Pattern Recognition
CS669

ASSIGNMENT 4 COMPLETE
(INDIVIDUAL)

Fisher linear discriminant analysis
Perceptron-based classifier
SVM-based classifier

Group Number 8

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1. Problem Description

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.

Data-sets:

- Data-set 1: 2-dimensional artificial data of 3 classes:
  - Linearly separable data set
  - Non-linearly separable data set
- Data-set 2: 32-dimensional BoVW representation of scene images

Data-set-1 75% of data of a class is to be used as training data for that class, and the remaining data is to be used as test data for that class.

Classifiers:

1. Reduce dimensions of data in the direction of maximum separability using(FDA) and Build Bayes classifier using both unomodal gaussian and GMM to classify data points of given test data-sets.
2. Build perceptron based classifier for dataset(1a) which is linearly separable and then train model using training set and check accuracy on test dataset.
3. Build SVM based classifier for given datasets and use training dataset for training and test dataset for checking performance. We have to build SVM-based classifier using (a) linear kernel, (b) polynomial kernel and (c) Gaussian/RBF kernel .

Objective:

1. Build classifiers to classify data points of given data-sets on the basis of specified classifiers.
2. For each classifier and each data-set we do :
   - Classification accuracy, precision for every class, mean precision, recall for every class, mean recall, F-measure for every class and mean F-measure on test data.
   - Confusion matrix based on the performance for test data.
   - In case of Fisher Linear Discriminant Analysis plot of reduced dimensional data.

2. Solution Approach

In Fisher Linear Discriminant Analysis(FDA) i take two classes in pair and then i calculated direction in which data of both classes most separable(Maximum separable direction) so that we can reduce dimension in that direction.
Direction is given by:

$$\overline{w} = \lambda \mathbf{S}_w^{-1}(\overline{u}_+ - \overline{u}_-), \tag{2..1}$$

where,λ is constant and $\mathbf{S}_w$ is total scatter matrix of classes and $\overline{u}_+$ is mean of positive classes and $\overline{u}_-$ is mean of negative classes.We used here inverse of scatter matrix.

Then we projected data of both classes in this direction and then we got single dimensional reduce data by projection. Now we build Bayes classifier using unomodal Gaussian and GMM. In GMM we took different clusters and calculated accuracy on test data. For multiclass classification we used two classes pairwise and then we classify data point with respect to each pair and the class which came maximum time we predicted data point in that class.

In perceptron based classifier it makes linear boundary between classes.Boundary is given by:

$$g_i(\mathbf{x}) = \mathbf{w}_1\mathbf{x}_1 + \mathbf{w}_2\mathbf{x}_2 + \cdots + \mathbf{w}_d\mathbf{x}_d + \mathbf{w}_0, \tag{2..2}$$

where, $\mathbf{w}_d$ is feature corresponding to feature $\mathbf{x}_d$ and $\mathbf{w}_0$ is constant. Then we trained this perceptron based classifier by updating its weights in each iteration.In multiclass classification case we can use one-vs-all method or one-vs-one method using voting.

A Support Vector Machine (SVM) is a discriminative classifier defined by a separating hyper plane. we trains SVM machine by training data and then classify new examples accordingly. it is a maximum margin hyper plane for separating linearly separable patterns.In two dimensional space this hyper plane is a line dividing a plane in two parts.In non-linearly separable patterns we use kernels.By using kernels we transform data in higher dimensional space and expected to be helpful in conversion of non-linearly separable data to linearly separable data.Here i used linear kernel,polynomial kernel and Gaussian kernel.

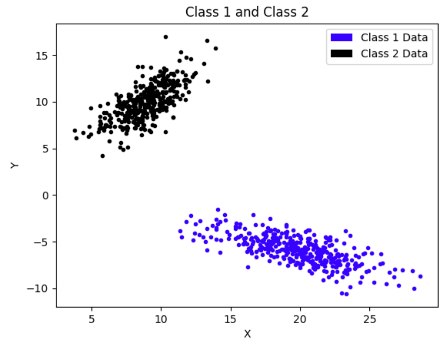
Note: In all the plots, feature 1 and feature 2 are represented on the X-axis and the Y-axis respectively.

3. Results and Plots

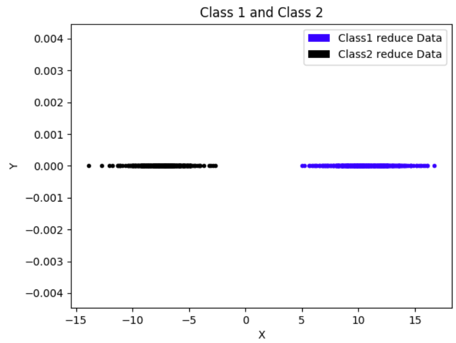
1 FDA based Classifier using uni modal Gaussian and GMM

1.1 Linear Data 1(a)

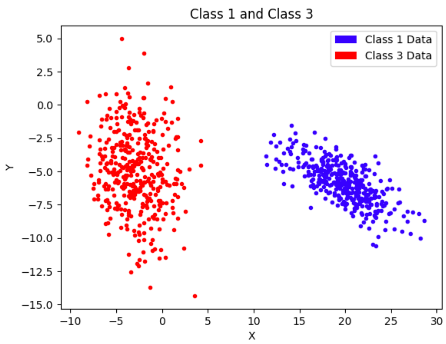
Training Data and Reduce training data plot



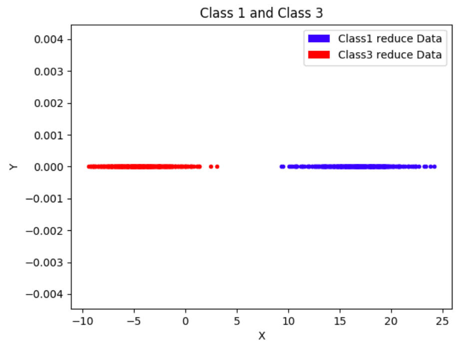
(a) Training data Class 1 and 2



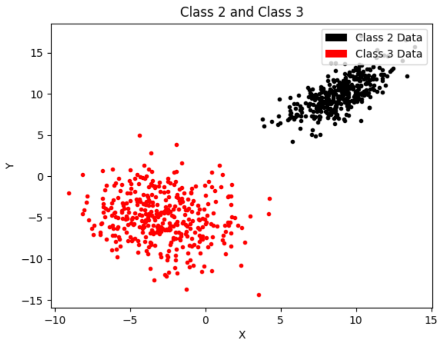
(b) Reduce Training data Class 1 and 2



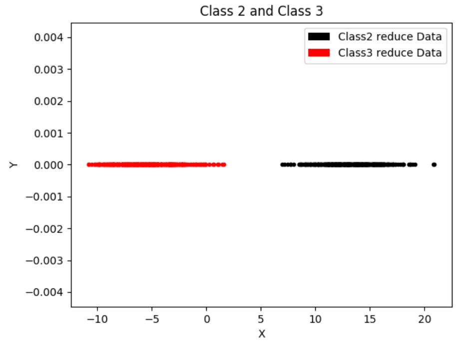
(a) Training data Class 1 and 3



(b) Reduce Training data Class 1 and 3



(a) Training data Class 2 and 3



(b) Reduce Training data Class 2 and 3

Figure 3..3. Linear Data1(a)

Here(in above figure) we observe that Reduce dimensional data (one dimensional) obtained by applying fisher linear discriminant analysis on Linear separable data(data set(1a)) is clearly separable by a point.So we can conclude that if class data is linear separable than its reduce dimensional data obtain using fda will also linearly(by point) separable.

Uni modal Gaussian Classifier for Reduce Linear Data(1a)

	Class1	Class 2
Class1	125	0
Class2	0	125

(a) Confusion Matrix

	Class1	Class2
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..1. Linear Reduce Data(Unomodal Classifier): Class 1 and Class 2

	Class1	Class 3
Class1	125	0
Class3	0	125

(a) Confusion Matrix

	Class1	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..2. Linear Reduce Data(Unomodal Classifier):
Class 1 and Class 3

	Class2	Class 3
Class2	125	0
Class3	0	125

(a) Confusion Matrix

	Class2	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..3. Linear Reduce Data(Unomodal Classifier):
Class 2 and Class 3

	Class1	Class2	Class 3
Class1	125	0	0
Class2	0	125	0
Class3	0	0	125

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F-Measure	1.0	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..4. Linear Reduce Data(Unomodal Gaussian) :
Class1 ,Class2 and Class3

GMM Classifier for Reduce Linear Data(1a)

	Class1	Class2	Class 3
Class1	125	0	0
Class2	0	125	0
Class3	0	0	125

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F-Measure	1.0	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..5. Linear Reduce Data(GMM Classifier,Clusters=1) : Class1 ,Class2 and Class3

	Class1	Class2	Class 3
Class1	125	0	0
Class2	0	125	0
Class3	0	0	125

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F-Measure	1.0	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..6. Linear Reduce Data(GMM Classifier,Clusters=2) : Class1 ,Class2 and Class3

	Class1	Class2	Class 3
Class1	125	0	0
Class2	0	125	0
Class3	0	0	125

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F-Measure	1.0	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..7. Linear Reduce Data(GMM Classifier,Clusters=4) : Class1 ,Class2 and Class3

	Class1	Class2	Class 3
Class1	125	0	0
Class2	0	125	0
Class3	0	0	125

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F-Measure	1.0	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..8. Linear Reduce Data(GMM Classifier,Clusters=8) : Class1 ,Class2 and Class3

	Class1	Class2	Class 3
Class1	125	0	0
Class2	0	125	0
Class3	0	0	125

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F-Measure	1.0	1.0	1.0

(b) Analysis

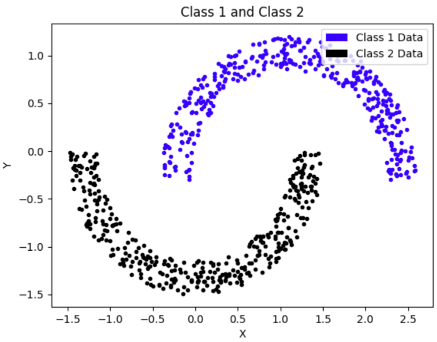
Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

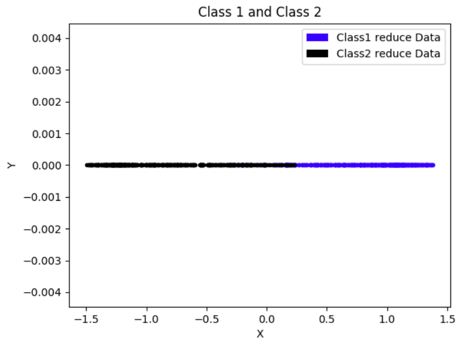
Table 3..9. Linear Reduce Data(GMM Classifier,Clusters=16) : Class1 ,Class2 and Class3

1.2 Non Linear Data 1(b)

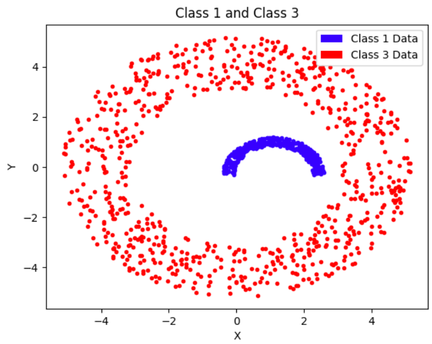
Training Data and Reduce training data plot



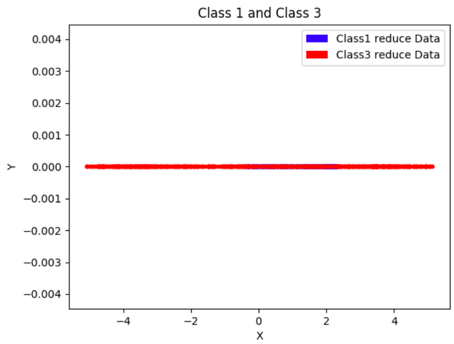
(a) Training data Class 1 and 2



(b) Reduce Training data Class 1 and 2

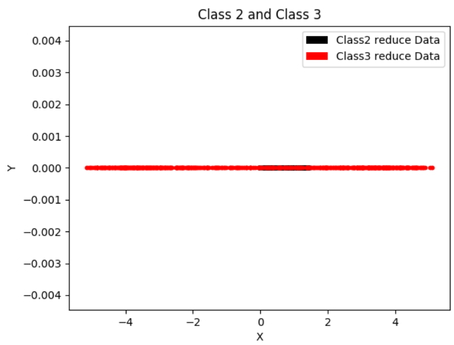


(c) Training data Class 1 and 3



(d) Reduce Training data Class 1 and 3

(e) Training data Class 2 and 3



(f) Reduce Training data Class 2 and 3

Figure 3..4. Non Linear Data1(b)

Here (in above figure) we observe that projected data of class1 and class2 is separable but not fully separable there is a overlapping region.class1 and class3 data is not separable class1 projected data come fully in class3 projected data similar for class2 and class3.So we can conclude that if data is not separable linearly than its projected data will also not be fully separable.

Uni modal Gaussian Classifier for Reduce Nonlinear Data(1b)

	Class1	Class 2
Class1	116	9
Class2	9	116

(a) Confusion Matrix

	Class1	Class2
Precision	0.928	0.928
Recall	0.928	0.928
F-Measure	0.928	0.928

(b) Analysis

Accuracy	92.8
mean precision	0.928
mean recall	0.928
mean F-Measure	0.928

(c) Result

Table 3..10. Reduce NonLinear Data(Unomodal Classifier): Class 1 and Class 2

	Class1	Class 3
Class1	112	13
Class3	56	194

(a) Confusion Matrix

	Class1	Class3
Precision	0.6667	0.9372
Recall	0.896	0.776
F-Measure	0.7645	0.849

(b) Analysis

Accuracy	81.6
mean precision	0.8019
mean recall	0.836
mean F-Measure	0.8068

(c) Result

Table 3..11. Reduce NonLinear Data(Unomodal Classifier): Class 1 and Class 3

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	Class2	Class 3
Class2	124	1
Class3	28	222

(a) Confusion Matrix

	Class2	Class3
Precision	0.8158	0.9955
Recall	0.992	0.888
F-Measure	0.8953	0.9387

(b) Analysis

Accuracy	92.27
mean precision	0.9057
mean recall	0.94
mean F-Measure	0.917

(c) Result

Table 3..12. Reduce NonLinear Data(Unomodal Classifier):
Class 2 and Class 3

	Class1	Class2	Class 3
Class1	112	9	4
Class2	9	116	0
Class3	60	21	169

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	0.6188	0.7945	0.9769
Recall	0.896	0.928	0.676
F-Measure	0.732	0.8561	0.7991

(b) Analysis

Accuracy	79.4
mean precision	0.7967
mean recall	0.8333
mean F-Measure	0.7957

(c) Result

Table 3..13. Reduce NonLinear Data(Unomodal Gaussian)
: Class1 ,Class2 and Class3

GMM Classifier for Reduce NonLinear Data(1a)

	Class1	Class2	Class 3
Class1	112	9	4
Class2	9	116	0
Class3	56	19	175

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	0.6328	0.8056	0.9777
Recall	0.896	0.928	0.7
F-Measure	0.7417	0.8625	0.8159

(b) Analysis

Accuracy	80.6
mean precision	0.8053
mean recall	0.8413
mean F-Measure	0.8067

(c) Result

Table 3..14. Reduce NonLinear Data(GMM Classifier,Clusters=1) : Class1 ,Class2 and Class3

	Class1	Class2	Class 3
Class1	116	9	0
Class2	9	116	0
Class3	63	21	166

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	0.617	0.7945	1.0
Recall	0.928	0.928	0.664
F-Measure	0.7412	0.8561	0.7981

(b) Analysis

Accuracy	79.6
mean precision	0.8038
mean recall	0.84
mean F-Measure	0.7985

(c) Result

Table 3..15. Reduce NonLinear Data(GMM Classifier,Clusters=2) : Class1 ,Class2 and Class3

	Class1	Class2	Class 3
Class1	116	9	0
Class2	9	116	0
Class3	57	20	173

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	0.6374	0.8	1.0
Recall	0.928	0.928	0.692
F-Measure	0.7557	0.8593	0.818

(b) Analysis

Accuracy	81.0
mean precision	0.8125
mean recall	0.8493
mean F-Measure	0.811

(c) Result

Table 3..16. Reduce NonLinear Data(GMM Classifier,Clusters=4) : Class1 ,Class2 and Class3

	Class1	Class2	Class 3
Class1	116	9	0
Class2	4	121	0
Class3	56	20	174

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	0.6591	0.8067	1.0
Recall	0.928	0.968	0.696
F-Measure	0.7708	0.88	0.8208

(b) Analysis

Accuracy	82.2
mean precision	0.8219
mean recall	0.864
mean F-Measure	0.8238

(c) Result

Table 3..17. Reduce NonLinear Data(GMM Classifier,Clusters=8) : Class1 ,Class2 and Class3

	Class1	Class2	Class 3
Class1	116	9	0
Class2	4	121	0
Class3	56	19	175

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	0.6591	0.8121	1.0
Recall	0.928	0.968	0.7
F-Measure	0.7708	0.8832	0.8235

(b) Analysis

Accuracy	82.4
mean precision	0.8237
mean recall	0.8653
mean F-Measure	0.8258

(c) Result

Table 3..18. Reduce NonLinear Data(GMM Classifier,Clusters=16) : Class1 ,Class2 and Class3

1.3 32 dimensional BOVW representation of scene images dataset

Unimodal Gaussian Classifier for Reduce Bovw Data(2a)

	Bayou	Chalet
Bayou	21	29
Chalet	10	40

(a) Confusion Matrix

	Bayou	Chalet
Precision	0.6774	0.5797
Recall	0.42	0.8
F-Measure	0.5185	0.6723

(b) Analysis

Accuracy	61.0
mean precision	0.6286
mean recall	0.61
mean F-Measure	0.5954

(c) Result

Table 3..19. Reduce BOVW Data(Unomodal Classifier): Bayou and Chalet

	Bayou	Creek
Bayou	20	30
Creek	14	36

(a) Confusion Matrix

	Bayou	Creek
Precision	0.5882	0.5455
Recall	0.4	0.72
F-Measure	0.4762	0.6207

(b) Analysis

Accuracy	56.0
mean precision	0.5668
mean recall	0.56
mean F-Measure	0.5484

(c) Result

Table 3..20. Reduce BOVW Data(Unomodal Classifier): Bayou and Creek

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	Chalet	Creek
Chalet	38	12
Creek	27	23

(a) Confusion Matrix

	Chalet	Creek
Precision	0.5846	0.6571
Recall	0.76	0.46
F-Measure	0.6609	0.5412

(b) Analysis

Accuracy	61.0
mean precision	0.6209
mean recall	0.61
mean F-Measure	0.601

(c) Result

Table 3..21. Reduce BOVW Data(Unomodal Classifier): Chalet and Creek

	Bayou	Chalet	Creek
Bayou	17	16	17
Chalet	12	32	6
Creek	13	20	17

(a) Confusion Matrix

	Bayou	Chalet	Creek
Precision	0.4048	0.4706	0.425
Recall	0.34	0.64	0.34
F-Measure	0.3696	0.5424	0.3778

(b) Analysis

Accuracy	44.0
mean precision	0.4335
mean recall	0.44
mean F-Measure	0.4299

(c) Result

Table 3..22. Reduce BOVW Data(Unomodal Gaussian) :Bayou Chalet and Creek

GMM Classifier for Reduce BOVW Data(2a)

	Bayou	Chalet	Creek
Bayou	17	16	17
Chalet	12	32	6
Creek	13	20	17

(a) Confusion Matrix

	Bayou	Chalet	Creek
Precision	0.4048	0.4706	0.425
Recall	0.34	0.64	0.34
F-Measure	0.3696	0.5424	0.3778

(b) Analysis

Accuracy	44.0
mean precision	0.4335
mean recall	0.44
mean F-Measure	0.4299

(c) Result

Table 3..23. Reduce BOVW Data(GMM Classifier,Clusters=1) :Bayou ,Chalet and Creek

	Bayou	Chalet	Creek
Bayou	19	12	19
Chalet	12	28	10
Creek	10	19	21

(a) Confusion Matrix

	Bayou	Chalet	Creek
Precision	0.4634	0.4746	0.42
Recall	0.38	0.56	0.42
F-Measure	0.4176	0.5138	0.42

(b) Analysis

Accuracy	45.33
mean precision	0.4527
mean recall	0.4533
mean F-Measure	0.4504

(c) Result

Table 3..24. Reduce BOVW Data(GMM Classifier,Clusters=2) : Bayou ,Chalet and Creek

	Bayou	Chalet	Creek
Bayou	22	8	20
Chalet	16	24	10
Creek	10	16	24

(a) Confusion Matrix

	Bayou	Chalet	Creek
Precision	0.4583	0.5	0.4444
Recall	0.44	0.48	0.48
F-Measure	0.449	0.4898	0.4615

(b) Analysis

Accuracy	46.67
mean precision	0.4676
mean recall	0.4667
mean F-Measure	0.4668

(c) Result

Table 3..25. Reduce BOVW Data(GMM Classifier,Clusters=4) :Bayou ,Chalet and Creek

	Bayou	Chalet	Creek
Bayou	25	10	15
Chalet	19	25	6
Creek	13	17	20

(a) Confusion Matrix

	Bayou	Chalet	Creek
Precision	0.4386	0.4808	0.4878
Recall	0.5	0.5	0.4
F-Measure	0.4673	0.4902	0.4396

(b) Analysis

Accuracy	46.67
mean precision	0.4691
mean recall	0.4667
mean F-Measure	0.4657

(c) Result

Table 3..26. Reduce BOVW Data(GMM Classifier,Clusters=8) : Bayou ,Chalet and Creek

	Bayou	Chalet	Creek
Bayou	27	6	17
Chalet	28	15	7
Creek	19	13	18

(a) Confusion Matrix

	Bayou	Chalet	Creek
Precision	0.3649	0.4412	0.4286
Recall	0.54	0.3	0.36
F-Measure	0.4355	0.3571	0.3913

(b) Analysis

Accuracy	40.0
mean precision	0.4115
mean recall	0.4
mean F-Measure	0.3946

(c) Result

Table 3..27. Reduce BOVW Data(GMM Classifier,Clusters=16) :Bayou ,Chalet and Creek

2 Perceprtron Based Classifier

2.1 Linear Data(1a)

	Class1	Class 2
Class1	125	0
Class2	0	125

(a) Confusion Matrix

	Class1	Class2
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..28. Linear Data: Class 1 and Class 2

	Class1	Class 3
Class1	125	0
Class3	0	125

(a) Confusion Matrix

	Class1	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..29. Linear Data: Class 1 and Class 3

	Class2	Class 3
Class2	125	0
Class3	0	125

(a) Confusion Matrix

	Class2	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..30. Linear Data: Class 2 and Class 3

	Class1	Class2	Class 3
Class1	125	0	0
Class2	0	125	0
Class3	0	0	125

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F-Measure	1.0	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..31. Linear Data : Class1 ,Class2 and Class3

3 SVM Based Classifier

3.1 Linear Data(1a)

Linear kernel

	Class1	Class 2
Class1	125	0
Class2	0	125

(a) Confusion Matrix

	Class1	Class2
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..32. Linear Data: Class 1 and Class 2

	Class1	Class 3
Class1	125	0
Class3	0	125

(a) Confusion Matrix

	Class1	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..33. Linear Data: Class 1 and Class 3

	Class2	Class 3
Class2	125	0
Class3	0	125

(a) Confusion Matrix

	Class2	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..34. Linear Data: Class 2 and Class 3

	Class1	Class2	Class 3
Class1	125	0	0
Class2	0	125	0
Class3	0	0	125

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F-Measure	1.0	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..35. Linear Data : Class1 ,Class2 and Class3

Polynomial kernel

	Class1	Class 2
Class1	125	0
Class2	0	125

(a) Confusion Matrix

	Class1	Class2
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..36. Linear Data: Class 1 and Class 2

	Class1	Class 3
Class1	125	0
Class3	0	125

(a) Confusion Matrix

	Class1	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..37. Linear Data: Class 1 and Class 3

	Class2	Class 3
Class2	125	0
Class3	0	125

(a) Confusion Matrix

	Class2	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..38. Linear Data: Class 2 and Class 3

	Class1	Class2	Class 3
Class1	125	0	0
Class2	0	125	0
Class3	0	0	125

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F-Measure	1.0	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..39. Linear Data : Class1 ,Class2 and Class3

Gaussian kernel

	Class1	Class 2
Class1	125	0
Class2	0	125

(a) Confusion Matrix

	Class1	Class2
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..40. Linear Data: Class 1 and Class 2

	Class1	Class 3
Class1	125	0
Class3	0	125

(a) Confusion Matrix

	Class1	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..41. Linear Data: Class 1 and Class 3

	Class2	Class 3
Class2	125	0
Class3	0	125

(a) Confusion Matrix

	Class2	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..42. Linear Data: Class 2 and Class 3

	Class1	Class2	Class 3
Class1	125	0	0
Class2	0	125	0
Class3	0	0	125

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F-Measure	1.0	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..43. Linear Data : Class1 ,Class2 and Class3

3.2 Non Linear Data(1b)

Linear kernel

	Class1	Class 2
Class1	116	9
Class2	9	116

(a) Confusion Matrix

	Class1	Class2
Precision	0.928	0.928
Recall	0.928	0.928
F-Measure	0.928	0.928

(b) Analysis

Accuracy	92.8
mean precision	0.928
mean recall	0.928
mean F-Measure	0.928

(c) Result

Table 3..44. Non Linear Data: Class 1 and Class 2

	Class1	Class 3
Class1	0	125
Class3	0	250

(a) Confusion Matrix

	Class1	Class3
Precision	0	0.66
Recall	0	1.0
F-Measure	0	0.8

(b) Analysis

Accuracy	66.66%
Mean Precision	0.33
Mean Recall	0.5
Mean F-Measure	0.4

(c) Result

Table 3..45. Non Linear Data: Class 1 and Class 3

	Class2	Class 3
Class2	0	125
Class3	0	250

(a) Confusion Matrix

	Class2	Class3
Precision	0	0.66
Recall	0	1.0
F-Measure	0	0.8

(b) Analysis

Accuracy	66.66%
Mean Precision	0.33
Mean Recall	0.5
Mean F-Measure	0.4

(c) Result

Table 3..46. Non Linear Data: Class 2 and Class 3

	Class1	Class2	Class 3
Class1	0	0	125
Class2	0	0	125
Class3	0	0	250

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	0	0	0.5
Recall	0	0	1.0
F-Measure	0	0	0.66

(b) Analysis

Accuracy	50.00%
Mean Precision	0.166
Mean Recall	0.333
Mean F-Measure	0.222

(c) Result

Table 3..47. Non Linear Data : Class1 ,Class2 and Class3

Polynomial kernel

	Class1	Class 2
Class1	125	0
Class2	0	125

(a) Confusion Matrix

	Class1	Class2
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..48. Non Linear Data: Class 1 and Class 2

	Class1	Class 3
Class1	125	0
Class3	0	250

(a) Confusion Matrix

	Class1	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..49. Non Linear Data: Class 1 and Class 3

	Class2	Class 3
Class2	125	0
Class3	0	250

(a) Confusion Matrix

	Class2	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..50. Non Linear Data: Class 2 and Class 3

	Class1	Class2	Class 3
Class1	125	0	0
Class2	0	125	0
Class3	0	0	250

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F-Measure	1.0	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..51. Non Linear Data : Class1 ,Class2 and Class3

Gaussian kernel

	Class1	Class 2
Class1	125	0
Class2	0	125

(a) Confusion Matrix

	Class1	Class2
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..52. Non Linear Data: Class 1 and Class 2

	Class1	Class 3
Class1	125	0
Class3	0	250

(a) Confusion Matrix

	Class1	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..53. Non Linear Data: Class 1 and Class 3

	Class2	Class 3
Class2	125	0
Class3	0	250

(a) Confusion Matrix

	Class2	Class3
Precision	1.0	1.0
Recall	1.0	1.0
F-Measure	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..54. Non Linear Data: Class 2 and Class 3

	Class1	Class2	Class 3
Class1	125	0	0
Class2	0	125	0
Class3	0	0	250

(a) Confusion Matrix

	Class1	Class2	Class3
Precision	1.0	1.0	1.0
Recall	1.0	1.0	1.0
F-Measure	1.0	1.0	1.0

(b) Analysis

Accuracy	100.00%
Mean Precision	1.0
Mean Recall	1.0
Mean F-Measure	1.0

(c) Result

Table 3..55. Non Linear Data : Class1 ,Class2 and Class3

3.3 32 dimensional BOVW Data(2a)

Linear kernel

	Bayou	Chalet
Bayou	28	22
Chalet	17	33

(a) Confusion Matrix

	Bayou	Chalet
Precision	0.6222	0.6
Recall	0.56	0.66
F-Measure	0.5895	0.6286

(b) Analysis

Accuracy	61.0
mean precision	0.6111
mean recall	0.61
mean F-Measure	0.609

(c) Result

Table 3..56. BOVW Data: Bayou and Chalet

	Bayou	Creek
Bayou	29	21
Creek	21	29

(a) Confusion Matrix

	Bayou	Creek
Precision	0.58	0.58
Recall	0.58	0.58
F-Measure	0.58	0.58

(b) Analysis

Accuracy	58.0
mean precision	0.58
mean recall	0.58
mean F-Measure	0.58

(c) Result

Table 3..57. BOVW Data: Bayou and Creek

	Chalet	Creek
Chalet	33	17
Creek	13	37

(a) Confusion Matrix

	Chalet	Creek
Precision	0.7174	0.6852
Recall	0.66	0.74
F-Measure	0.6875	0.7115

(b) Analysis

Accuracy	70.0
mean precision	0.7013
mean recall	0.7
mean F-Measure	0.6995

(c) Result

Table 3..58. BOVW Data: Chalet and Creek

	Bayou	Chalet	Creek
Bayou	21	13	16
Chalet	19	21	10
Creek	20	8	22

(a) Confusion Matrix

	Bayou	Chalet	Creek
Precision	0.35	0.5	0.4583
Recall	0.42	0.42	0.44
F-Measure	0.3818	0.4565	0.449

(b) Analysis

Accuracy	42.67
mean precision	0.4361
mean recall	0.4267
mean F-Measure	0.4291

(c) Result

Table 3..59. BOVW Data :Bayou Chalet and Creek

Polynomial kernel

	Bayou	Chalet
Bayou	31	19
Chalet	20	30

(a) Confusion Matrix

	Bayou	Chalet
Precision	0.6078	0.6122
Recall	0.62	0.6
F-Measure	0.6139	0.6061

(b) Analysis

Accuracy	61.0
mean precision	0.61
mean recall	0.61
mean F-Measure	0.61

(c) Result

Table 3..60. BOVW Data: Bayou and Chalet

	Bayou	Creek
Bayou	36	14
Creek	21	29

(a) Confusion Matrix

	Bayou	Creek
Precision	0.6316	0.6744
Recall	0.72	0.58
F-Measure	0.6729	0.6237

(b) Analysis

Accuracy	65.0
mean precision	0.653
mean recall	0.65
mean F-Measure	0.6483

(c) Result

Table 3..61. BOVW Data: Bayou and Creek

	Chalet	Creek
Chalet	41	9
Creek	24	26

(a) Confusion Matrix

	Chalet	Creek
Precision	0.6308	0.7429
Recall	0.82	0.52
F-Measure	0.713	0.6118

(b) Analysis

Accuracy	67.0
mean precision	0.6868
mean recall	0.67
mean F-Measure	0.6624

(c) Result

Table 3..62. BOVW Data: Chalet and Creek

	Bayou	Chalet	Creek
Bayou	31	11	8
Chalet	19	24	7
Creek	14	18	18

(a) Confusion Matrix

Precision	0.4844	0.4528	0.5455
Recall	0.62	0.48	0.36
F-Measure	0.5439	0.466	0.4337

(b) Analysis

Accuracy	48.67
mean precision	0.4942
mean recall	0.4867
mean F-Measure	0.4812

(c) Result

Table 3..63. BOVW Data :Bayou Chalet and Creek

Gaussian kernel

	Bayou	Chalet
Bayou	46	4
Chalet	43	7

(a) Confusion Matrix

	Bayou	Chalet
Precision	0.5169	0.6364
Recall	0.92	0.14
F-Measure	0.6619	0.2295

(b) Analysis

Accuracy	53.0
mean precision	0.5766
mean recall	0.53
mean F-Measure	0.4457

(c) Result

Table 3..64. BOVW Data: Bayou and Chalet

	Bayou	Creek
Bayou	50	0
Creek	50	0

(a) Confusion Matrix

	Bayou	Creek
Precision	0.5	0
Recall	1.0	0
F-Measure	0.666	0

(b) Analysis

Accuracy	50.0
mean precision	0.25
mean recall	0.5
mean F-Measure	0.33

(c) Result

Table 3..65. BOVW Data: Bayou and Creek

	Chalet	Creek
Chalet	49	1
Creek	50	0

(a) Confusion Matrix

	Chalet	Creek
Precision	0.4949	0
Recall	0.98	0
F-Measure	0.6577	0

(b) Analysis

Accuracy	49.0
mean precision	0.2475
mean recall	0.49
mean F-Measure	0.33

(c) Result

Table 3..66. BOVW Data: Chalet and Creek

	Bayou	Chalet	Creek
Bayou	46	4	0
Chalet	42	7	1
Creek	46	4	0

(a) Confusion Matrix

Precision	0.3433	0.4667	0.0
Recall	0.92	0.14	0.0
F-Measure	0.5	0.2154	0

(b) Analysis

Accuracy	35.33
mean precision	0.27
mean recall	0.3533
mean F-Measure	0.238

(c) Result

Table 3..67. BOVW Data :Bayou Chalet and Creek

4. Comparison Between Different Classifiers

1 Linear Dataset(1a)

Classifier	Accuracy
Classifier1	100%
Classifier2	100%
Classifier3	100%
Classifier4	100%

(a) Unomodal Gaussian Classifier

Classifier	Accuracy
Unomodal Gaussian	100%
GMM(clusters=1)	100%
GMM(clusters=2)	100%
GMM(clusters=4)	100%
GMM(clusters=8)	100%
GMM(clusters=16)	100%

(b) FDA using uni modal Gaussian and GMM Classifiers

Classifier	Accuracy
Perceptron	100%
SVM(kernel=linear)	100%
SVM(kernel=poly)	100%
SVM(kernel=RBF)	100%

(c) Perceptron and SVM Classifiers

Table 4..1. Linear Dataset(1a)

For Linear separable dataset(1a) we got 100 % accuracy irrespective of what classifier we are using.So we can use any classifier for classification of linearly separable data.All classifiers are good for classification of linearly separable data.

2 Non Linear Dataset(1b)

Classifier	Accuracy
Classifier1	45.0%
Classifier2	45.0%
Classifier3	97.19%
Classifier4	96.99%

(a) Uni modal Gaussian Classifier

	Accuracy
Cluster=1	95.19%
Cluster=2	97.99%
Cluster=4	100.00%
Cluster=8	100.00%
Cluster=16	100.00%
Cluster=32	100.00%

(b) GMM

Classifier	Accuracy
Uni modal Gaussian	79.4%
GMM(clusters=1)	80.6%
GMM(clusters=2)	79.6%
GMM(clusters=4)	81.0%
GMM(clusters=8)	82.2%
GMM(clusters=16)	82.4%

(c) FDA using uni modal Gaussian and GMM Classifiers

Classifier	Accuracy
SVM(kernel=linear)	50%
SVM(kernel=poly)	100%
SVM(kernel=RBF)	100%

(d) SVM Classifiers

Table 4..2. Non Linear Dataset(1b)

Here in non linearly separable data-set(1b)we got 100% accuracy for classifier using Gaussian mixture modal(GMM) with no of clusters more than 2.We are also getting 100% accuracy using classifier based on support vector machine(SVM) using polynomial and Gaussian kernel.For classification of non linearly separable data classifier using GMM is always good.

3 32 dimensional BOVW Representation of Scene Images Dataset(2a)

	Accuracy
Cluster=1	34.67%
Cluster=2	46.0%
Cluster=4	45.33%
Cluster=8	54.67%
Cluster=16	46.66%
Cluster=32	38.0%

(a) GMM on BOVW representation

	Accuracy
Cluster=1	46.0%
Cluster=2	24.66%
Cluster=4	40.0%
Cluster=8	45.33%
Cluster=16	40.66%
Cluster=32	47.99%

(b) GMM for color Histogram Representation

Classifier	Accuracy
SVM(kernel=linear)	42.67%
SVM(kernel=poly)	48.67%
SVM(kernel=RBF)	45.33%

(c) SVM Classifiers

Classifier	Accuracy
Unomodal Gaussian	44.0%
GMM(clusters=1)	44.0%
GMM(clusters=2)	45.33%
GMM(clusters=4)	46.67%
GMM(clusters=8)	46.67%
GMM(clusters=16)	40%

(d) FDA using unomodal gaussian and GMM Classifiers

	C = 1	C = 2	C = 4	C = 8
L = 2	34.67%	34.67%	34.0%	37.33%
L = 5	29.33%	43.33%	36.0%	40.67%
L = 10	30.67%	42.0%	34.67%	39.33%
L = 15	34.0%	44.67%	42.0%	43.33%
L = 21	30.67%	32.67%	45.33%	45.33%

(e) PCA using GMM Classifiers

Table 4..3. 32 Dimensional BOVW representation Dataset(2a)

Here classifier based on gaussian mixture modal(GMM) is giving highest accuracy(54.67%). All other classifiers are giving nearly equal accuracy less than 50%.

5. Conclusions and Inferences

1. The decision boundary between classes comes out to be straight line when we used perceptron based classifier for classification.
2. Perceptron based classifier can stuck at local minima during learning so we sometimes may not get desire accuracy.
3. Percepron Classifier is good for linearly separable classes beacause it makes linear decision boundary.
4. In Support Vector Machine we can convert non linearly separable classes into linearly separable classes using kernels and so we can also do classification of non linearly separable classes with accuracy.
5. Support Vector Machine is a maximum margin separating hyperplane for linearly separable patterns.
6. Maximum margin hyperplane means separating hyperplane which have maximum distance from nearest examples of both classes.
7. Fisher Linear Discriminant analysis used to reduce dimension of high dimensional feature space data .
8. For classification of data we can apply any classifier on reduce data of FDA .It will have less time complexity because dimension of data is not high.
9. For classification of linearly separable dataset all classifiers gives good accuracy.
10. For classification of non linearly separable dataset we should use classifier using GMM because it gives good accuracy.

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