

Applied Machine Learning

Report on Practice Assignment

Team 34

Fall Semester 2017

1 Introduction

2 Datasets

The initial dataset was composed of 4 classes with 12 images per class. Figure 1 shows the composition of the different classes, that were chosen based on their varied geometrical and chromatic features: Watches are dark and have a round shape, bananas are long and yellow, chairs have angular features and pens are long and thin. This representative features are summarized in Table 1.



(a) Banana



(b) Chair



(c) Pen



(d) Watch

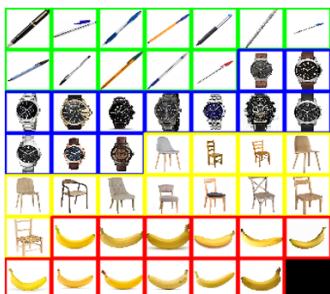
Figure 1: Four different classes

The pictures are normalized when imported in MLDemos to have the same size. The initial dataset (see Figure 2a) is stored in a single 336×336 image constituted of a 7 by 7 matrix of images. Thus, each image has a size of 48×48 pixels and a number of features of $48 \times 48 \times 3$.

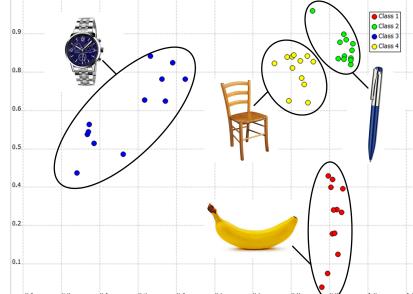
Classes	Shape	Colour	Number of images	Size in pixels
Banana	Long	Yellow	12	$48 \cdot 48$
Pens	Long and thin	Multicoloured	12	$48 \cdot 48$
Watches	Round	Dark	12	$48 \cdot 48$
Chairs	Angular	Light	12	$48 \cdot 48$

Table 1: Dataset characteristics

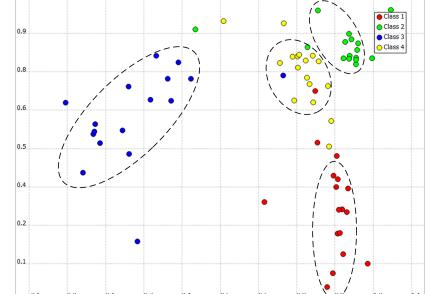
An effort was made to have a linear separable dataset in the beginning for learning purposes. In order to obtain that, the images for each class were purposely chosen to have similar characteristics such as shape, color and orientation in space. For the second part of this report the same dataset was used, but some noisy datapoints were added by hand in MLDemos (4 per class). This new dataset can be seen in Figure 2c.



(a) Pictures in dataset 1



(b) Projected datapoints of dataset 1



(c) Projected datapoints of dataset 2

Figure 2: Comparison of the datasets used for the report

3 Dimensionality Reduction

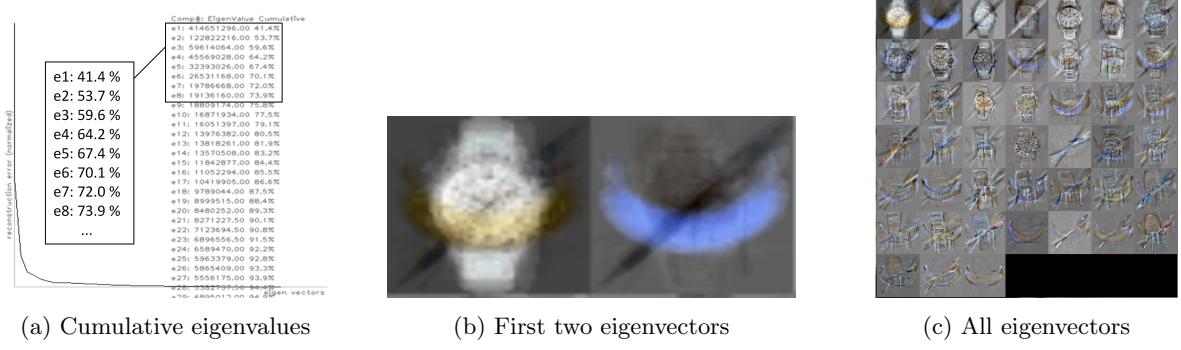


Figure 3: First PCA

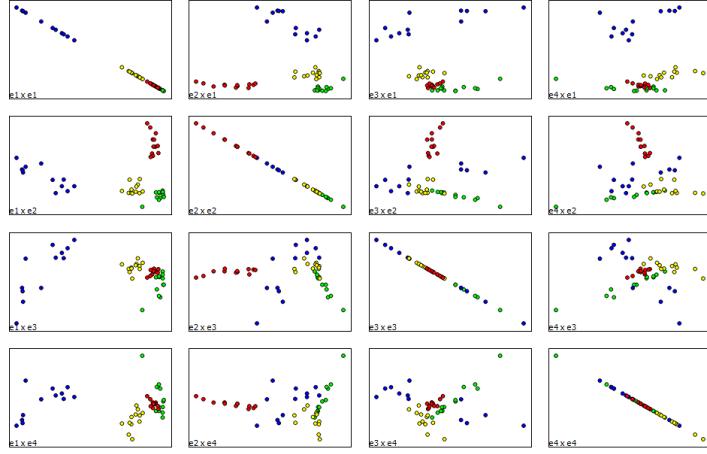


Figure 4: PCA projection matrix on eigenvectors 1 to 4

PCA was applied to the dataset 1. Figure 3a shows the cumulative reconstruction error: it can be noticed that 73.9% of the dataset can be reconstructed with the first 8 eigenvectors. It can be seen in Figure 4 that the projection onto e1-e2 was the optimal projection for clustering purposes as expected: indeed they represent most of the variance of the data. The first eigenvector corresponds to a white watch, a yellow banana and the shape of a pen in the background. On the other hand the second eigenvector shows a blue banana, a pen and a shape of a chair in the background. As such, eigenvector 1 will separate well the watches class from the rest, while the second one will separate better the banana class from the rest. The two principal eigenvectors are shown in Figure 3b while the first 45 eigenvectors can be seen in Figure 3c.

4 Clustering - qualitative assessment

In order to assess the functionalities of unsupervised clustering methods, the dataset 1 was used (see Figure 2a). In particular, the algorithms K-Means, Soft K-Means and DBScan were applied.

4.1 K-means

The hyperparameters for the K-means method are:

- the number of clusters;
- the metric (L_1 , L_2 , L_∞ , L_p).

In Figure 5, correct results are shown for K-Means applied for K=4 and different metrics. It can be observed that the type of metric affects the shape of the borders between cluster. Indeed, L_1 defines distances that are the sum of the coordinates, as such the edges generated will have $n \cdot 45^\circ$ slopes. On the other hand, L_2 defines distances in the euclidian way, as such the edges generated will be straight. Finally, L_p distances will generate higher parabolic functions, as the p degree of the polynomial function increases. When $p \rightarrow \infty$, L_∞ is defined which generated the same edges as the L_1 metric.

Although all metrics were able to correctly separate the classes, some errors were typically shown, as can be seen in Figure 6. These errors can be mainly due to the random initialisation of K-Means (see Initialization below) and the fact that the classes do not have similar distributions, which is the condition K-Mean works best for.

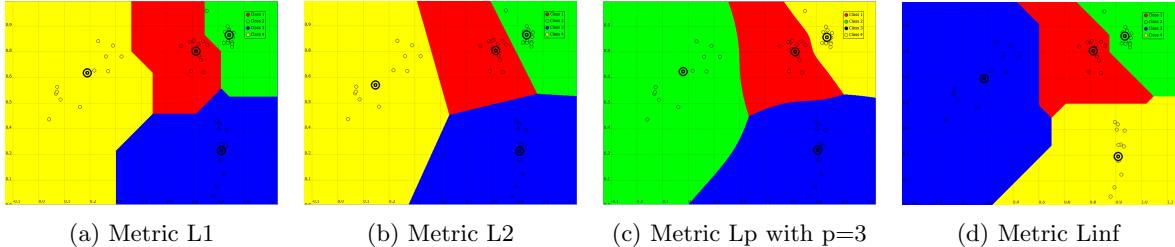


Figure 5: Dataset 1 with correct K-Means clustering, different metrics and $K=4$

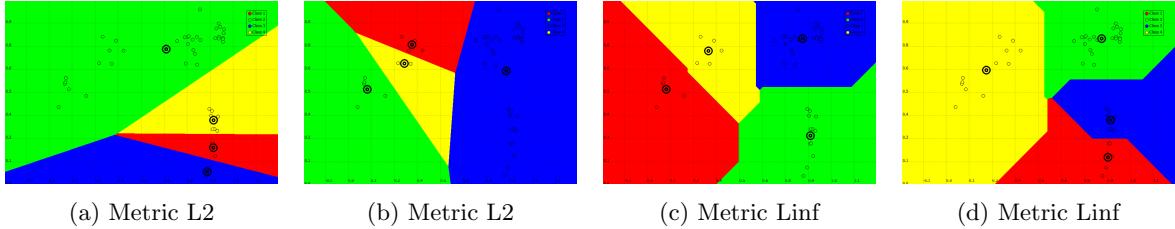


Figure 6: Dataset 1 with incorrect K-Means clustering, metrics L2 and Linf and $K=4$

Finally, K-Means behaviour was tested for different values of K (see Figure 7). Since clustering does not use the label of each point, the separation of datapoints is done according to the position of the points in the PCA projection. For dataset 1, the classes Chairs and Pens are quite close in the PCA projection (see Figure 2b). As such, when the cluster number is smaller than the total number of classes as in Figure 7a, the classes Chairs and Pens are left in the same cluster.

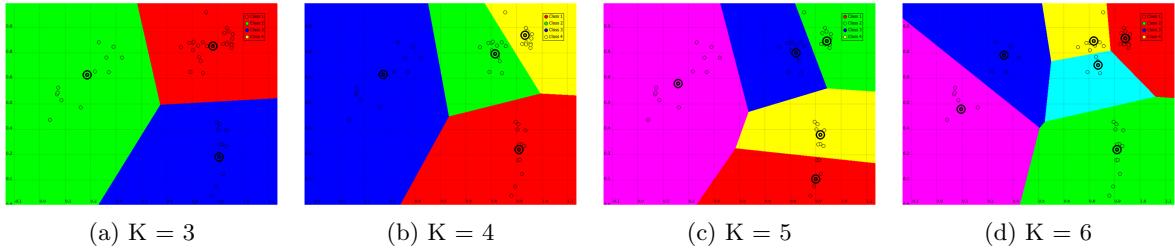


Figure 7: Dataset 1 with K-Means clustering, Euclidean metrics and different value of K

4.2 Soft K-Means

The hyperparameters for the soft K-means method are:

- the number of clusters;
- the stiffness β .

In Figure 8, results for $K=4$ and different values of β are shown. The higher the value of β , the more similar soft K-Means becomes to hard K-Means. When the stiffness is too low, the classes are difficult to distinguish. From $\beta = 30$, the 4 classes are clearly distinguished and correctly clustered.

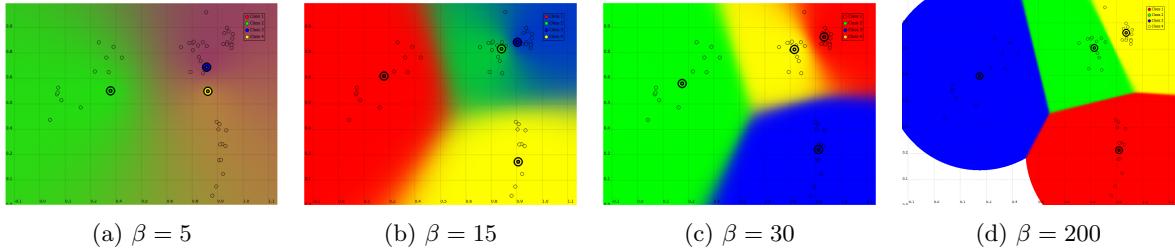


Figure 8: Dataset 1 with soft K-Means clustering, $K = 4$ and different value of β

It can be noticed that the results for soft K-Means when varying the K don't differ considerably from what obtained with hard K-Means, as shown in Figure 9.

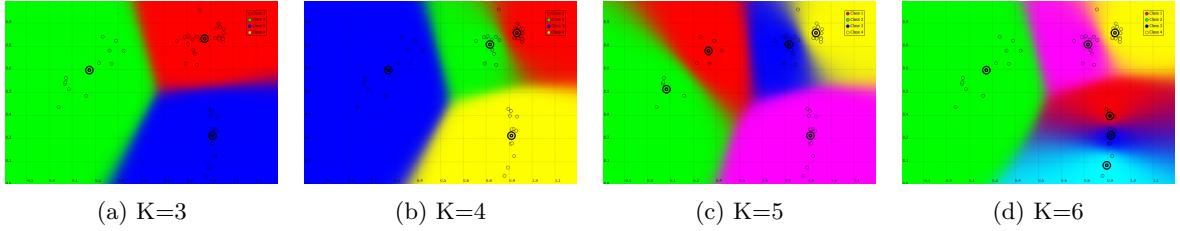


Figure 9: Dataset 1 with soft K-Means clustering, $\beta = 30$ and different values of K

Initialization

The methods above apply a random initialisation of the cluster centers. The effect of this random procedure can be observed in Figure 10. In particular, Figures 10a to 10d show an initialization that results in an incorrect clustering, while Figures 10e to 10h show a correct clustering starting from iteration 3.

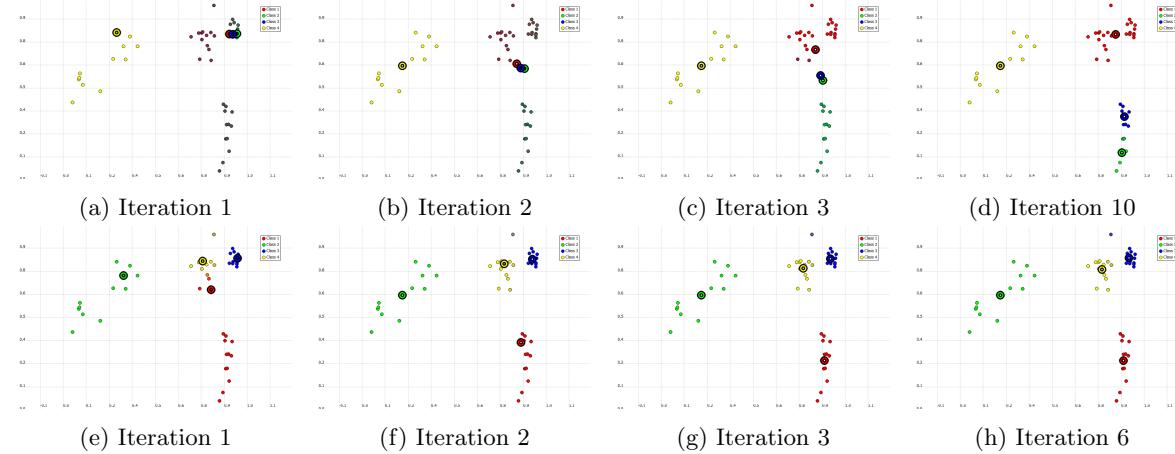


Figure 10: Dataset 1 with soft K-Means clustering for $K=4$ and $\beta = 30$, showing effects of random initialization

4.3 DBSCAN

The hyperparameters for the DBScan method are:

- the minimum number of points in a cluster MinPts;
- the size of neighborhood ϵ .

It can be noticed that when the number of Minpoints increases (see Figure 11), the smaller clusters are lost, and more and more points are considered outliers as the ϵ doesn't change.

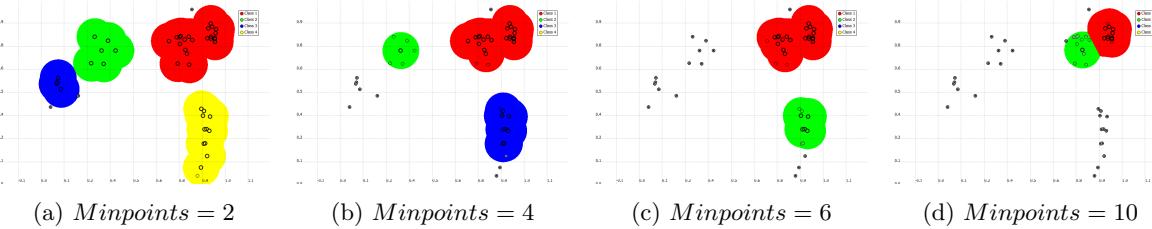


Figure 11: Dataset 1 with DBSCAN clustering, $\epsilon = 0.1$ and different value of *Minpoints*

The value of ϵ was then varied for a fixed Minpt = 2, as it can be seen in Figure 12. For smaller values of ϵ (as Figure 12a), the size of the clusters is expectedly smaller, and as the density of the dataset is not uniform, many outliers are present. This method results in clusters than are not necessarily globular, which is an advantage compared to K-Means for this particular dataset, but it clusters datapoints whose inter-distance is smaller than ϵ . As such, in this particular case, the classes Chairs and Pens can be distinguished only for small values of ϵ , which do not cluster well the other classes as their density is lower. When the value of ϵ is higher, (i.e. Figure 12d), the classes Bananas and Watches are correctly clustered but the other two are fused together.

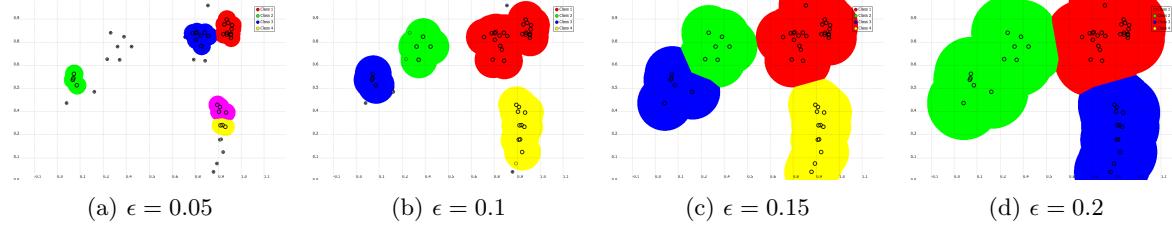


Figure 12: Dataset 1 with DBSCAN clustering, $Minpoints = 2$ and different value of ϵ

5 Classification

5.1 Methods comparison

The purpose of this section is to compare the GMM and SVM method with the dataset 2. Several factors can influence the performance of the GMM and C-SVM classification methods. Since there are many factors to take into account, a comparison plan is fixed in Figure 13. The first parameters to set are the test/ratio train and the number of folds for crossvalidation because these parameters directly influences the classification results for each method.

Train/test ratio

As the dataset in question is quite small, the training/testing ratio must be carefully chosen. Indeed, the lower the ratio, the less the classifier will be trained but the more it will be robust (less variance on testing set). This is a good approach for a dataset with enough datapoints. On the contrary, the higher the ratio, the more the classifier will be possibly overfitting to the training set and the variance for unseen data will be higher. A good trade-off was found to be the ratio 0.667.

ADD PROOF!!

Number of folds sensitivity

In MLDemos, the crossvalidation method is based on a random separation of the data between train and test on which the classifier is applied. The separation is then repeated f times and the results in the end are averaged. With this type of crossvalidation a sufficiently large number of folds is recommended to obtain consistent results with lower variance. However, a too high number of repetitions is not useful because after a while the results do not improve but the cost of calculation increases. A good trade-off for our dataset was found to be 30 folds as it was at this point that the results started to stabilize between several cross validation process.

ADD PROOF!!

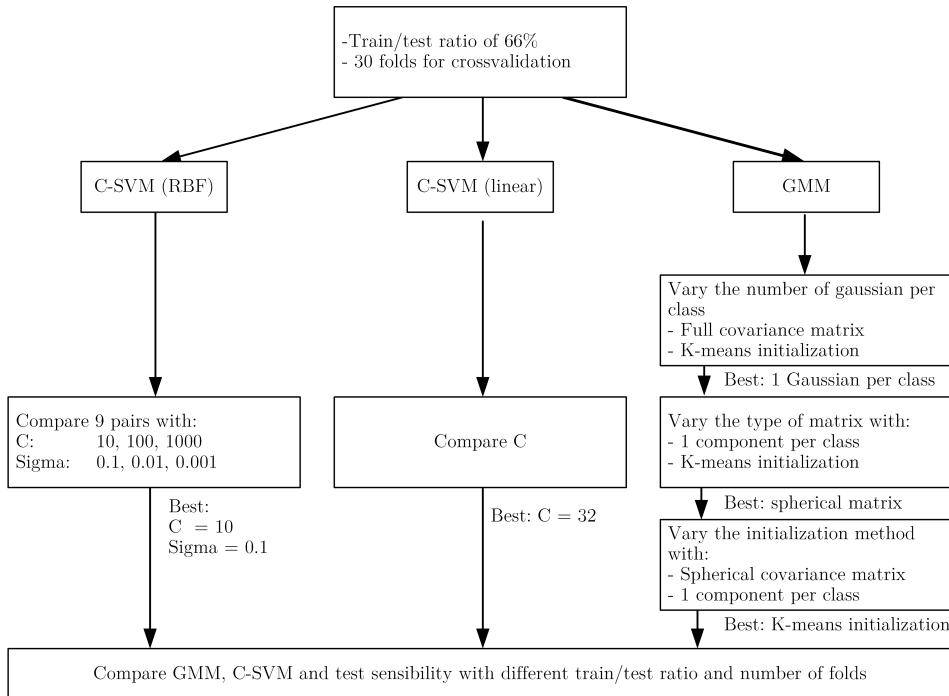


Figure 13: Comparison method block diagram

5.2 GMM classification

For the GMM classification, the hyperparameters to be found were:

- the number of gaussian components;
- the type of matrix (spherical, diagonal, full);
- the initialization method (random, uniform, K-Means).

These hyperparameters were found in three stages. First, the K-Means initialization mode is set as it is a method expected to be more efficient than the random and uniform methods. A full covariance matrix is set to allow as much freedom as possible. In Figure 14 it is shown that the optimal choice for the number of gaussian components in this case would be 1.

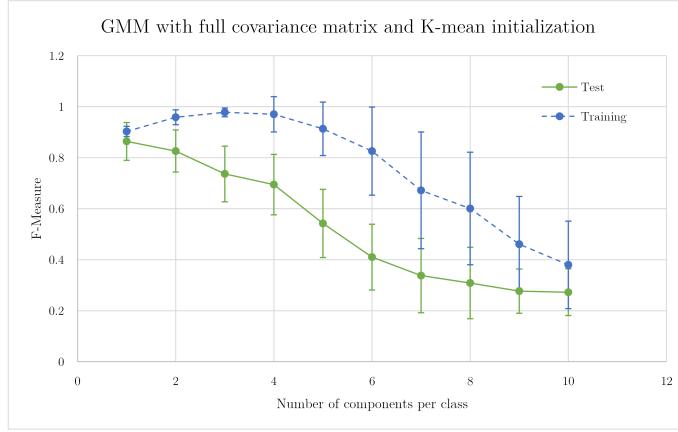
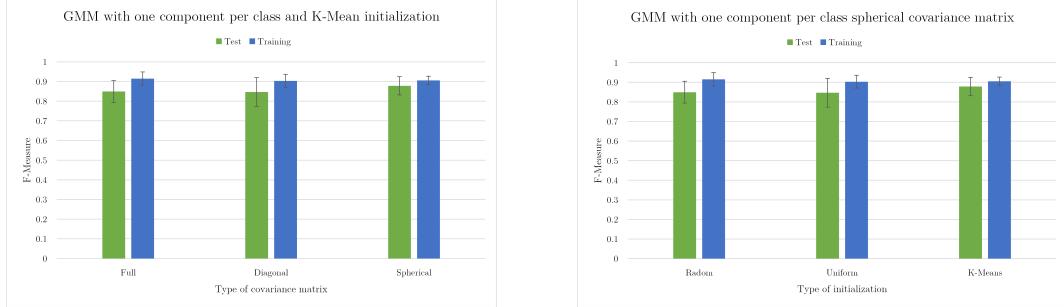


Figure 14: GMM: comparison for different number of gaussian components per class

The training set shows better results with a higher number of GMMs per class but the F-Measure for the testing set gets worse and the variance becomes higher, which is possibly due to an overfitting phenomenon. It can be noticed that for 4 and 5 components, the F-Measure's variance limit is higher than 1. As it is not possible to have a F-Measure higher than 1, this can be explained by the fact that the graph was produced with Excel, and the variance values are the same for the lower and higher limits. TO REWRITE!!



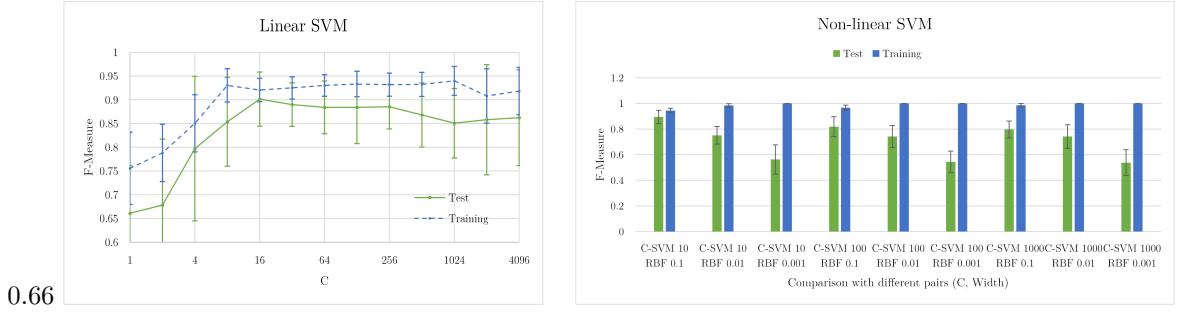
(a) GMM: comparison for different type of matrix (b) GMM: comparison for different initialization

Figure 15: F-measure comparison for different type of matrix and initialization

By following the procedure explained in the block diagram in Figure 13, the plots in Figure 15 are obtained. In particular, they show that a spherical covariance matrix and a K-Means initialization method achieve the smallest variance on the training set. Indeed, a large variance on the testing set indicates an overfitting problem of the training set.

I'm now fully convinced the explanation why the full matrix: to check

5.3 C-SVM classification (linear & RBS)



(a) Linear C-SVM: comparison for different penalty factor C

(b) C-SVM with RBF kernel: comparison for different pairs of hyperparameters

Figure 16: F-measure comparison for different type of matrix and initialization

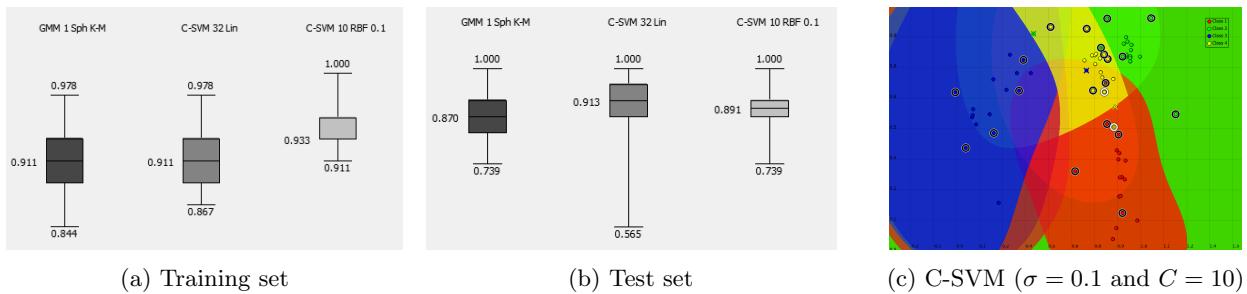
The hyperparameter that must be chosen for the SVM classification method are:

- the penalty term C;
- the width of the RBS kernel (RBS only).

The goal was to find the best tradeoff between minimizing the classification errors and maximizing the margin. In Figure 16a. To have a lower variance on the testing set classification a C of 32 is chosen. Lower variance is preferable even though the average of the F-Measure is a little smaller to minimize the overfitting of the training set. For the non-linear SVM classification some values of *sigma* and C are chosen and all combinations are compared in the figure 16b. This figure shows that the best combination is $C = 10$ and $\sigma = 0.1$ with the highest F-measure and the lowest variance on training and testing set.

5.4 C-SVM and GMM comparison

The SVM method with an RBF kernel is the most appropriate for classifying dataset 2.



(a) Training set

(b) Test set

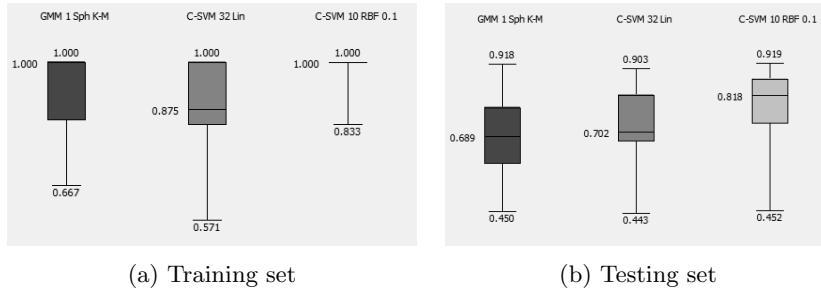
(c) C-SVM ($\sigma = 0.1$ and $C = 10$)

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Figure 17: F-measure box-plot comparison with a train/test ratio of 66% and 30 folds for cross validation.

5.5 Test of sensitivity



(a) Training set

(b) Testing set

Figure 18: F-measure box-plot comparison with a train/test ratio of 66% and 30 folds for cross validation.

5.6 Overall discussion and conclusion