

Comparative Analysis of PCA, 2DPCA and 2D²PCA on Iris

¹Navdeep Dhiman, ²Monica Sharma, ³Tulika Mehta

^{1,2}Dept. of Electronics, SSiet, Derabassi, Punjab, India

³Dept. of Electronics, IEC Baddi, Himachal Pradesh, India

Abstract

The growing demand for security as the basis for authentication has put the intelligent personal identification biometric systems in top priority. Iris recognition system works on the concept of automatic differentiation of an individual based on the information obtained from their iris images. This technique is extremely beneficial in identifying an individual in the course of accessing a system for authenticity owing to its high precision and reliability. In this paper, a comparative analysis of the recognition scheme is presented based on the three different techniques: PCA, 2DPCA and 2D²PCA on iris biometric trait. In the beginning of the recognition process the iris image is preprocessed. Then these three techniques are applied on the preprocessed images independently to extract the features. Then, the extracted features are placed in the database. The test sample is then matched with the one which is stored in the database. The results are evaluated on the basis of recognition rate and the number of input samples provided to the system. From the experimental outcomes, it is observed that 2D²PCA out performs PCA and 2DPCA techniques when implemented in iris recognition.

Keywords

Biometrics, Iris, PCA, 2DPCA, 2D²PCA, Recognition Rate

I. Introduction

A tremendous escalation has been witnessed in the era of biometrics due to the growing need for high security. As the society network is increasing, it brings the necessity for the humans to authenticate themselves to the security machines. Therefore, biometrics is the means to distinguish ourselves from the crowd and prove a person's individual identity. The biometric traits being unique to a person possess the potential to differentiate between the authentic individual and the imposter. The conventional methods for authentication process are formed on either physical assets (key, card, etc.) or knowledge (pin, password, etc.). These methods are prone to a variety of problems as a card can get misplaced or stolen and similarly a password is easy to be estimated or unremembered. The biometric methods with the human sample (iris, finger vein, fingerprint, gait, voice, etc.) keep the authenticity criteria intact with the person. Iris recognition is a promising biometric recognition scheme that authenticates the individuals on the basis of iris patterns. The iris patterns are highly distinctive and stable. The iris pattern of every individual is different from the others, even the iris pattern of the right and left eye of a person are not same. Iris recognition is a reliable noninvasive process of biometric identification of an individual owing to the stability of the iris over one's lifetime [1]. Compared to fingerprints, iris is hard to be forged or stolen as it is an internal organ. It is very clean and convenient to use as the images of eye are taken without contact with the instrument. An iris recognition process consists of the subsequent steps: Firstly, the iris images are captured with the help of the scanners. Secondly, the iris images are made to undergo the preprocessing stage. Thirdly, the extraction process is carried out where the features are extracted from the pattern. Finally, the extracted features are matched with the ones kept in database. The identification of an individual based on iris recognition has

following advantages:

1. Iris patterns are highly random
2. Iris is very secure as it is an internal organ of the eye
3. Iris can be seen at a distance
4. The authenticity of the liveliness can be confirmed from the changing size of the pupil
5. Limited genetic interference
6. Huge variability of the iris pattern between individuals
7. Iris remains stable throughout a person's life

The iris consists of over 400 distinguishing characteristics which can be used to identify an individual. For the identification purpose, approximately 260 of the characteristics are possible to attain. Iris texture consists of unique set of characteristics, such as, freckles, crypts, stripes and furrows [12]. The structure of the iris starts forming in the phase of the gestation and the formation gets completed by the eighth month. Therefore, iris is a multiple layer structure which is unique by birth. There are no two individuals who have the identical texture patterns of the iris; even the twins do not have the same pattern. These unique characteristics make the iris six times more distinctly identifiable as compared to fingerprint [2].

PCA (Principle Component Analysis) is a linear dimensionality reduction technique. It is also used for feature extraction process. The images given as input are the 2-dimensional images. PCA converts the two dimensional image matrixes into one dimensional vector. As a result, a covariance matrix is obtained which is very huge in size and it takes a lot of time to evaluate the projection matrix that consists of the eigenvectors of the covariance matrix. To overcome the limitations of PCA, a new method called 2DPCA was proposed by Yang et al. to decrease the size of the covariance matrix. This technique saved a lot of time to compute the projection matrices [3]. 2DPCA directly converts the image matrix into covariance matrix. In this technique, the 2-dimensional image matrix is not transformed into a 1-dimensional column vector. In this way, the size of the related covariance matrix is drastically reduced. Now the feature projection matrix is obtained with lesser time. It computes only the row direction of images. Further to enhance the system and increase the efficiency of the computation time, Zhang and Zhou introduced 2D²PCA. This technique presented both the row and column directions of the image simultaneously. It consumed reduced time to evaluate the projection matrix. Experimentally, enhanced results were computed on face recognition [4].

II. Related work

The initial start up in the field of iris recognition was initiated by Flom and Safir who used the iris trait for the biometric authentication. In 1987, their work [5] was collaborated with Daugman's to develop iris identification software [6]. Daugman proposed a system in which he used 2-D Gabour wavelet filter for the purpose of localization of iris, feature extraction was done by Gaussian transform and 256-byte iris code was used for computational work. This paper presented the statistical theory for degree of freedom of iris code agreement [7]. Wildes et al. proposed a system which consisted of acquiring image rig interface to a Sun SPARCstation20. The work was focused on acquisition

of the images of iris and applying Laplacian pyramid to make routine procedures of iris efficient [8]. Tieniu et al. presented a segmentation algorithm that dealt with the noisy iris images to get better results. In the first step the reflection was removed. The clustering based coarse iris localization method was implemented to locate the iris. The papillary boundaries were located with the help of integrodifferential constellation that accelerated the traditional operator and enhanced the global convergence. The main area of concern in the iris identification includes dealing with eyelids and eyelashes. To deal with this difficulty, curvature model and prediction model were used. This proposed technique worked efficiently for non-cooperative iris recognition [9]. Daugman presented the new advancements in iris recognition to increase its efficiency. The methods for distinguishing the interior and exterior boundaries of iris with active contours were introduced. These lead to increased flexible embedded coordinate systems. The issues relating to projective geometry and trigonometry were addressed using Fourier-based methods. For the detection and exclusion of eyelashes, statistical inference methods were used. According to the quantity of data available in the iris, the score normalization was explored [10]. Xiuli et al. worked on the low dimensions of iris feature matrices. In the experiments, the dimensions of matrix were lowered. The method used to extract feature was Complete 2-Dimension PCA (C- 2DPCA). The results indicated that the technique used performed better as compared to 2DLDA and 2DPCA. The average computation time was less and the equal error rate was reduced [11]. Shashi et al. proposed an iris recognition system in which PCA (Principle Component Analysis) and DWT (Discrete Wavelet Transform) were implemented. In this technique, the morphological process was used to locate the iris. The left and the right part of the iris was taken by excluding the eyelids and eyelashes; this information was stored in a template. The histogram of iris template was taken and DWT was implemented on it. PCA was used for the feature extraction. The success rate of KNN classifier was better in comparison to SVM and RF [12]. Tianyi Zhang et al. presented the Point wise Detection method to locate the iris. The Sobel operator was used to detect the boundary of pupil and to detect the centre of pupil the radius of the pupil was evaluated. Now, to obtain the binary image of the iris, otsu technique was implemented with considerable threshold. Morphological edge extraction was used to smooth out the edges. This technique was finally used to extract the features of iris. These techniques lead to higher speed, lower calculation costs and higher accuracy for the boundary location [13]. E. Mattar proposed a system in which principle component analysis was used for iris recognition. Iris segmentation was performed using Libor Masek algorithm that segmented the iris from undesired noises. The features were extracted using PCA. The resultant was used to train an artificial neural network. The proposed system gave a high accuracy of 91% for identification process [14].

III. Procedure

A. PCA Implementation

The implementation of PCA consists of three steps:

Step 1: In this step, the pre-processing of the iris images is done. The iris training samples are picked and given as input. The image is taken from the image database and is made to process under various stages of processing. Initially, the image is resized to specific dimensions in order to get uniform sized images. Then normalization is carried out on the image. The resultant of the pre-processing stage is the Euclidean distance which is obtained

from the image processing.

Step 2: In this step, feature extraction is carried out with the help of PCA technique. The image transformation consists of images being converted to vector form. The training images are transformed to the column vector. The transformed image matrix L is evaluated from the data matrix A. Now the mean M is taken out from the transformed column matrix. This mean M is then subtracted from every column of the data matrix. Next, the covariance matrix is calculated. The formula for the covariance matrix is as follows:

$$C = A \cdot A^T \quad (1)$$

Equation (1) describes the covariance matrix C, where A denotes the data matrix and A^T denotes the transpose matrix. The corresponding matrix obtained is used to find out the Eigenvectors matrix E. The Eigen value vectors of the covariance matrix are kept in vector V. The Eigen values are placed in descending order. The feature matrix P is obtained by projecting matrix A over matrix E. The formula for the feature matrix is as follows:

$$P = E^T \cdot A \quad (2)$$

Equation (2) describes the projection matrix P, where A denotes the data matrix and E^T denotes the transpose matrix of the Eigenvector matrix.

Step 3: In this step, the recognition process is carried out. The image, suppose D, that needs to be recognized is picked from the testing database. The mean of the testing image database is evaluated. The calculated mean is subtracted from the whole image matrix. Next, the covariance matrix is calculated. Then, the Eigen vectors and Eigen values are obtained for the image matrix D. In relation to the image matrix D, the feature matrix Q is calculated. In order to recognize the exact image, both the feature matrices Q and P are taken and the Euclidean distance is evaluated between them. The minimum distance is considered for the recognition procedure.

B. 2DPCA Implementation

The implementation of 2DPCA consists of three steps:

Step 1: In this step, the pre-processing of the iris images is done. The iris training samples are picked and given as input. The image is taken from the image database and is made to process under various stages of processing. Initially, the image is resized to specific dimensions in order to get uniform sized images. Then normalization is carried out on the image.

Step 2: In this step, feature extraction is carried out with the help of 2DPCA technique. In the beginning, matrix A is evaluated which is the average of all the images in training samples. The formula for taking out average matrix is given by:

$$A = \frac{1}{M} \sum_{i=1}^M A_i \quad (3)$$

Equation (3) describes the average matrix A, where M denotes the mean. Next, the image covariance matrix G is calculated. With respect to d-maximum Eigen values of G, the d-ortho normal vectors are calculated. In this way, d-dimensional projection subspace is evaluated. The principal component vector Y is obtained by projecting matrix A onto the projection subspace.

Step 3: In this step, the preprocessing procedure is implemented on the testing image database. An image matrix D is picked from the test images. In order to recognize the selected image, the Euclidean distance is evaluated in 2-dimensionality. The minimum Euclidean distance between the training and testing images is considered as a match.

C. 2D²PCA Implementation

The implementation of 2D²PCA consists of three steps:

Step 1: In this step, the pre-processing of the iris images is done. The iris training samples are picked and given as input. The image is taken from the image database and is made to process under various stages of processing. Initially, the image is resized to specific dimensions in order to get uniform sized images. Then size normalization is carried out on the image.

Step 2: In this step,

IV. Experimental Results and Analysis

A. Database

For the experimental purposes to test the performance of the algorithms used, the CASIA iris image database was used which contained 250 iris images of individual's right and left eye. Out of the 250 training samples, 200 images were used to test the system that included both original and fake iris images to test the robustness of the system. The system was trained using the training images and then testing was done using testing image. The original size of the image was 320×280 . After pre-processing, the size of the area under consideration for feature extraction was resized to 96×60 in order to obtain good features and less computational timings. Some iris samples are shown in Fig. 1.

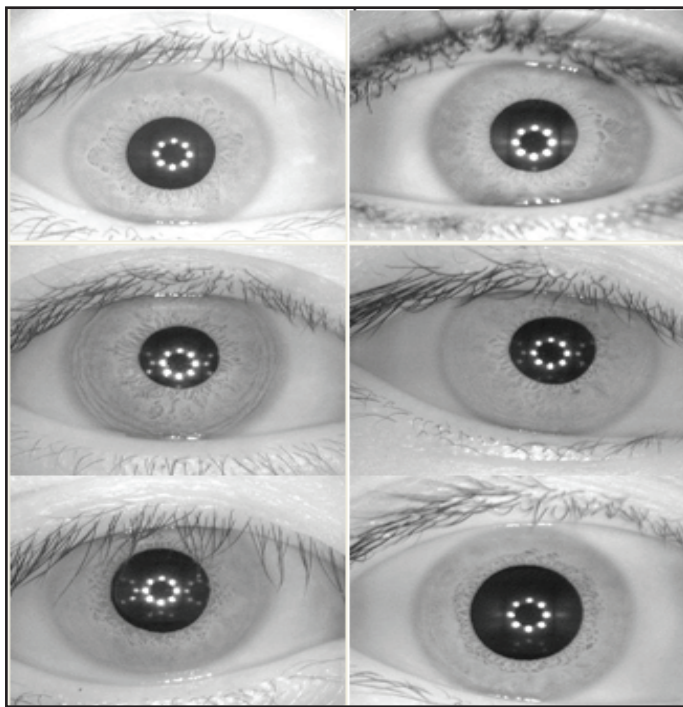


Fig. 1: Iris Samples

B. Experimental Setup

The experiments were conducted on a system of 2.44 GZ processor, 3 GB RAM with Matlab 2012a version.

C. Comparative Analysis

In PCA technique, 2D image matrix is transformed into 1D column vector, resulting in too much large size of covariance matrix. With this huge data size of covariance matrix, computational time for calculating Eigen values and Eigen vectors becomes too large thus resulting in poor performance in terms of computational time. In 2DPCA technique, the 2D image matrix is not converted to 1D column vector. Direct operations are employed on 2D image matrix itself. Thus, the size of covariance matrix is minimized and the

features are extracted in less time as compared to PCA technique. Moreover, 2DPCA is employed only in the row direction of original image matrix. This results in the drawback of the method. 2D²PCA technique can work in both rows as well as column direction of original image matrix to obtain the feature matrix. Experiments were performed using PCA, 2DPCA and 2D²PCA on same set of database and results have shown that 2D²PCA outperforms the former two techniques in both computational time and recognition rate.

Table 1: Number of Samples used for Training and the Recognition Rate

Training Samples	Recognition rate PCA	Recognition rate 2DPCA	Recognition rate 2D ² PCA
50	77.3%	78.4%	81.3%
75	78.6%	79.8%	81.9%
100	79.2%	80.8%	82.1%
125	80.4%	81.4%	82.7%
150	86.6%	88.6%	89.8%
175	85.2%	90.3%	91.6%
200	88.1%	91.2%	94.8%
225	93.3%	95.6%	96.7%

Table 1 depicts the comparison between the three techniques PCA, 2DPCA and 2D²PCA on the basis of experiments carried out on iris images. A steady increase in the recognition rate can be viewed in the experimental results. Different recognition rates are obtained with the input of varied count of training samples. PCA implementation results to a recognition rate of 93.3%. The rate of recognition rises to 95.6% in case of 2DPCA. Finally, the Implementation of 2D²PCA generates the high recognition rate that reaches to a new level of 96.7%.

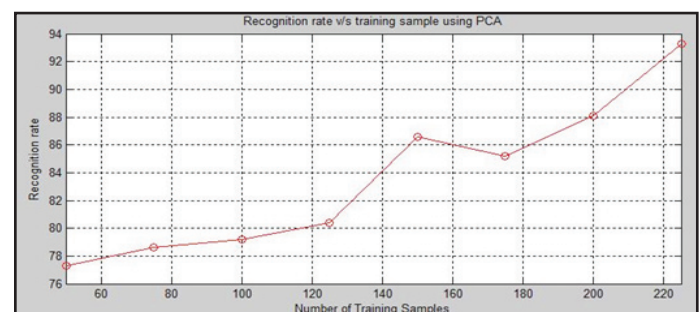


Fig. 2: Recognition Rate of PCA Technique

Fig. 2 depicts the graph of recognition rate versus number of training samples using the technique PCA. It achieved the recognition rate of 93.3% on implementation of 225 training samples.

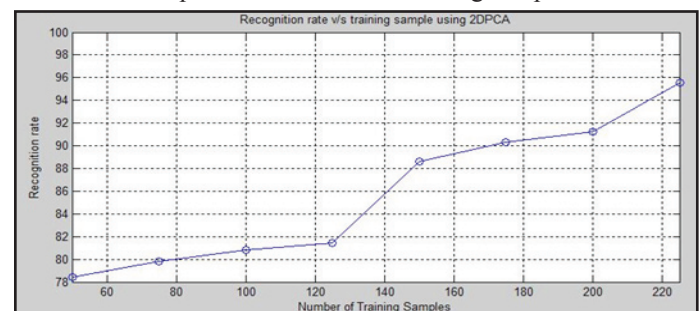


Fig. 3: Recognition Rate of 2PCA Technique

Fig. 3 depicts the graph of recognition rate versus number of training samples using the technique 2DPCA. It acquired the

recognition rate of 95.6% on implementation of 225 training samples.

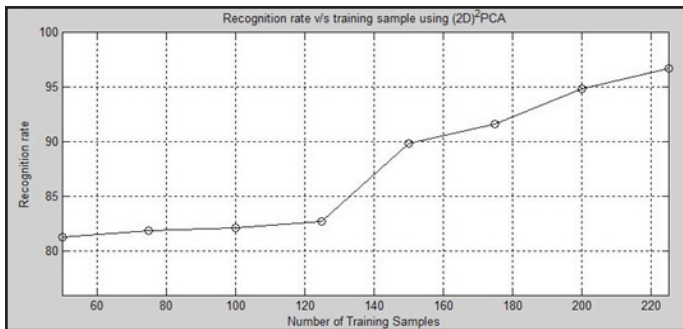


Fig. 4: Recognition Rate of 2D²PCA Technique

Fig. 4 depicts the graph of recognition rate versus number of training samples using the technique 2D²PCA. It achieved the recognition rate of 96.7% on implementation of 225 training samples.

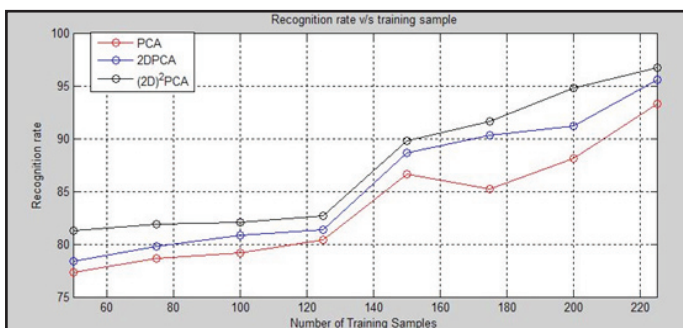


Fig. 5: Comparative Analysis of all the Techniques

Fig. 5 compares all the three techniques on a single graph. The overall recognition rate maximizes with the increase in the count of training images in the database. On a level count of 225 images in the training sample, the recognition rate of the system implementing 2D²PCA reaches 96.7%. From the experimental analysis, it is seen that the technique 2D²PCA performs better as compared to PCA and 2DPCA techniques.

V. Conclusion

Iris recognition in biometrics has high potentials to explore. In this paper, a comparative analysis of the three techniques: PCA, 2DPCA and 2D²PCA in iris recognition is presented. All the three techniques can effectively differentiate among different individuals by identifying their irises. In terms of computation, 2D²PCA technique is more efficient and effective. Real time applications require good processing speed and high recognition rate, therefore, 2D²PCA has shown good results towards the requirements. From the experimental results stated above, it is seen that 2D²PCA technique has highest recognition rate of 96.7% in iris recognition. This technique performed better as compared to PCA and 2DPCA techniques. The research conduct verifies the high accuracy and authenticity of the iris in biometric recognition and features the robustness of 2D²PCA in image recognition. The future work can be done by taking a much larger database of iris and taking into consideration the iris images with low quality.

References

[1] R.P. Wildes, "Iris Recognition: An Emerging Biometric Technology", *Proceedings of the IEEE*, Vol. 85, pp. 1348-1363, Sept. 1997.

[2] Te Chu, Chia, Ching-Han Chen, "High performance iris recognition based on LDA and LPCC." In *Tools with Artificial Intelligence*, 2005. ICTAI 05. 17th IEEE International Conference on, pp. 5-pp. IEEE, 2005.

[3] Yang, Jian, David Zhang, Alejandro F. Frangi, Jing-yu Yang, "Two-dimensional PCA: A new approach to appearance-based face representation and recognition." *Pattern Analysis and Machine Intelligence*, IEEE Transactions on 26, No. 1, 2004, pp. 131-137.

[4] Zhang, Daoqiang, Zhi-Hua Zhou, "(2D) 2PCA: Two-directional two-dimensional PCA for efficient face representation and recognition." *Neurocomputing* 69, No. 1, pp. 224-231, 2005.

[5] Flom, Leonard, Aran Safir, "Iris recognition system." U.S. Patent 4, 641, 349, Issued February 3, 1987.

[6] Daugman, John, "High confidence personal identification by rapid video analysis of iris texture", In *Security Technology*, 1992. Crime Countermeasures, Proceedings. Institute of Electrical and Electronics Engineers 1992 International Carnahan Conference on, pp. 50-60. IEEE, 1992.

[7] Daugman, John G., "High confidence visual recognition of persons by a test of statistical independence." *Pattern Analysis and Machine Intelligence*, IEEE Transactions on 15, No. 11, 1993, pp. 1148-1161.

[8] Wildes, Richard P., Jane C. Asmuth, Gilbert L. Green, Stephen C. Hsu, Raymond J. Kolczynski, James R. Matey, Sterling E. McBride, "A system for automated iris recognition." In *Applications of Computer Vision*, 1994. Proceedings of the Second IEEE Workshop on, pp. 121-128. IEEE, 1994.

[9] Tan, Tieniu, Zhaofeng He, Zhenan Sun, "Efficient and robust segmentation of noisy iris images for non-cooperative iris recognition", *Image and Vision Computing* 28, No. 2, pp. 223-230, 2010.

[10] Daugman, John, "New methods in iris recognition." *Systems, Man, and Cybernetics, Part B: Cybernetics*, IEEE Transactions on 37, No. 5, pp. 1167-1175, 2007.

[11] Xu, Xiuli, Ping Guo, "Iris feature extraction based on the complete 2DPCA." In *Advances in Neural Networks-ISNN 2009*, pp. 950-958. Springer Berlin Heidelberg, 2009.

[12] Kumar, DR Shashi, K. B. Raja, N. Nuthan, B. Sindhuja, P. Supriya, R. K. Chhotaray, Sabyasachi Pattnaik, "Iris recognition based on DWT and PCA." In *Computational Intelligence and Communication Networks (CICN)*, 2011 International Conference on, pp. 489-493. IEEE, 2011.

[13] Zhang, Tianyi, Yongmei Hu, Chunxiao Zhang, Heng An, Wenwen Xu, "A New Method for Iris' Location Based on Pointwise Detection." In *Bioinformatics and Biomedical Engineering (iCBBE)*, 2010 4th International Conference on, pp. 1-4. IEEE, 2010.

[14] Mattar, E., "Principal Components Analysis Based Iris Recognition and Identification System." *International Journal of Soft Computing and Engineering (IJSCE)*, pp. 2231-2307, 2013.