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Master in Artificial Intelligence

Computational vision

Face recognition

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Contents

List of Figures

List of Tables

1 Gender recognition

For this exercise we used a gender recognition system based on the AR-Face database. The used code and files are listed in appendix A.

1.1 Questions

Question 1:

- Which is the information contained in ARFace.person?
- Why the size of the field internal, size(ARFace.internal), is 1188×2210?

ARFace is a matlab struct. `ARFace.person` contains 2210 numeric values that link each image of a person in the database to a unique numeric identifier that corresponds to this person. There are 85 different persons in the database, each occurring in 26 different images.

The images are internally stored as bitmaps with a resolution of 33×36 pixels (which can be recalled from the field `ARFace.internalSz`. The images are reshaped and then saved as a vector of length $33 \times 36 = 1188$. The size of the field `ARFace.internal` corresponds to 2210 different images of size 1188 pixel each.

Question 2:

- What are the variables '`n`' and '`index`' of the function `fold_validation.m`?

The variables `n` and `index` are used to sample the data in different subsamples of training and test data. We are using F-fold validation, using F different, mutually exclusive subsamples as test data. The variable `n` is used in each iteration to pick $\lfloor \frac{N}{F} \rfloor$ new persons to be used as test sample in this iteration, with N being the number of unique persons and F the number of iterations. The variable `index` links the matrix of images to a logical matrix with value 0 if the image is not of a person being used for the test sample in this iteration and 1 otherwise. The training and test data can then easily be set in each iteration based on this logical matrix.

In the example of the 2110 images from the AR-Face database and a 10-fold validation, we use 10 subsamples as test data, each containing images of $\lfloor \frac{N}{F} \rfloor = \lfloor \frac{85}{10} \rfloor = 8$ persons. The unique persons are shuffled and `n` contains 8 of them in each iteration in not overlapping windows. In the first iteration, `n` contains the 8 first persons of the shuffled list of unique persons, in the second iteration persons 9 through 16, and so on. The variable `index` maps the persons selected for the test data to the features and labels, splitting them in four different sets: `TrainSet, TrainLabels, TestSet, TestLabels`.

Question 3:

- The function `main_gender_recognition.m` computes some evaluation measures obtained with 'PCA' ($dim = 5$), 'PCA95' (95% variance explained) and 'LDA'. Explain the meaning of these measures and discuss which is the best obtained result.

The used measures are based on the 4 different outcomes of a binary classification: True positives (TP) and true negatives (TN) for correct classifications and false positives (FP) and false negatives (FN) for incorrect classifications. The following measures are used:

- **Sensitivity / Recall** (also True Positive Rate) is the proportion of positives that are correctly classified as such: $\frac{TP}{TP+FN}$

Method:	Sensitivity	Specifity	Precision	FAR	Accuracy	Error
PCA $dim5$	82.4786	82.7797	79.6698	21.0470	82.6442	17.3558
PCA 95%	54.2510	83.2418	74.5480	18.5223	69.4712	30.5288
LDA	99.7863	99.7378	99.6798	0.3205	99.7596	0.2404

Table 1: Results with different feature extraction methods for $k = 2$

- **Specifity** (also True Negative Rate) is the proportion of negatives that are correctly classified as such: $\frac{TN}{TN+FP}$
- **Precision** (also Positive Predictive Value) is the proportion of positive classifications that are actually positives: $\frac{TP}{TP+FP}$
- **False Alarm Rate** (also False Positive Rate) is the proportion of positive classifications that are actually negatives: $\frac{FP}{FP+TN}$
- **Accuracy** is the proportion of correct classifications out of all classifications: $\frac{TP+TN}{TP+FP+TN+FN}$
- **Error**[1] is the proportion of incorrect classifications out of all classifications: $\frac{FP+FN}{TP+FP+TN+FN}$

The results of a k-nearest-neighbors classification with $k = 2$ using different feature extraction methods can be seen in table 1. The LDA feature extraction obtains the best results in all categories. The LDA method especially has a large advantage looking at the sensitivity. In addition, the LDA method takes less time to execute. This result is as we expected. As Martinez & Kak showed [2], LDA is superior in most cases, if the training set is not very small. Since we have a rather large collection of data, LDA is the preferred method.

Figure 1 shows 30 eigenfaces created based on the PCA method.

2 Subject recognition

Question 4:

• Knowing that the AR-Face database has several instances (photos) of the same subject, how do you have to distribute the samples in the fold-cross validation strategy for the subject recognition problem?

Unlike before, now we want examples of the same subject in both in the training set and the test set: if there are no examples of a certain subject in the training set, then there is no way for the classifier to correctly recognize him in the test set and the goodness of the classifier cannot be ascertained; if there are no examples of a certain subject in the test set, then the performance of the classifier cannot be tested against such individual.

Therefore, an option for distributing the images in the fold-cross is alternating the images of the different subjects (e.g. the first picture of all the individuals, followed by the second photo of all the individuals and so on and so forth).

Another option (which is the one we have picked for the optional exercise) is to just distribute the pictures randomly. If the F parameter is large enough (say greater than 10) then it is highly unlikely that one subject is absent from either the training or the test set.

[1]The provided code initially had a bug where the error was not calculated correctly due to missing brackets for the numerator. The correct code in `fold_validation.m` should be: `error(i)=(FP(i)+FN(i))/NTest;`

[2]Martinez, A. Kak, "PCA versus LDA", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 23, no. 2, pp. 228-233, 2001.

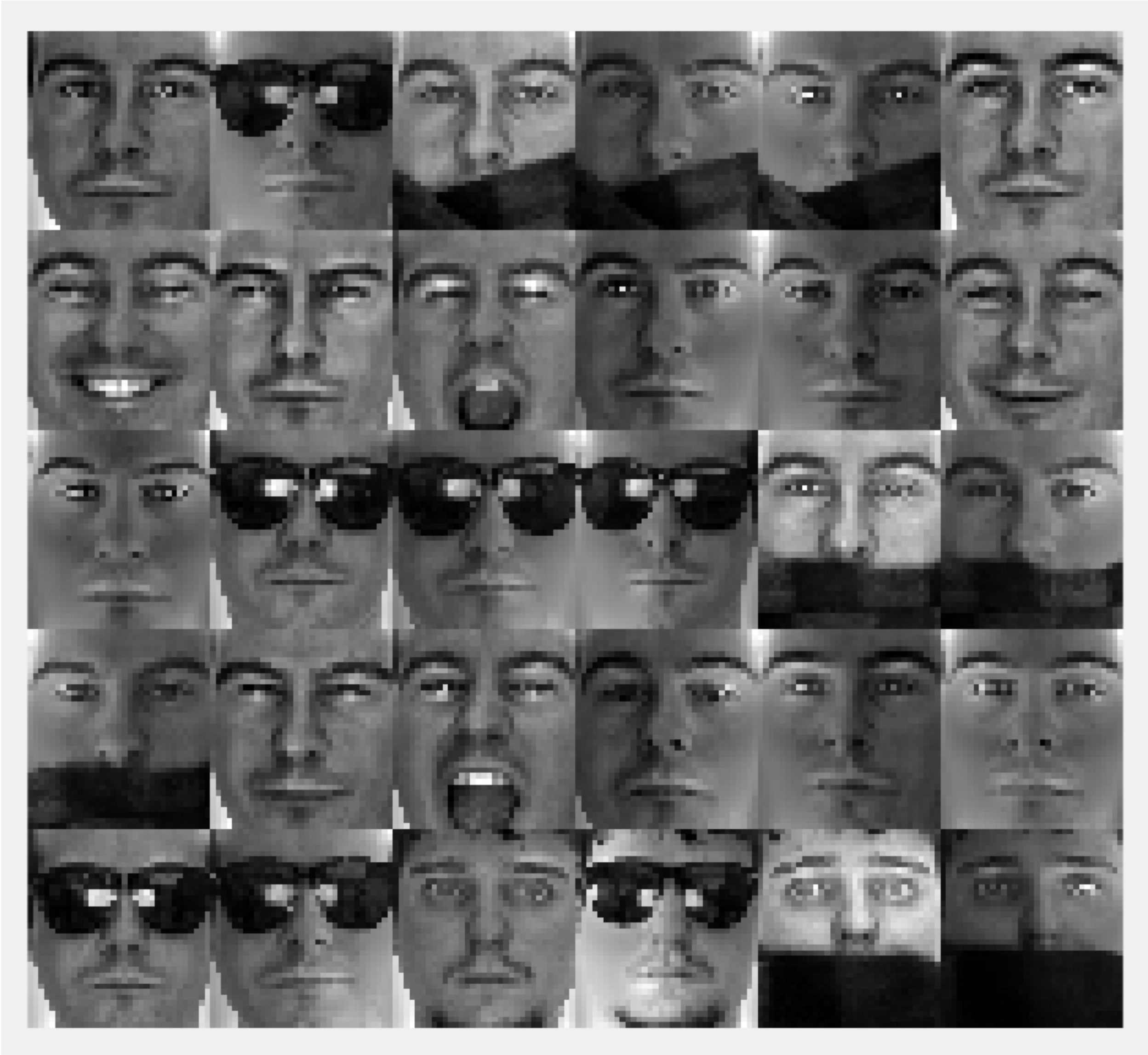

Figure 1: Eigenfaces based on PCA method

Notice that when $F = N$, we are performing LOOCV (Leave-One Out Cross Validation). In such a case, then our premise is guaranteed.

2.1 Optional exercise

Questions:

- Which are the necessary changes in the code? Detail all the changes you need to do when changing to the subject recognition problem.
- Which is the best dimensionality reduction method for this particular problem?
- Include error measure and confusion matrices to illustrate the results and conclusions for the methods.
- Comment the particularities of this problem.

  One of the most important changes is in the labels. Now, instead of considering the gender as the target, we consider the subject. Another important change is how the

Table 2: Confusion matrix for PCA and 5 subjects. Columns represent recognized class, and rows represent real class

21	4	0	0	0
4	10	3	3	0
1	5	20	0	4
0	6	3	23	0
0	1	0	0	22

Table 3: Confusion matrix for PCA95 and 5 subjects

25	0	0	0	0
0	25	0	0	0
0	0	25	0	0
1	1	0	26	0
0	0	1	0	26

confusion matrix is computed. Since now there are more than two classes (say, C), we have to deal with a $C \times C$ confusion matrix. To perform this computation, we assume that the ids of the subjects are correlative. This is not the case in general, but it is when we consider just the first 5 subjects.

The results are consistent with the previous sections. LDA turns out to outperform the other methods, both when tested against the whole database (without computing the confusion matrix) and when tested with the first 5 subjects.

The errors for the whole database are:

- Error PCA: 72.7879%
- Error PCA95: 24.9899%
- Error LDA: 0.72727%

The results for the 5 first subject are significantly different in terms of the absolute accuracy (which is understandable, since there are less subjects and the probability of classifying one wrongly is smaller), but the classifier ranking is the same (first LDA, then PCA95 and then PCA). The confusion matrices can be seen at tables 2, 3 and 4. The error (1 minus the accuracy, which can be inferred from these tables) is as follows:

- Error PCA: 26.2%
- Error PCA95: 2.3%
- Error LDA: 0.77%

The validation has been performed with a fold equal to the number of examples (this is, we have done LOOCV).

Table 4: Confusion matrix for LDA and 5 subjects

26	0	0	1	0
0	26	0	0	0
0	0	26	0	0
0	0	0	25	0
0	0	0	0	26

Appendices

A Annex

- `main_gender_recognition.m` contains the main code for the gender recognition problem
- `main_subject_recognition.m` contains the main code for the subject recognition problem problem
- `fold_validation_subject.m` f-fold validation for the subject recognition problem
- `/feature_extraction/apply_pca.m` contains the code modifications to perform PCA.
- `/out/` contains example outputs of faces in the database.