FACE RECOGNITION USING PCA WAVELET DECOMPOSITION

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KEYWORDS: Biometrics, Extraction, Identification, Recognition, Automation.

ABSTRACT

Face recognition plays an important role in biometrics base personal identification. The need for reliable recognition and identification of interacting users is obvious. The biometrics recognition technique acts as an efficient method and wide applications in the area of information retrieval, automatic banking, control of access to security areas and so no. This paper describes a method of face recognition based on Principal Component Analysis (PCA) and wavelet decomposition. The proposed scheme exploits feature extraction capabilities of the Discrete Wavelet Transform Decomposition and invokes certain normalization techniques that increase its robustness to variations in facial geometry and illumination. Traditionally, to represent the human face, PCA is performed on the whole facial image. In this method, wavelet transform is used to decompose an image into different frequency subbands, and a mid-range frequency subband is used for PCA representation. In comparison with the traditional use of PCA, the proposed method gives better recognition accuracy and discriminatory power; further, the proposed method reduces the computational load significantly when the image database is large. Experimental results show that the proposed method is effective and possesses several desirable properties when it compared with many existing algorithms.

1. INTRODUCTION

Face recognition has become and active area of research as it plays an important role in biometrics base personal identification. Thus, the need for reliable recognition and identification of interacting users is obvious. Human face recognition finds its application in law enforcement and commercial applications. Some of these applications are: *static matching* of controlled format photographs such as passports, credit cards, photo ID's, driver's licenses, and mug shots, as well as *dynamic matching* (real time matching) of video images (Zhang, 2000).

In spite of this, face recognition technology seems to be a difficult task to develop since the appearance of a face varies dramatically because of illumination, facial expression, head pose, and image quality determine the recognition rate. In addition, the number of the same face in the database with different facial expression should be sufficient so that the person can be recognized in all possible situations. The recent research on face recognition is based on Principal Component Analysis (PCA). However, any system in this world has its limitations and can be improved. To overcome the disadvantages of PCA, such as large computational load and low discriminatory power it can be combined with Wavelet Transform (Chen *et al*, 2003).

A system capable of recognizing faces with different orientations and facial expression base on PCA and Wavelet decomposition was developed in fully using MATLAB. A review of basic fundamental of Principal Component Analysis and Wavelet Decomposition are introduced. Experimental results using 10 images with five orientations are shown. The accuracy and performance of the system also presented.

2. PRINCIPLE COMPONENT ANALYSIS (PCA)

PCA is a statistical measurement method, which operates in the linear domain and can be used to reduce the dimensionality of an image. A face image can be viewed as vectors and represented in matrix form. This method can be described as follows:

Suppose $A=[a_{ij}]_{rxc}$ is a face image, where r and c are the number of rows and column of the images, respectively; a_{ij} is the grey value of the pixel in the i^{th} row and j^{th} column. This matrix can be arranged into a column vector:

$X = [a_{11}\, a_{21} \dots a_{r1}\, a_{12}\, a_{22} \dots a_{r2} \dots a_{1c}\, a_{2c} \dots a_{rc}]^T$;
where X is a D = rxc dimension vector.

One face image can be considered as statistical sample. Thus, giving a group of face image samples in the training database, G = $\{ X_0, X_1, \dots, X_{M-1} \}$ and the covariance matrix can be calculated as

$$S = \frac{1}{M}\sum_{i=0}^{M-1}(Xi-m)(Xi-m)^T;$$

where m is the average vector of the training samples and M is the number of images in the training sample set.

$$m = \frac{1}{M}\sum_{i=0}^{M-1} Xi$$

Let $\lambda_1, \lambda_2, \dots, \lambda_d$ and $\mu_1, \mu_2, \dots, \mu_d$ be eigenvalues and corresponding eigenvector obtain from the covariance of S

respectively. The eigenvalues can be arranged in a descending order ($\lambda 1 \geq \lambda 2 \geq ... \geq \lambda d > 0$) with the highest eigenvalues corresponding to the eigenvectors dimensions that has the strongest correlation to the original image (Gonzalez et al, 2003).
The eigenvalues that are very small, whose corresponding eigenvectors give insignificant contribution to represent the face image samples are ignored. The eigenvectors with the highest eigenvalues are projected into space and are known are eigenfaces since these images are like faces. This projection results in a vector represented by fewer dimensions (d<D) containing coefficients [a_1, …a_d].

3. WAVELET DECOMPOSITION

Wavelet Transform has been a popular tool for multiresolution image analysis for the past ten years (Mallat, 1989, Rioul, 1991, Daubechies, 1992, Chen et al, 2003). In this paper wavelet is used to decompose the original image into wavelet subbands each with different coefficients. An image, which is a 2D signal, is decomposed using the 2D wavelet tree decomposition algorithm [3].

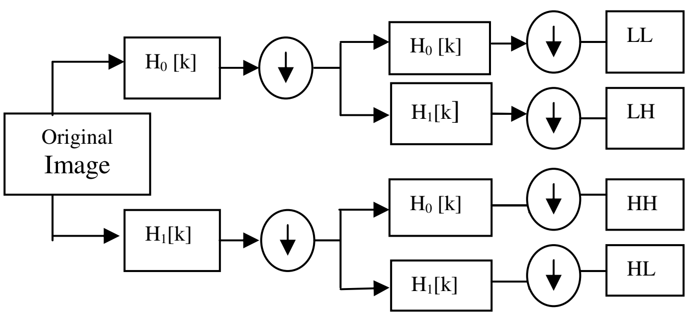

Figure 1: Wavelet Decomposition Algorithm

The original image is process along the x and y direction by $H_0[k]$ and $H_1[k]$ filterbank which, is the row representation of the original image. It is decomposed row-wise for every row using 1D decomposition algorithm to produce 2 levels of Low (L) and High (H) components approximation. The term L and H refer to whether the processing filter is lowpass or highpass. Because of the downsampling operation that is perform on the L and H image the resultant matrices are rectangular of size (N x N/2). These matrices are then transposed and decomposed row-wise again to obtain four N/2 x N/2 square matrices. The downsampling that is then performs on these matrices will generate LL, LH, HH, HL components. Each of these images corresponds to four different wavelet subband [4]. The LL component (the approximation function component) decomposed to obtain further details of the image; the other wavelet component (LH, HH, HL) can also be decomposed further. In this project the original images was decomposed until (LLLL, LHLLL, HLLL, HHLL) where the original image with a size 200X200 was decomposed into an approximation image of 50X50. Figure 2 shows two wavelet decomposition to one of training images.

Figure 2: Level 2 Wavelet Decomposition

4. FACE DATABASE CREATION

There are two face database used in the simulation. The first database contains ten training images (frontal face). The Olivetti and Oracle Research Laboratory (ORL) face database is used in order to test our method in the presence of head pose variations. There are ten different images of each of 40 distinct subjects. For some subjects, the images were taken at different times, varying lighting, facial expressions (open / closed eyes, smiling / not smiling), facial details (glasses / no glasses) and head pose (tilting and rotation up to 20 degrees). All the images were taken against a dark homogeneous background. Figure 4.3 shows the whole set of 40 individuals 10 images per person from the ORL database. These images are trained by performing PCA in wavelet decomposition domain on them and their eigenfaces are saved in eigenfaces database. The second database consists of testing images. Each of these images has eight samples of different face orientation so that the test should involve matching of the same face with different facial expression and orientation. The original size of each image is 112x92 pixels. Figure.3 shows some of 40 individuals 10 images per person from the ORL database.

5. IMPLEMENTATION AND RESULTS

The proposed algorithm was tested in order to determine the performance and efficiency of the system. There were two stages in the process: the first is the training stage, done to obtain eigenfaces of the database images and second is testing stage, done to test images of different orientations whether it match with the database images.
In addition, both stages have three steps:
1. For each image presented above, wavelet decomposition was performed according to level (level 1, 2 and 4) to reduce the size of the original image and only the lowband wavelet was taken as the approximation image.
2. Next, PCA was performed on this approximation image to obtain its eigenfaces and were then stored in the database as training images.
3. Eigenfaces of the testing and database images were compared to find the best match.
System performance was measured in percentage considering the accuracy of matching images with those in the database. The accuracy of the system was measured based on the levels of the wavelet decomposition and the number of eigenfaces that each image has in the database.
Tables 1 to 3 shows sample of the results obtained. If the face orientation of each sample image does not differ to much form its

frontal face images then the system can easily match it to the database image.

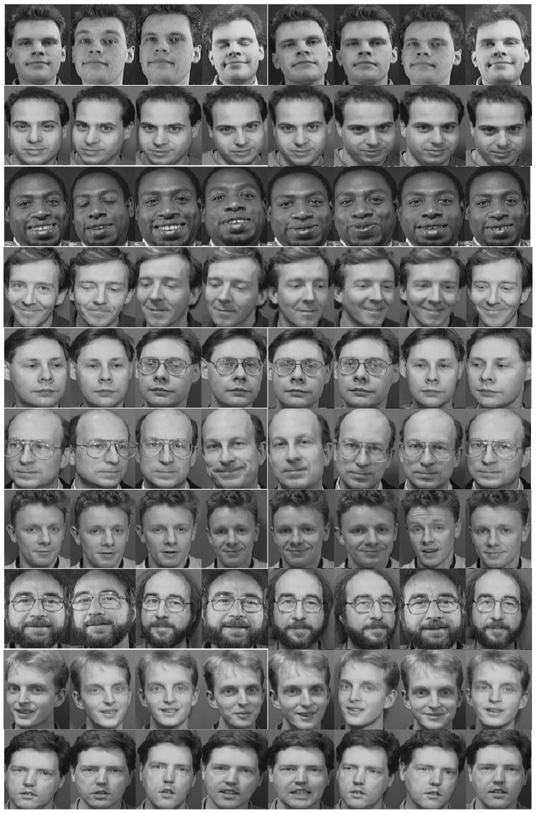

Figure 3: Example of the images from ORL face database

Tables 1 to 3 shows sample of the results obtained. If the face orientation of each sample image does not differ to much form its frontal face images then the system can easily match it to the database image. However if the sample images shows a high variance in term of light illumination and the size of the face itself, the accuracy of the system reduces.
Table 4 shows the overall result for all ten images for level 2 wavelet decomposition. The system accuracy which is calculated is 86.25%. It can be seen that some tests showed 100% accuracy, but image 8 has showed low accuracy due to the factor mention previously. Figures 4. 5 and 6 show the performance accuracy of the proposed system using different wavelet multiresolution and decompositions, also the accuracy and the efficient of the proposed method using a different number of orientations.

Table 1

Images	Matching
Image 1_1	Yes
Image 1_2	No
Image 1_3	Yes
Image 1_4	Yes
Image 1_5	No
Image 1_6	Yes
Image 1_7	Yes
Image 1_8	Yes
System Accuracy	75%

Table 2

Images	Matching
Image 2_1	Yes
Image 2_2	Yes
Image 2_3	Yes
Image 2_4	Yes
Image 2_5	Yes
Image 2_6	Yes
Image 2_7	Yes
Image 2_8	Yes
System Accuracy	100%

Table 3

Images	Matching
Image 4_1	Yes
Image 4_2	No
Image 4_3	No
Image 4_4	Yes
Image 4_5	Yes
Image 4_6	No
Image 4_7	Yes
Image 4_8	Yes
System Accuracy	62.5%

Table 4

Images	System Accuracy (%) for level 2 Wavelet Decomposition
Image1	75
Image2	100
Image3	100
Image4	62.5
Image5	100
Image 6	87.5
Image 7	100
Image 8	37.5
Image 9	100
Image 10	100
Total Accuracy	86.25

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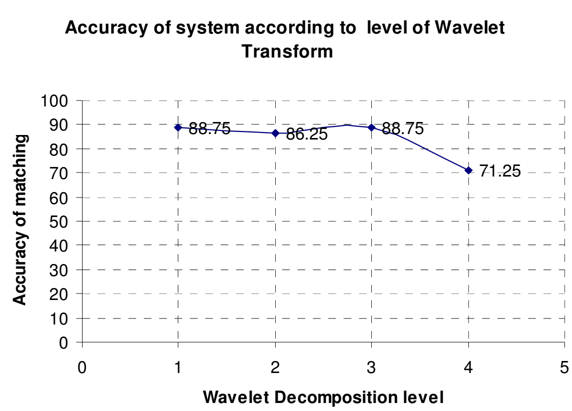

Figure 4: Accuracy based on Levels of Wavelet

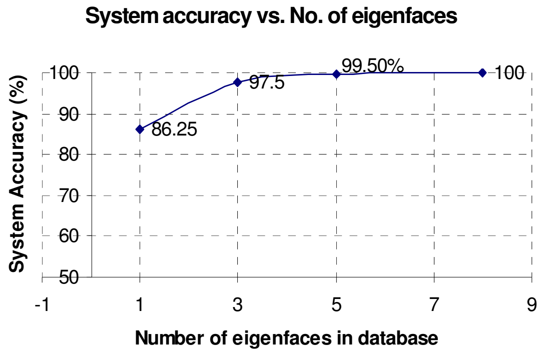

Figure 5: Accuracy base on Eigenfaces

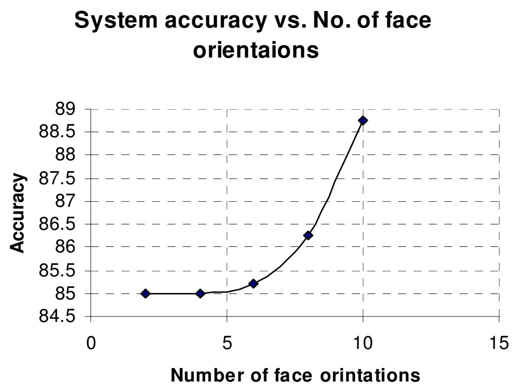

Figure 6 System Accuracy vs Number of Face orientations

6. CONCLUSION

Face recognition has been an attractive field of research for engineering, computer vision scientists and security purposes.. Humans are able to identify reliably a large number of faces and scientists are interested in understanding the perceptual and cognitive mechanisms at the base of the face recognition process. Since 1888, many algorithms have been proposed as a solution to automatic face recognition. Although none of them could reach the human recognition performance. This paper presented an algorithm for face recognition by performing PCA on Wavelet Transform. The Wavelet Transform is used to decompose the original image into four Wavelet subbands, each with a different frequency component. PCA is then applied on this Wavelet to reconstruct the image into vector representation. Wavelet Transform provides an excellent image decomposition and texture description. The combination of Wavelet Transform and PCA gives a better recognition accuracy and significant performance improvement when the database has large number of images. It reduces computational load and increases accuracy of the system. The paper has resulted in an overall success being able to perform reliable recognition in a constrained environment. a recognition accuracy of 86% has been achieved. While the problem of recognizing faces under gross variations remains largely unsolved, a thorough analysis of the strengths and weaknesses of face recognition using PCA has been presented and discussed.

REFERENCES

Zhang, D. 2000. Zhang. *Automated Biometrics: Technologies and Systems*, Kluwer Academic Publishers, pp. 137-142.

Chen, C. F, Tsent, Y. S. and Chen Y. C., 2003. Combination of PCA and Wavelet Transform for Face Recognition on 2.5D Images. Image and Vision Computing NZ. Palmerston North, pp. 343-347.

Gonzalez, R. C. and Woods, R. E. 2003. *Digital Image Processing,* 2nd Edition, Addison-Wesley Publishing Company.

Daubechies, I., 1992. *Ten Lectures on Wavelets*, Society for Industrial and Applied Mathematics, Philadelphia.

Goswami, J. C. Chan A. K. 1999. *Fundamentals of Wavelets, Theory, Algorithm and Applications*, John Wiley and Sons, pp.. 210-266.

Rioul, O. and Vetterli, M. 1991. Wavelet and signal Processing, *IEEE SP Magazine*, pp. 14 – 37.

Rioul, O. and Duhamel, P., 1992. Fast Algorithms for Discrete and Continuous Wavelet Trnasforms, *IEEE Trans. On Information Theory, Vol. 38, No. 2*, pp. 569-586.

Mallat, S. G., 1989. A Theory for Multiresolution Signal decomposition: The wavelet representation, *IEEE Trans. On Pattern Analysis and Machine Intelligence, Vol. 11, NO. 7*, pp. 674 – 693.

Mallat, S. G.,1989. Multifrequency Channel Decompositions of Images and Wavelet Models, *IEEE Trans. Acoust., Speech, Signal Processing, Vol. 37, No. 12*, pp. 2091-2110.

Christophe G., Giorgos Z. and Giorgos T. *A Wavelet Based Framework for Face Recognition*, Foundation for Research and Technology-Hellas (ICS), Crete, Greece.

Zhao, W., Chellappa, R, Rosenfeld, A. and Phillips, P.J. 2000 Face Recognition: A Literature Survey, UMD CFAR Technical Report CAR-TR-948.

Singh, R. K. and Rajagopalan, A. N. 2002. Background Learning For Robust Face Recognition, *16th International Conference on Pattern Recognition (ICPR).* August 1-15.

Hong, L 1998 Integrating faces and fingerprints for personal identification, IEEE Trans. PAMI, Vol 20, pp. 1295-1307.