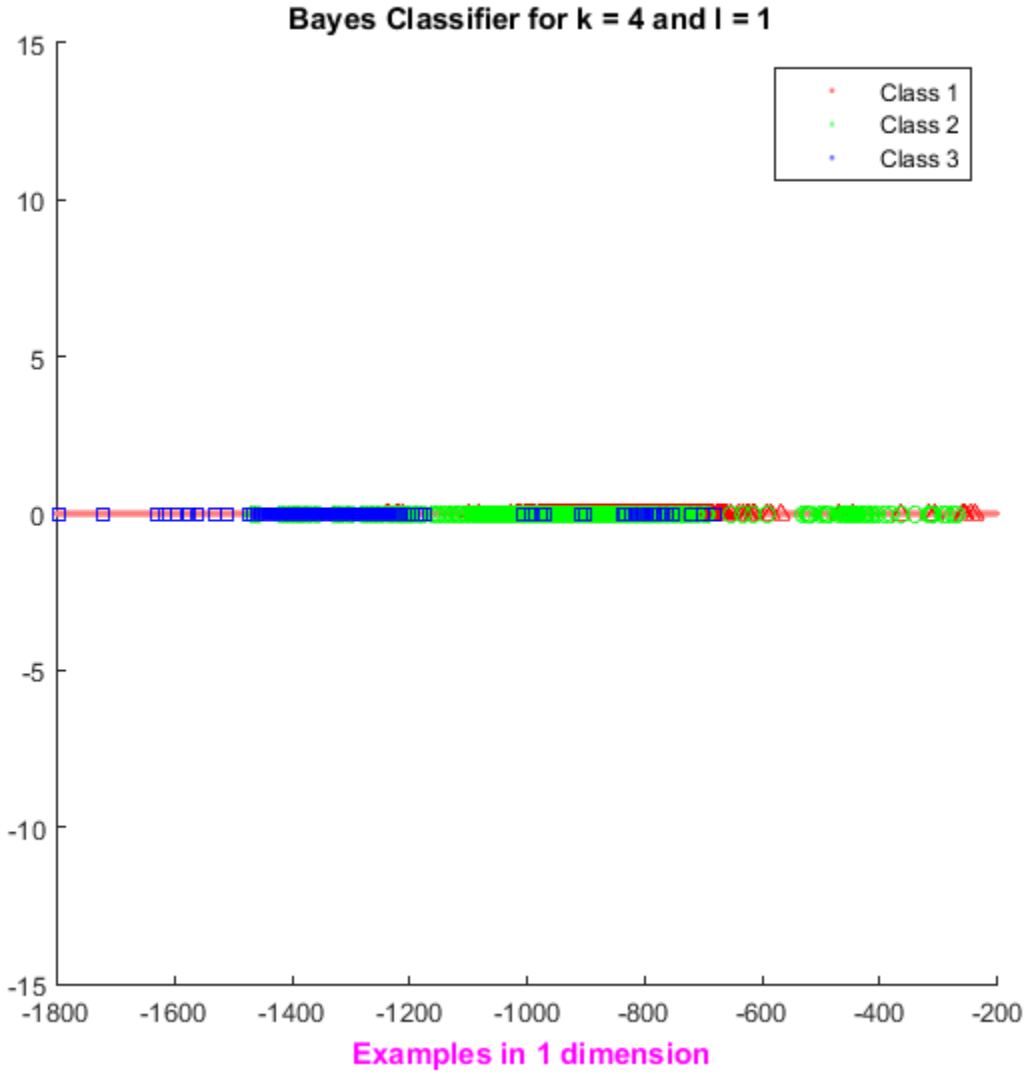


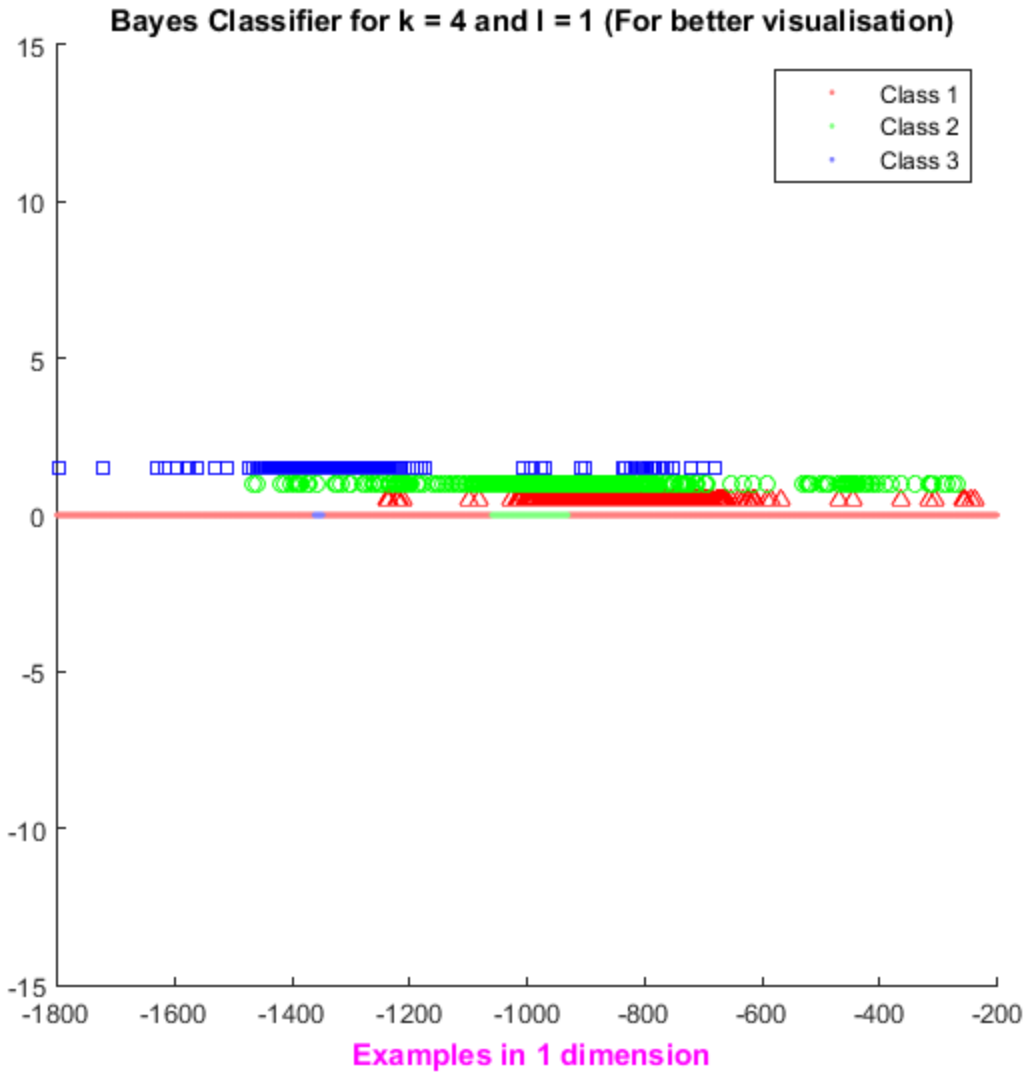
- **K = 4 and dimension reduction to 1**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	573	42	7
Class 2	265	305	44
Class 3	26	4	511

- *Classification accuracy on test data*

  Overall Accuracy: 78.16
  Class 1 Accuracy: 92.12
  Class 2 Accuracy: 49.67
  Class 3 Accuracy: 94.45



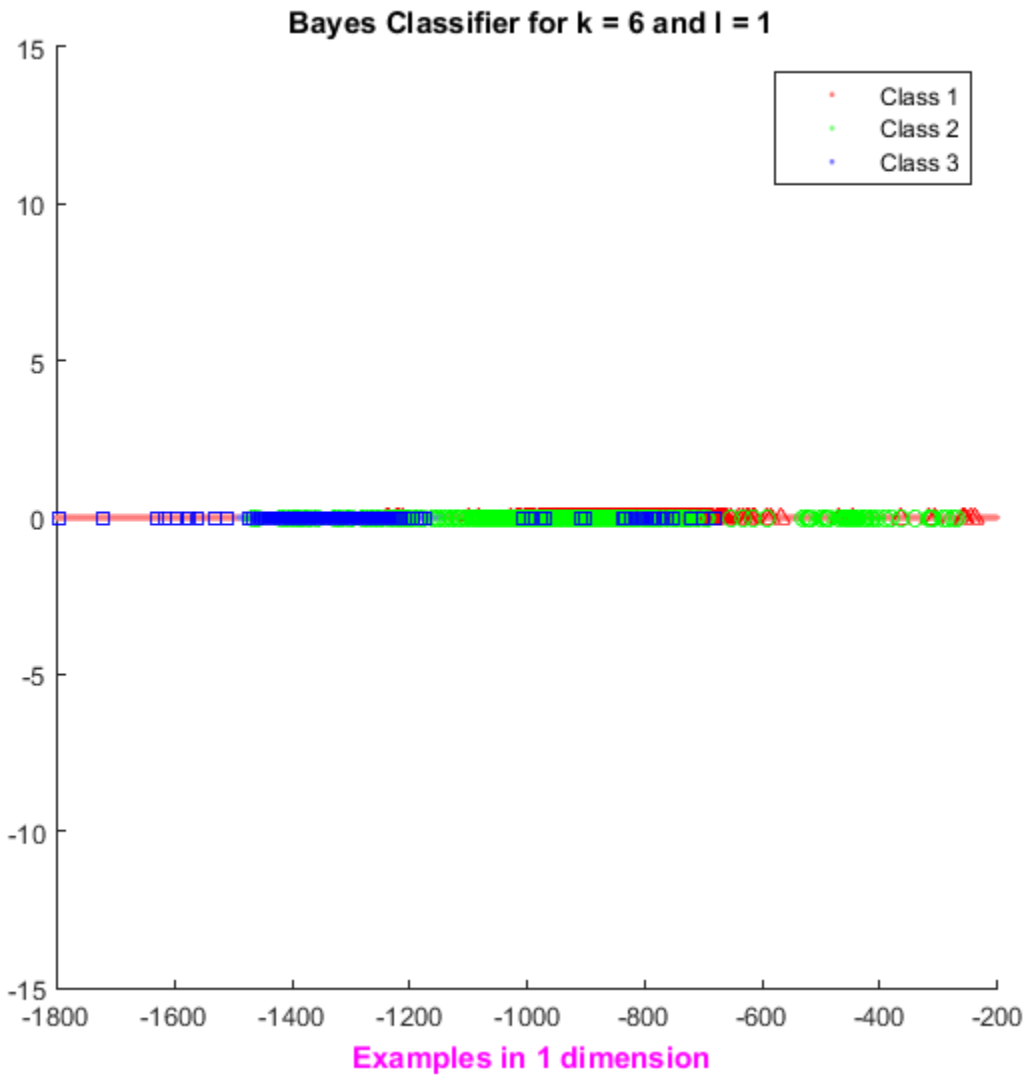


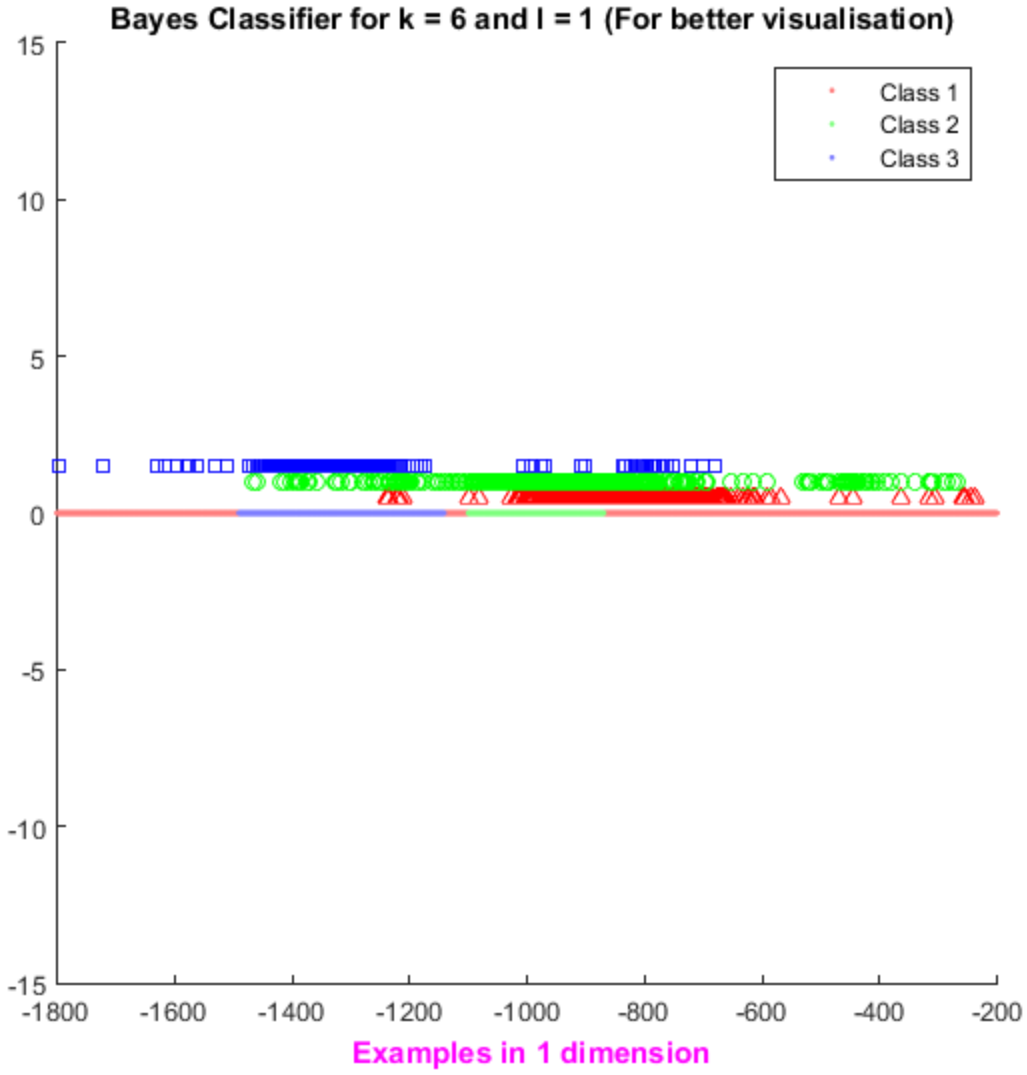
- **K = 6 and dimension reduction to 1**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	570	45	7
Class 2	126	445	43
Class 3	34	5	502

- *Classification accuracy on test data*

Overall Accuracy: 85.368599
Class 1 Accuracy: 91.639871
Class 2 Accuracy: 72.475570
Class 3 Accuracy: 92.791128




Bayes Classifier for k = 6 and l = 1 (For better visualisation)
Class 1
Class 2
Class 3
15
10
5
0
-5
-10
-15
-1800
-1600
-1400
-1200
-1000
-800
-600
-400
-200
Examples in 1 dimension

C. On reduced Dimensions using Fisher Discriminant Analysis (PCA)-

- **K = 2**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	571	48	3
Class 2	183	410	21
Class 3	18	12	511

  - *Classification accuracy on test data*

Overall Accuracy: 0.839617
Class 1 Accuracy: 0.918006
Class 2 Accuracy: 0.667752
Class 3 Accuracy: 0.944547

- **K = 4**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	577	43	2
Class 2	226	374	14
Class 3	19	13	509

  - *Classification accuracy on test data*

Overall Accuracy: 82.1609
Class 1 Accuracy: 92.7653
Class 2 Accuracy: 60.9121
Class 3 Accuracy: 94.0850

- **K = 6**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	561	51	10
Class 2	205	396	13
Class 3	17	16	508

  - *Classification accuracy on test data*

Overall Accuracy: 82.442319
Class 1 Accuracy: 90.192926
Class 2 Accuracy: 64.495114
Class 3 Accuracy: 93.900185

3. For Dataset 2(b)-

A. On actual Dimensions

- Scene image data corresponding to 3 different classes

(A 23-dimensional feature vector is extracted from local blocks of an image for a particular scene. The 23-dimensional features include color histogram, edge directed histograms and entropy of wavelet coefficients. Each scene image is represented as a collection of 23-dimensional local feature vectors.)

FOR CLUSTER SIZE 2

- *Confusion Matrix based on performance for test data-*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	40	19	6
Class 2	4	55	14
Class 3	27	16	46

- *Classification accuracy on test data –*

Overall Accuracy – 62.1145
Classifier Accuracy for class 1 – 61.5385
Classifier Accuracy for class 2 – 75.3425
Classifier Accuracy for class 3 – 51.6854

FOR CLUSTER SIZE 8

- *Confusion Matrix based on performance for test data-*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	53	11	1
Class 2	5	58	10
Class 3	29	15	45

- *Classification accuracy on test data –*

Overall Accuracy – 67.8414
Classifier Accuracy for class 1 – 81.5385

Classifier Accuracy for class 2 – 79.4521
Classifier Accuracy for class 3 – 50.5618

FOR CLUSTER SIZE 16

- *Confusion Matrix based on performance for test data-*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	47	15	3
Class 2	4	51	18
Class 3	10	08	71

- *Classification accuracy on test data –*

Overall Accuracy – 74.4493
Classifier Accuracy for class 1 – 72.3077
Classifier Accuracy for class 2 – 69.8630
Classifier Accuracy for class 3 – 79.7753

FOR CLUSTER SIZE 32

- *Confusion Matrix based on performance for test data-*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	52	11	2
Class 2	7	50	16
Class 3	18	6	65

- *Classification accuracy on test data –*

Overall Accuracy – 73.5683
Classifier Accuracy for class 1 – 80.0000
Classifier Accuracy for class 2 – 68.4932
Classifier Accuracy for class 3 – 73.0337

FOR CLUSTER SIZE 64

- *Confusion Matrix based on performance for test data-*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	56	9	0
Class 2	3	59	11
Class 3	20	9	60

- *Classification accuracy on test data –*

Overall Accuracy – 77.0925
Classifier Accuracy for class 1 – 86.1538
Classifier Accuracy for class 2 – 80.8219
Classifier Accuracy for class 3 – 67.4157

B. On reduced Dimensions using Principal Component Analysis (PCA)-

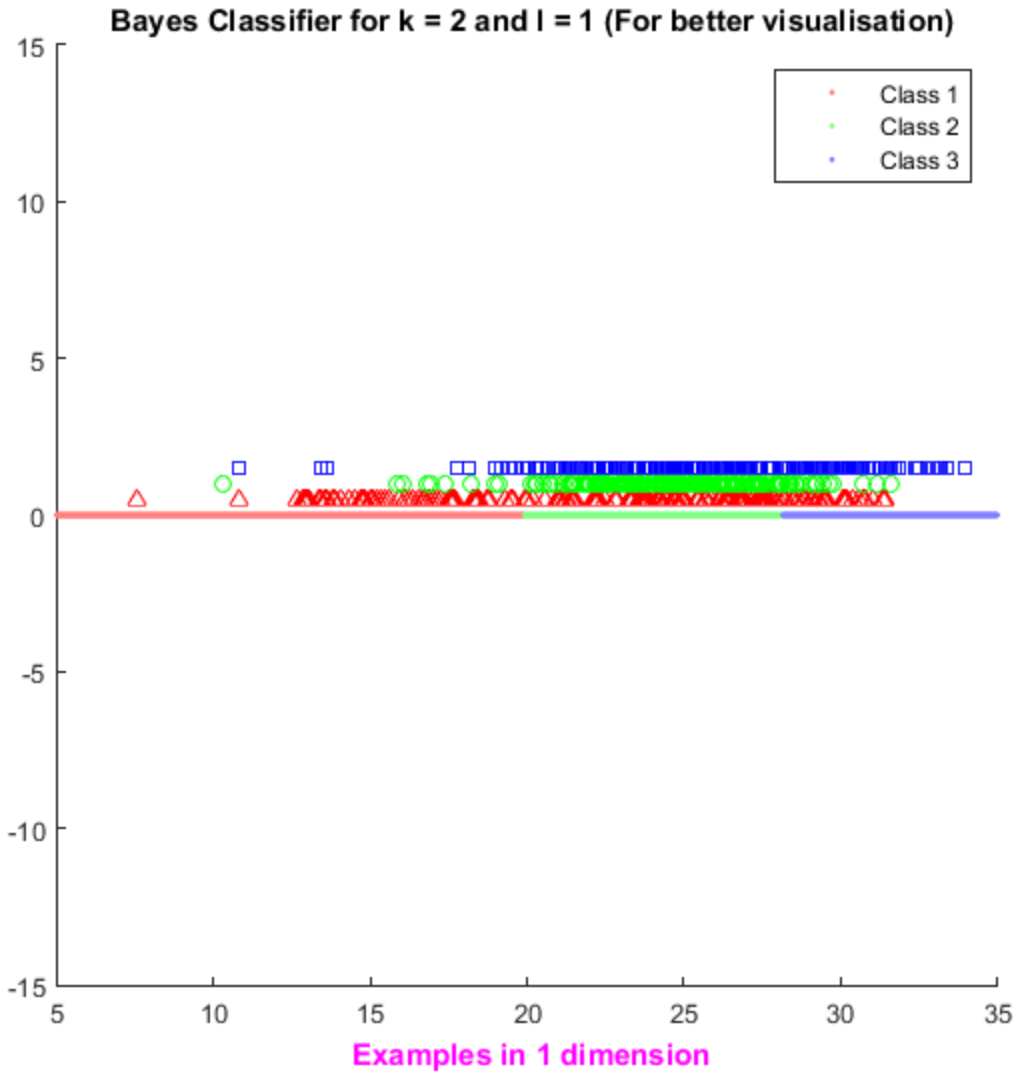
This dataset has three classes. This data has 828(in the form of a super vector) dimensions originally, after application of PCA the dimension was reduced to one and two.

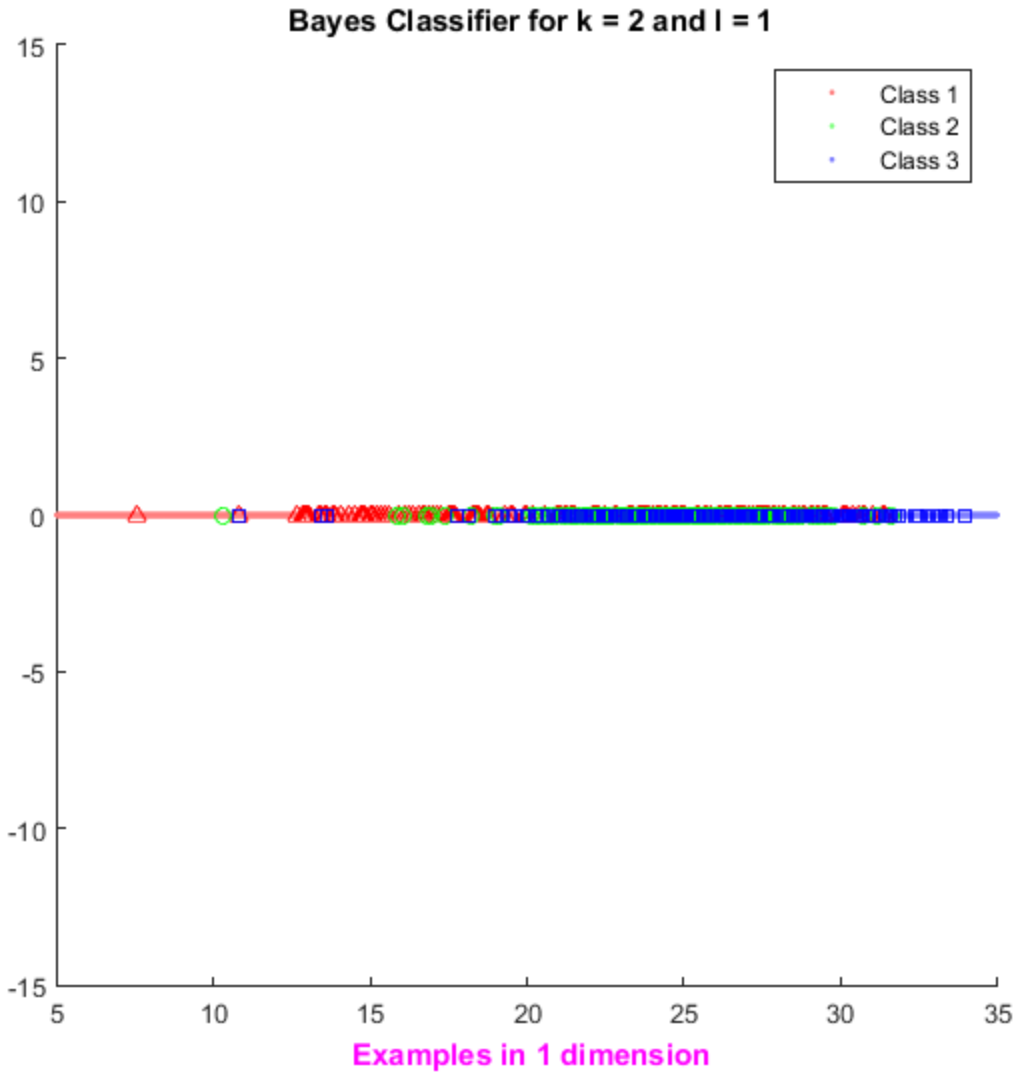
- **K = 2 and dimension reduction to 1**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	2	39	24
Class 2	8	56	9
Class 3	5	62	22

  - *Classification accuracy on test data*

Overall Accuracy: 35.242291
Class 1 Accuracy: 3.076923
Class 2 Accuracy: 76.712329
Class 3 Accuracy: 24.719101


Bayes Classifier for k = 2 and l = 1 (For better visualisation)
Class 1
Class 2
Class 3
15
10
5
0
-5
-10
-15
5
10
15
20
25
30
35
Examples in 1 dimension

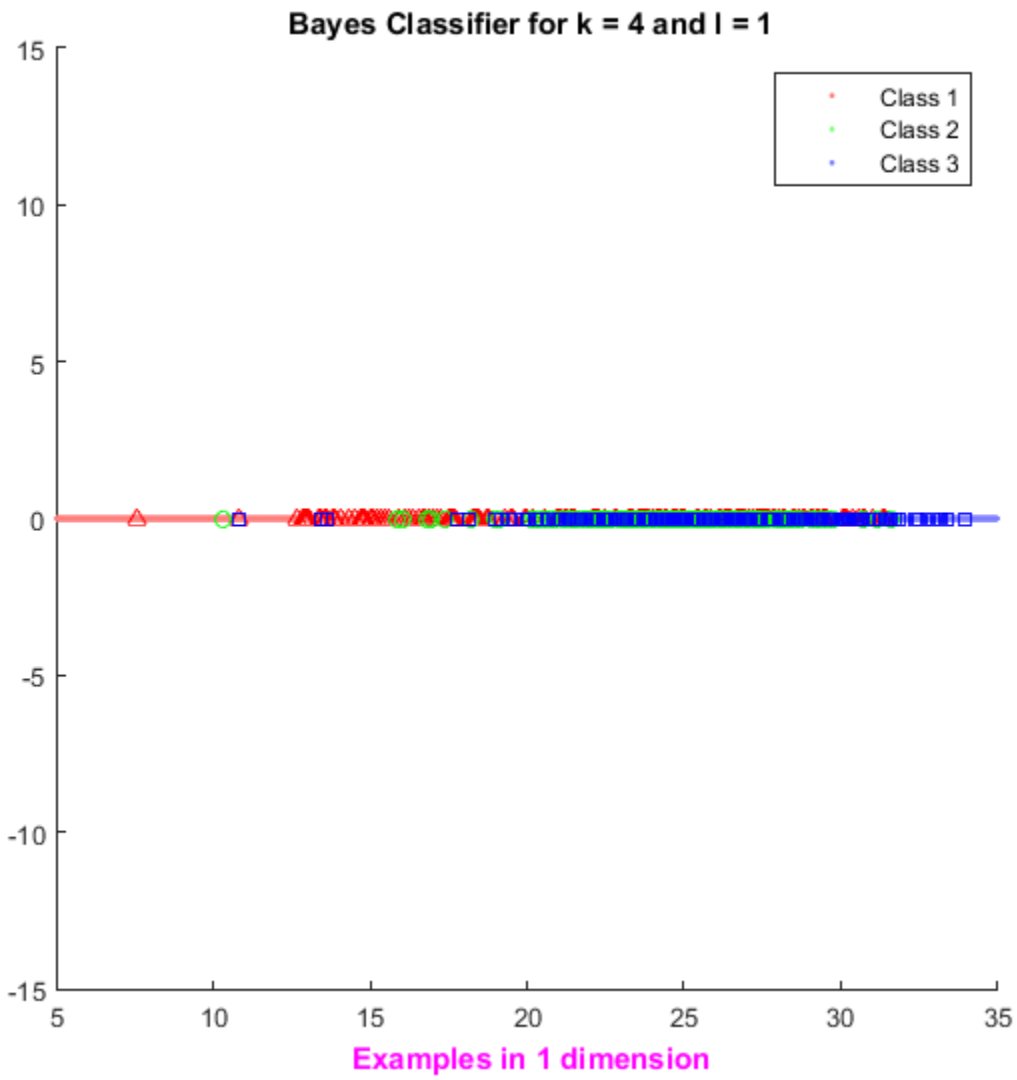


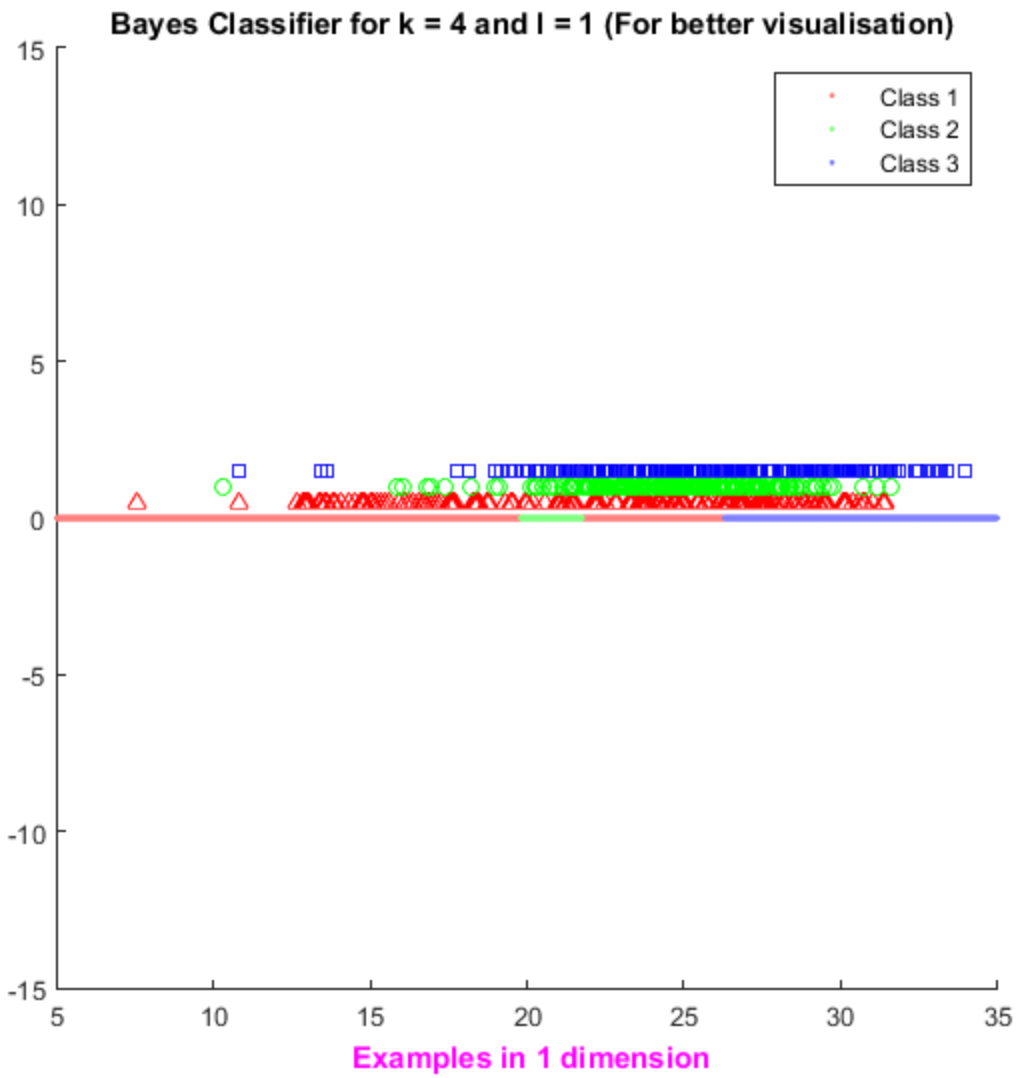
- **K = 4 and dimension reduction to 1**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	18	4	43
Class 2	45	4	24
Class 3	34	12	43

  - *Classification accuracy on test data*

Overall Accuracy: 28.634361
Class 1 Accuracy: 27.692308
Class 2 Accuracy: 5.479452
Class 3 Accuracy: 48.314607


Bayes Classifier for k = 4 and l = 1
Class 1
Class 2
Class 3
15
10
5
0
-5
-10
-15
5
10
15
20
25
30
35
Examples in 1 dimension

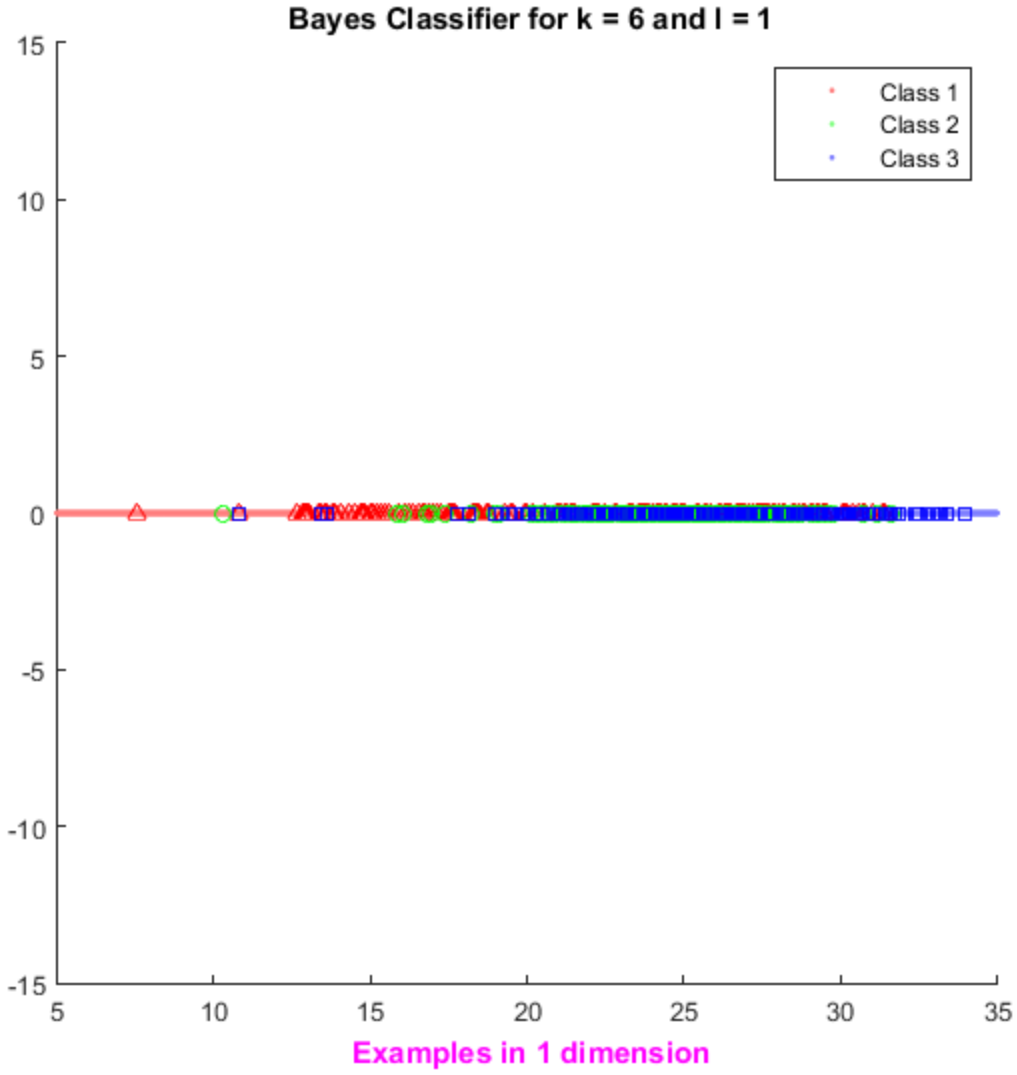


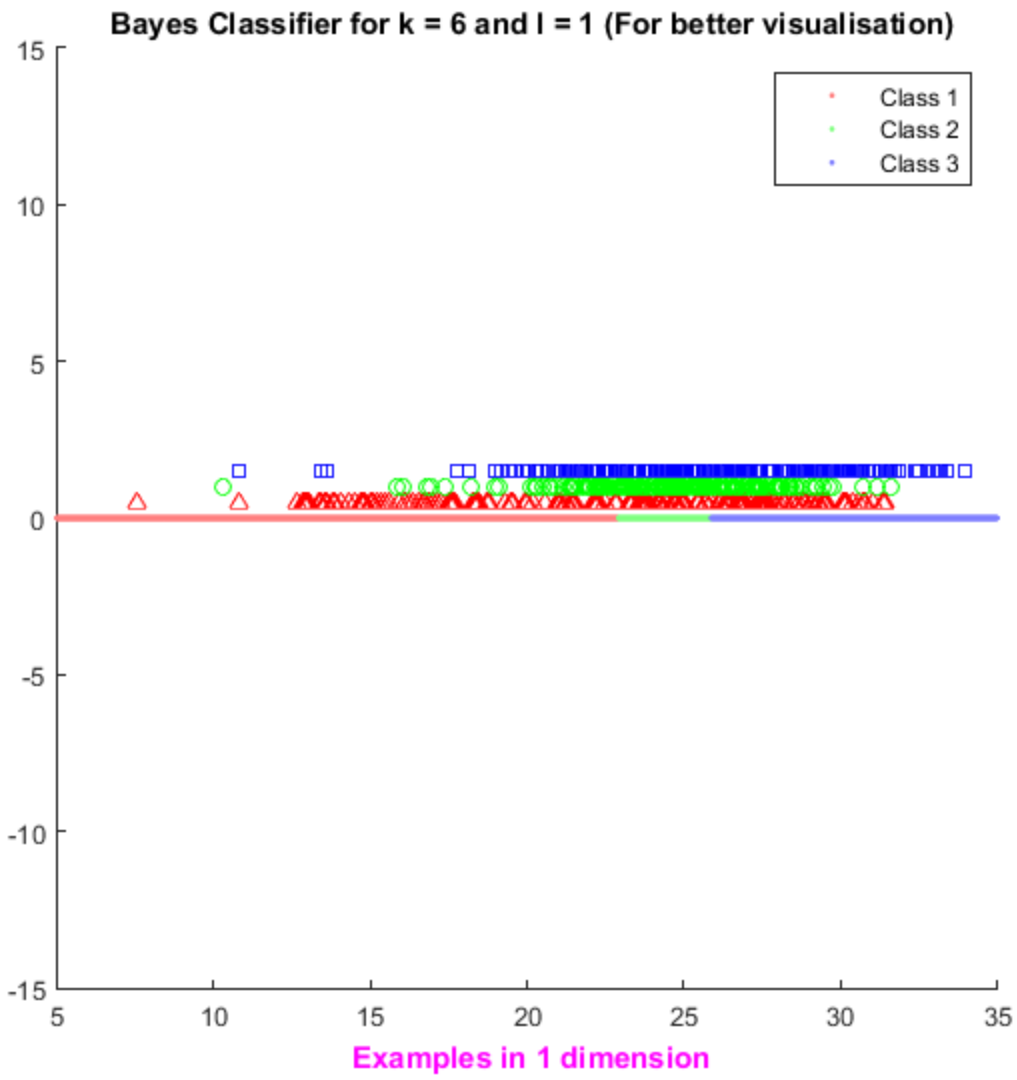
- **K = 6 and dimension reduction to 1**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	10	10	45
Class 2	15	31	27
Class 3	22	20	47

  - *Classification accuracy on test data*

Overall Accuracy: 38.766520
Class 1 Accuracy: 15.384615
Class 2 Accuracy: 42.465753
Class 3 Accuracy: 52.808989


Bayes Classifier for k = 6 and l = 1
Class 1
Class 2
Class 3
15
10
5
0
-5
-10
-15
5
10
15
20
25
30
35
Examples in 1 dimension

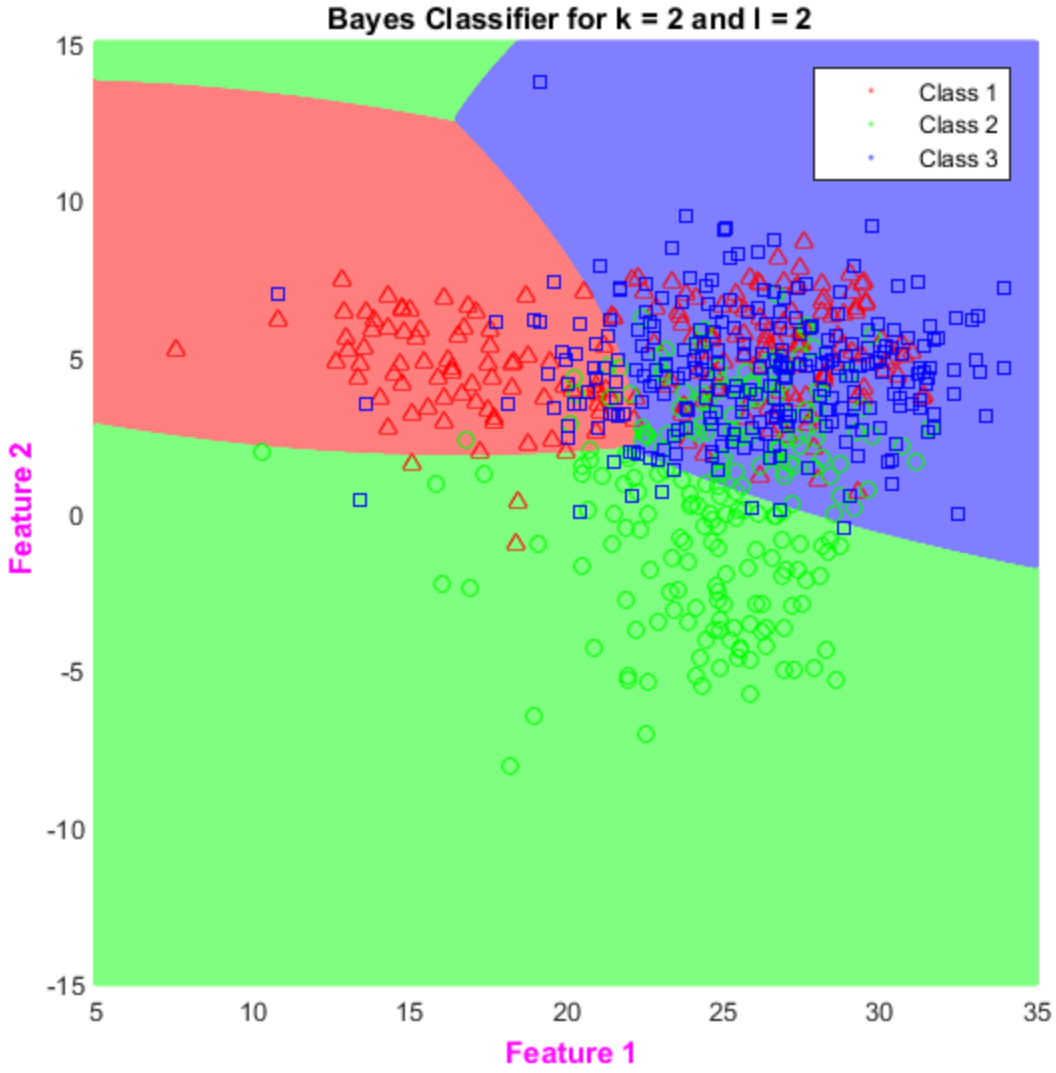


- **K = 2 and dimension reduction to 2**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	5	1	59
Class 2	6	30	37
Class 3	16	2	71

  - *Classification accuracy on test data*

Overall Accuracy: 46.696035
Class 1 Accuracy: 7.692308
Class 2 Accuracy: 41.095890
Class 3 Accuracy: 79.775281

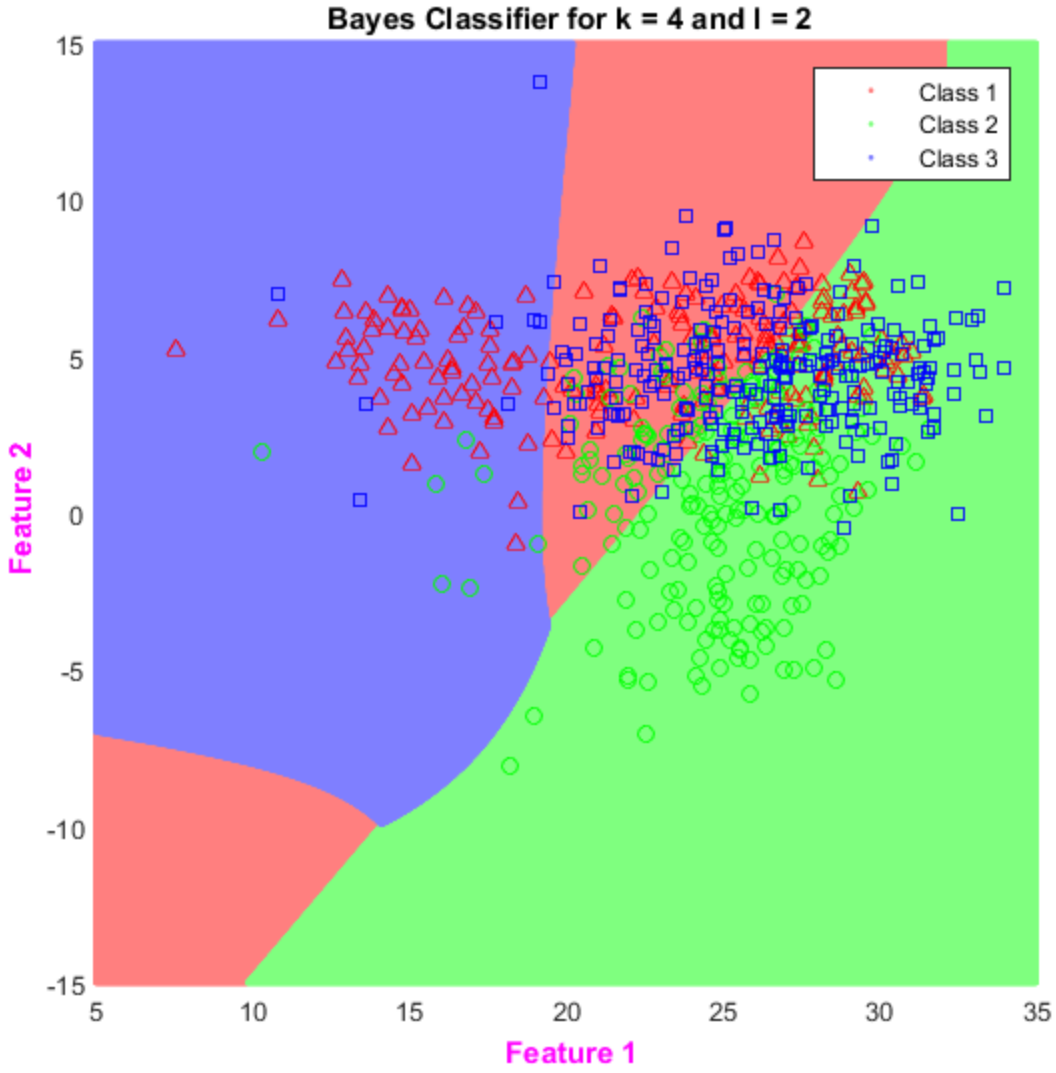


- **K = 4 and dimension reduction to 2**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	23	40	2
Class 2	19	47	7
Class 3	41	43	5

  - *Classification accuracy on test data*

Overall Accuracy: 33.039648
Class 1 Accuracy: 35.384615
Class 2 Accuracy: 64.383562
Class 3 Accuracy: 5.617978

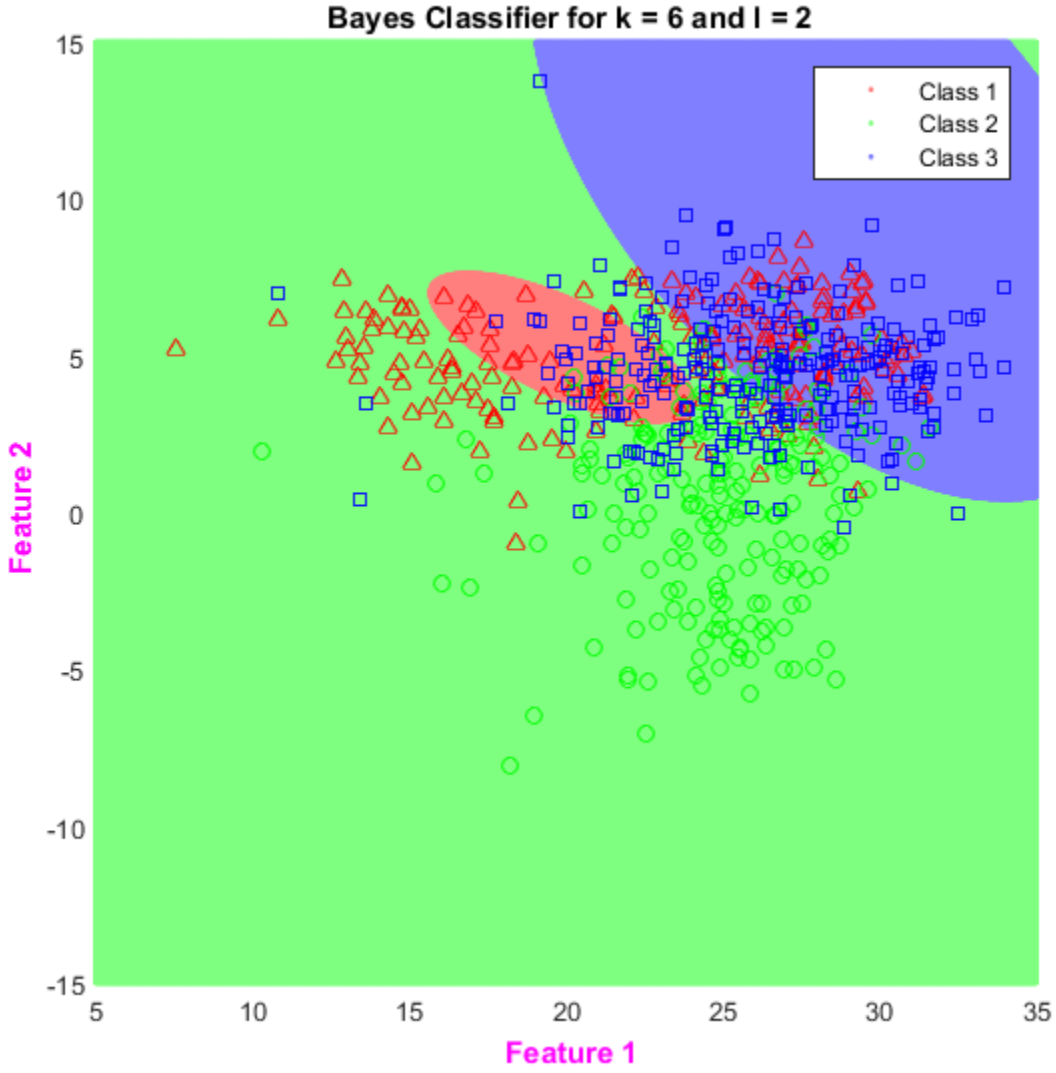


- **K = 6 and dimension reduction to 2**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	7	12	46
Class 2	5	57	11
Class 3	19	28	42

  - *Classification accuracy on test data*

Overall Accuracy: 46.696035
Class 1 Accuracy: 10.769231
Class 2 Accuracy: 78.082192
Class 3 Accuracy: 47.191011


Bayes Classifier for k = 6 and l = 2
Class 1
Class 2
Class 3
Feature 1
Feature 2
15
10
5
0
-5
-10
-15
5
10
15
20
25
30
35

C. <u>On reduced Dimensions using Fisher Discriminant Analysis (PCA)-</u>

- **K = 2**
  - *<u>Confusion Matrix based on performance for test data</u>*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	33	21	11
Class 2	21	32	20
Class 3	38	12	39

  - *<u>Classification accuracy on test data</u>*

Overall Accuracy: 0.458150
Class 1 Accuracy: 0.507692
Class 2 Accuracy: 0.438356
Class 3 Accuracy: 0.438202

- **K = 4**
  - *<u>Confusion Matrix based on performance for test data</u>*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	25	26	14
Class 2	20	31	22
Class 3	30	13	46

  - *<u>Classification accuracy on test data</u>*

Overall Accuracy: 0.449339
Class 1 Accuracy: 0.384615
Class 2 Accuracy: 0.424658
Class 3 Accuracy: 0.516854

- **K = 8**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	29	22	14
Class 2	20	30	23
Class 3	31	13	45

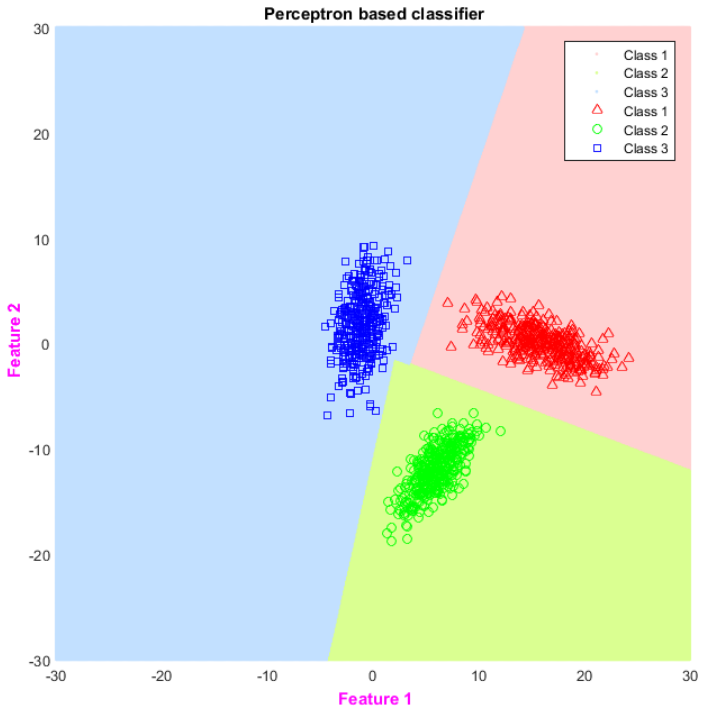
  - *Classification accuracy on test data*

Overall Accuracy: 0.458150
Class 1 Accuracy: 0.446154
Class 2 Accuracy: 0.410959
Class 3 Accuracy: 0.505618

III. Perceptron classifier–

1. For Dataset 1(a)-

- *Decision region plot for all the classes together with the training data superposed –*



- *Confusion Matrix based on performance for test data-*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	125	0	0
Class 2	0	125	0
Class 3	0	0	125

- *Classification accuracy on test data –*

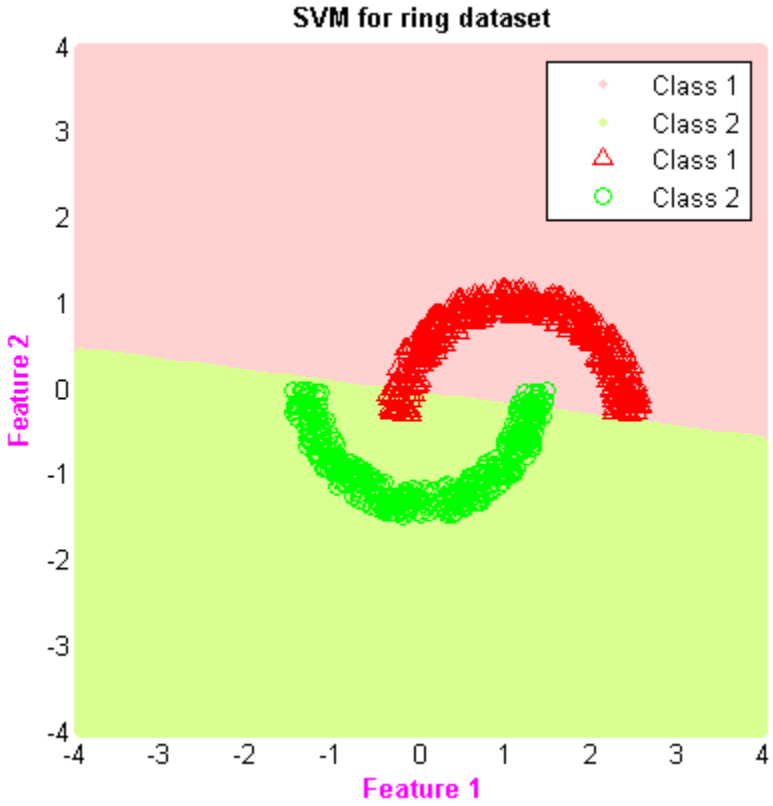
Overall Accuracy – 100.0000
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 100.0000
Classifier Accuracy for class 3 – 100.0000

IV. Support Vector Machine (SVM) based classifier -

1. For Dataset 1(b)-

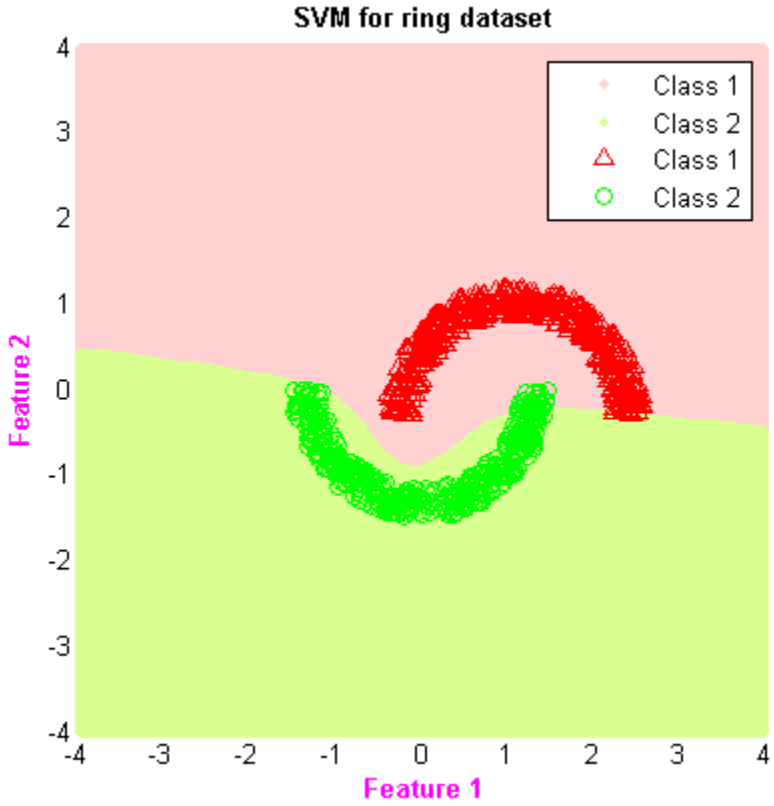
A. Interlock Classes –

a) Linear Kernel



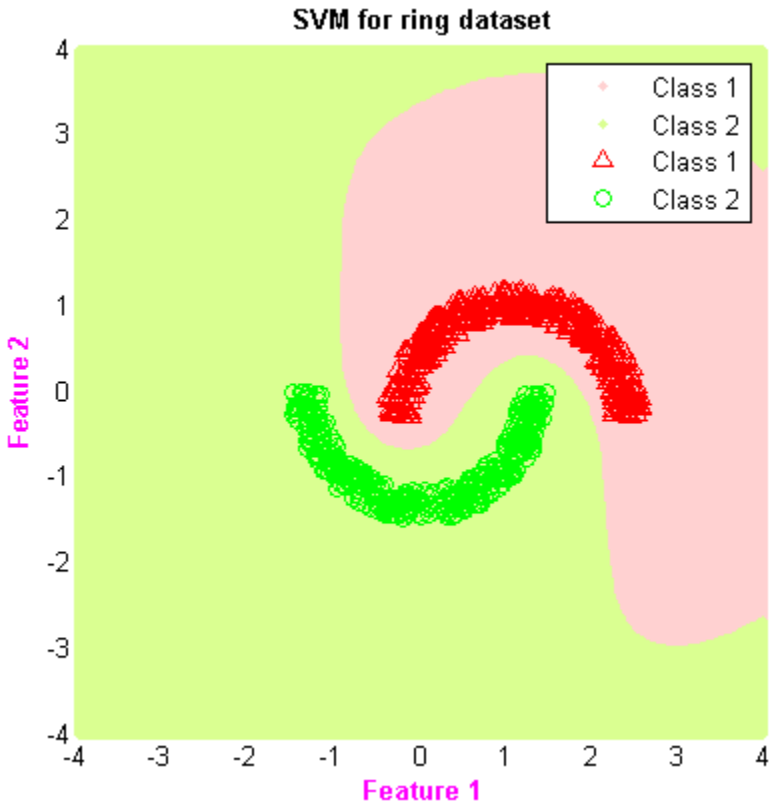
Overall Accuracy =96.8

b) Polynomial Kernel -



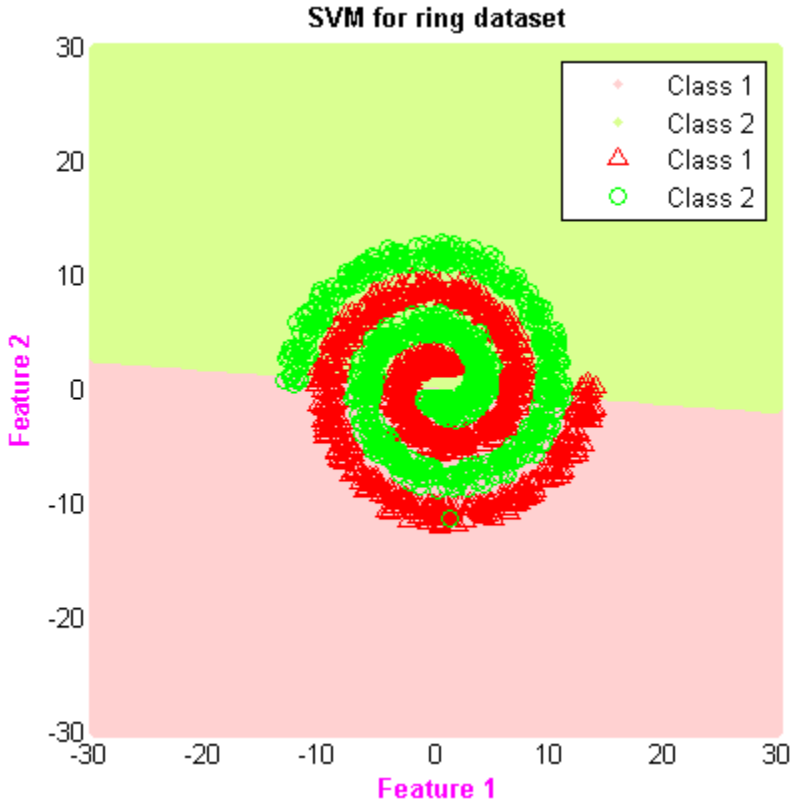
Overall Accuracy = 98.4

c) Gaussian Kernel



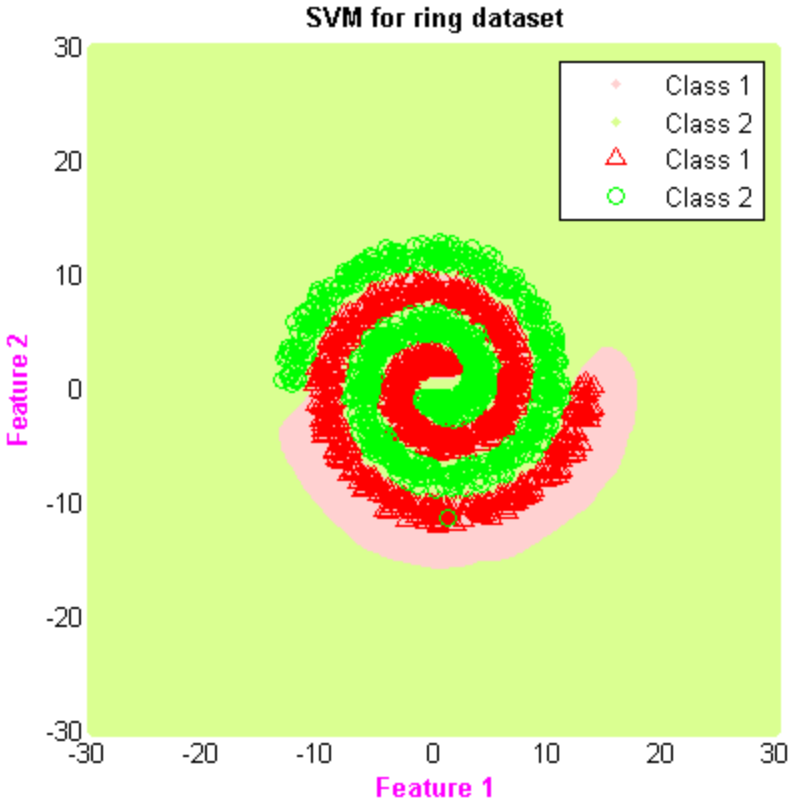
B. Spiral Classes –

a) Linear Kernel –



Overall Accuracy = 53.681

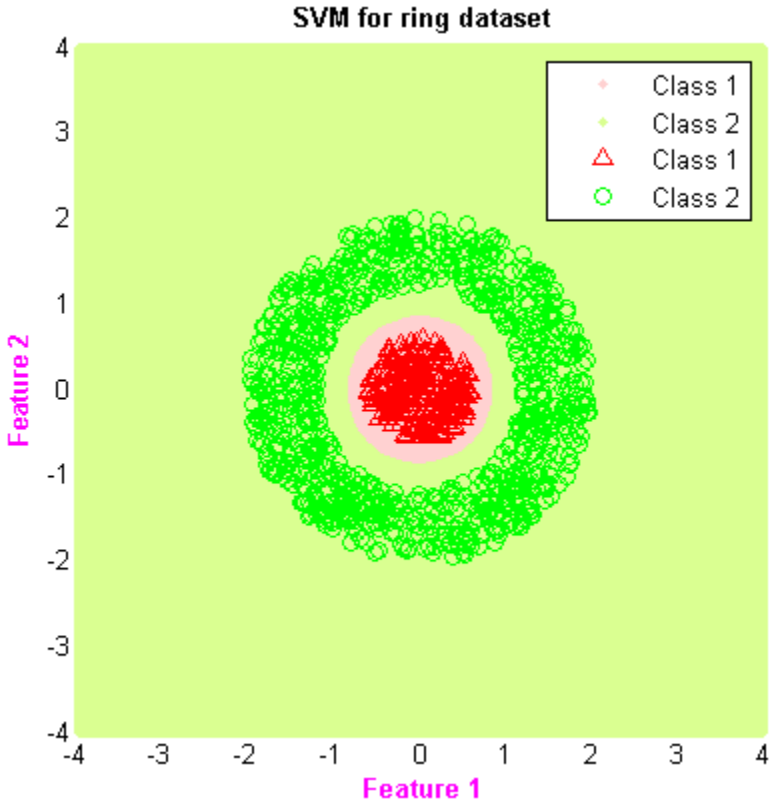
a) Gaussian Kernel –



Overall Accuracy – 100.000

A. Ring Classes –

a) Gaussian Kernel -



Overall Accuracy – 100.000