Face Recognition using Sub-Holistic PCA

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Abstract

This paper proposes a face recognition scheme that enhances the correct face recognition rate as compared to conventional Principal Component Analysis (PCA). The proposed scheme, Sub-Holistic PCA (SH-PCA), was tested using ORL database and out performed PCA for all test scenarios. SH-PCA requires more computational power and memory as compared to PCA however it yields an improvement of 6% correct recognition on the complete ORL database of 400 images. The correct recognition rate for the complete ORL database is 90% for the SH-PCA technique.

Keywords: Holistic, PCA, Histogram Equalization, Eigenface, Eigenvalues.

1. Introduction

Face recognition is a difficult task because of the inherent variation in images. These variations can occur because of change in lighting conditions, gestures, positioning and orientation. These variations occur in un-controlled environments. However for surveillance purposes these factors can be adequately controlled. Surveillance is the verification whether a given probe belongs to a relatively small database or not. Surveillance is of utmost importance in order to ensure safety of people and places.

There are two broad classifications of techniques applied for face recognition. The first, *abstractive*, approach extracts discrete local features for identifying faces and standard statistical pattern recognition techniques are used for matching faces using these measurements. The second, *holistic*, approach attempts to identify faces using global representations. Examples of this technique are PCA [1] and connectionist methods such as back propagation [2]. The proposed scheme makes use of the

second technique however it modifies it by making use of sub-holistic images a hybrid approach in between the two afore mentioned approaches. The concept behind the approach is reductionism. This concept is a common practice in daily life as well as in intelligent systems. Instead of finding a single match to the face a number of matches are found and from among these candidate matches the final result is sought. The process involves three separable phases: a) Pre-processing of database b) Training with the given database c) Testing of images.

2. ORL Database

All face recognition techniques are data set dependent. This is because of the statistical nature of the problem. A technique might perform better under a given set of conditions and may perform poorly for another set of conditions. Therefore, it is necessary to describe the database that is used for the testing of an algorithm.

The (Olivetti research laboratory) ORL database consists of 40 subjects each having 10 images, there are 400 images in total. All of the images are grey scale. They are front views and have a black background. These images were taken over a period of 2 years and with variation in subject gestures and head orientation. The subject images have a tilt and rotational tolerance up to 20 degree and a tolerance of up to 10% scaly [3],[4]. Images of two different subjects are shown below as example.

Figure 1: Example of Images in ORL Database

3. Principal Component Analysis (PCA)

PCA also known as Karhunen-Loeve method is a technique commonly used for dimensionality reduction in computer vision, particularly in face recognition. A method called Eigenface, based on PCA was used in face recognition in [1]. In this paper this method will be referred to as the conventional application of PCA for face recognition.

In PCA, the principal components of the distribution of faces or the eigenvectors of the covariance matrix of the set of face images are sought treating an image as a point in a very high dimensional space. These eigenvectors can be thought of as a set of features that together characterize the variation between face images. Each image contributes to each eigenvector so that a sort of ghostly face called *eigenface* can be formed.

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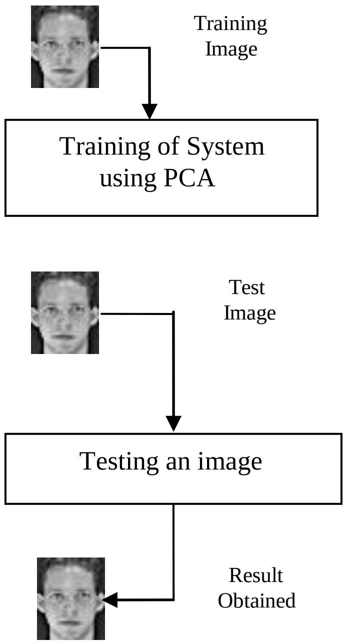

Figure 2: Block Diagram Conventional PCA

Mathematically, consider a face image *Zi* to be a two-dimensional *m*x*m* array of grey scale values. An image may be considered as a vector of dimension m^2. Denote the training set of *n* face images by $E = (E_1, E_2, E_3, \ldots E_n)$ and each image belongs to one of the *c* classes. The covariance matrix for this dataset can be calculated as [1],[3]

$$\Gamma = (1/n) \sum_{i=1}^{n} (Ei - \bar{E})(Ei - \bar{E})^T \qquad (1)$$

$$= \Phi \Phi^T \qquad (2)$$

Where $\Phi = (\Phi_1, \Phi_2, \Phi_3, \ldots \Phi_n)$ and $\bar{E} = (1/n) \sum_{i=1}^{n} Ei$. Then the eigenvalues and eigenvectors of the covariance matrix Γ are calculated. Let $U = (U_1, U_2, U_3, \ldots U_r)$ be the r eigenvectors corresponding to the r largest eigenvalues. Thus, for a set of original face images E their corresponding eigenface based feature X can be obtained by projecting E into the eigenface space as :

$$X = U^T E \qquad (3)$$

4. Proposed Application of PCA

The conventional PCA usage involves creation of a single face space from the given database of images. The procedure involves i)Generation of a mean face from the given database of face images, ii) Formation of a covariance matrix by subtracting each image from the mean face image, iii) Calculation of eigenvectors and eigenvalues of the covariance matrix, iv) Projection of the training set into the face space using the calculated eigenvectors and eigenvalues, v) projection of test image into the generated face space.

In the proposed scheme each face image is not only taken as a whole but four sub-images are also formed from the given image. The four sub-images are formed by taking 1/4th of the image from each corner. The given image and the four new images formed are shown below in *Figure 3*

Figure3: Database Image and the four sub-face Images.

In the proposed scheme, instead of generating a single face space, five face spaces are generated. The image to be tested is also divided into four parts and the complete image with the four sub-parts is projected in their
respective face spaces. The results from all five face spaces are obtained and from the five proposed matches one match is found. Since the generation of five face spaces results in a substantial increase in the computational intensity it is essential to reduce the size of the images. This results in slight blurring of the images. This blurring can be reduced by means of filtering.

5. Phase 1 of SH-PCA

The first phase of SH-PCA is a pre-processing phase. The dimensions of images in the ORL database are reduced from 98x112 to 29x36. This results in blurring of the images. The blurring in the images is reduced by using an image sharpening filter. The effect of filtering is shown below in *Figure 4*.

Figure 4: Image before and after filtering

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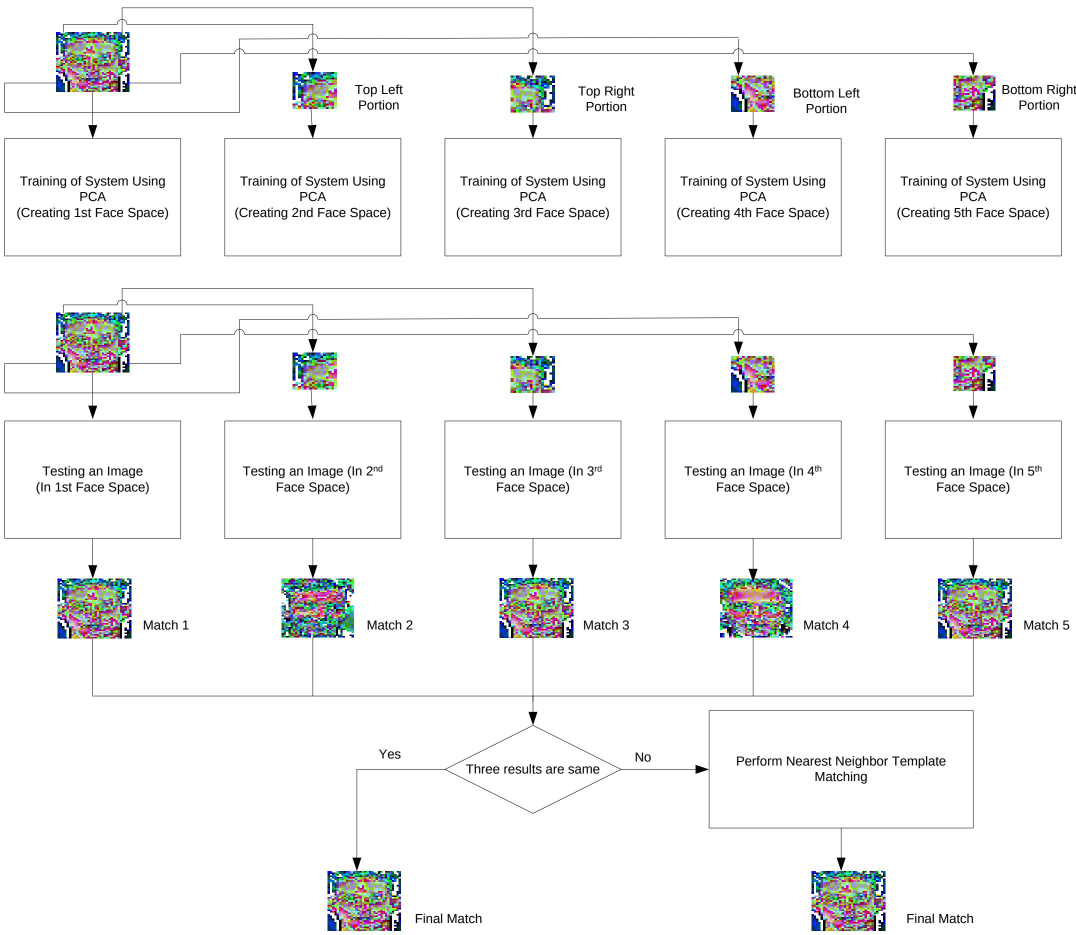

Figure 5 Block Diagram of Proposed PCA-SH

Now the image obtained is divided into four parts and the image along with its four parts is saved for further use. It was observed that the pre-processing phase alone can improve the results of face recognition for PCA. This is true for all the tests conducted on the given ORL database. A comparison of correct detection rate, between use of pre-processed and non-pre-processed images for PCA is shown in *figure 6*.

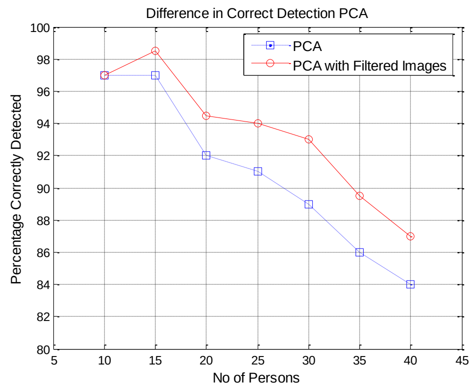

Figure6: Effects of pre-filtering on PCA

6. Phase 2 of SH-PCA

The second phase of SH-PCA is the creation of the face space using the training images in the database. The complete image is used to create one database and the four sub-images, obtained from the complete image, are used to create the other four face spaces. Each face space is created using the before mentioned procedure of face space creation for PCA.

Once the face spaces have been created images to be tested can be presented to the system. The image to be tested is also divided into four parts and each part is passed to the corresponding face space for testing. This results in five matches one for each image space as shown in *figure 5*. The Euclidean distance is used as a measure for best match. Hence if an unknown image is given and projected onto a space the training image that corresponds to the nearest neighbor projection is considered to be the best match. After this step the number of images to search for the correct match has been reduced to five subjects at the maximum and one subject at the minimum, there exists a possibility that all five face spaces provide the same result or all of them provide different results.

If three of the five images belong to the same class then no further classification is made and the class is displayed as the result. Otherwise, the five resultant classes are used as source to the *nearest neighbor template matching* classifier and the result from this classifier is used as the final result.

7. Experimental Results

Two factors are important in the process of testing face recognition algorithm. First is the number of classes (different subjects) used for the creation of the face space and second is the number of images of each class used for training. If the number of images of each class is increased it is observed that the correct detection rate of the system increases. However, on the other hand if the number of different classes increases then this results in a decrease in the correct detection rate.

The SH-PCA algorithm was tested and compared with PCA under two different set of conditions. In the first testing phase the number of images of each class was fixed to five and the system was tested after training it with different number of subject classes. The number of classes was increased in steps of 5 from 10 to 40.The resultant comparison between PCA and SH-PCA is shown below:

No of Classes	**PCA**	**SH-PCA**
	Correct Detection Percentage	
10	**97 %**	**99 %**
15	**97 %**	**99 %**
20	**92 %**	**96 %**
25	**91 %**	**95 %**
30	**89 %**	**95 %**
35	**86 %**	**92 %**
40	**84 %**	**90 %**

Table 1: Comparison of PCA and SH-PCA algorithm's correct detection rate for 5 training images of each class

Figure 7: Comparison of PCA and SH-PCA correct detection rate for 5 training images of each class

The above shown results are for the system trained with five images of each subject class.

In [5] a unified approach of PCA and Independent Component Analysis (ICA) was tested for 10 classes of ORL database, with 5 images being used from each class for training. The correct detection rate for this hybrid scheme was stated to be 99% for the 100 images of the 10 classes. The same result is achieved using SH-PCA as shown in the first entry of table 1.

No of Classes	**PCA**	**SH-PCA**
	Correct Percentage	**Detection**
10	**95 %**	**97 %**
15	**92 %**	**96 %**
20	**87 %**	**91 %**
25	**88 %**	**92 %**
30	**88 %**	**91 %**
35	**85 %**	**89 %**
40	**82 %**	**87 %**

Table 2: Comparison of PCA and SH-PCA algorithm's correct detection rate for 3 training images of each class

The above shown table is for the system trained with three images of each subject class. There is a reduction in the correct detection rate of the system as compared to the correct detection rate of the system which was trained with 5 images of each subject.

Figure 8: Comparison of PCA and SH-PCA correct detection rate for 3 training images of each class

The effects of histogram equalization were also tested on the PCA algorithm. It was observed that histogram equalization results in a decrease in the correct detection rate as compared to when normal images were provided in the training phase. A comparison of all three tests is shown below.

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No of Classes	PCA	PCA with Histogram Equalization	SH-PCA
	Correct Detection Percentage		
10	97 %	95 %	99 %
15	97 %	95 %	99 %
20	92 %	92 %	96 %
25	91 %	91 %	95 %
30	89 %	89 %	95 %
35	86 %	86 %	92 %
40	84 %	84 %	90 %

Table 3: Comparison of PCA, PCA with histogram equalization and SH-PCA algorithm's correct detection rate for 5 training images of each class

8. Conclusion

An algorithm using five face spaces was proposed in this paper. The algorithm training process consists of two steps. In the first step images, are pre-processed, prepared for the training step. In the second step the dimensionally reduced, filtered image and its four sub-images are used for the creation of five separate face spaces. Each image to be tested is

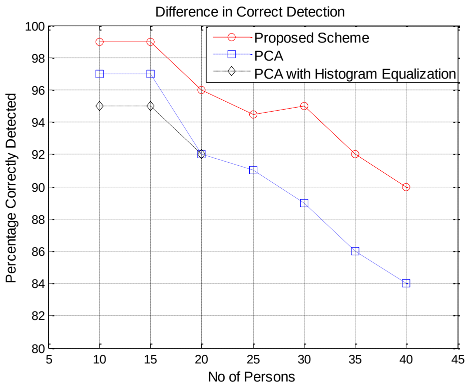

Figure 9: Comparison of PCA, PCA with histogram equalization and SH-PCA algorithm's correct detection rate for 5 training images of each class

projected in these five face spaces and the best result is selected. The proposed algorithm out performs conventional PCA usage for each variation in number of images used for training and the number of different subjects.

Further work is underway to determine the effects of non-uniform backgrounds on this algorithm.

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