2011 International Conference on Software and Computer Applications
IPCSIT vol.9 (2011) © (2011) IACSIT Press, Singapore

Eye Recognition Technique Based on Eigeneyes Method

Khamael Abbas AL-phalahi Al-dualimi+

Department of Computer Science, College of Science, University of AL-Nahrain,
Iraq, Baghdad, Al-Jadriya

Abstract. A robust recognition technique for identifying and recognizing human-eye images is presented. The recognition process utilizes the mean reduced eyes to produce the Eigeneye basis for the eye space. Image's eigenvalues and eigenvectors are computed, using covariance matrix algorithm. The least square criterion is then utilized to determine the similarity between the existed (in Database file) eyes with a new eye's images. A threshold value is designed to differentiate between existed and non-existed stored eye's images.

Keywords*:* - eigeneye, eigenvectors, Mean square error.

1. Introduction

Identification of humans is a goal as ancient as humanity itself. As technology and services have developed in the modern world, human activities and transactions have proliferated in which rapid and reliable personal identification is required. Examples include passport control, computer login control, bank automatic teller machines and other transactions authorization, premises access control, and security systems generally. All such identification efforts share the common goals of speed, reliability and automation [1]. The use of biometric indicia for identification purposes requires that a particular biometric factor be unique for each individual that it can be readily measured, and that it is invariant over time. Biometrics such as signatures, photographs, fingerprints, voiceprints and retinal blood vessel patterns all have significant drawbacks. Although signatures and photographs are cheap and easy to obtain and store, they are impossible to identify automatically with assurance, and are easily forged. Electronically recorded voiceprints are susceptible to changes in a person's voice, and they can be counterfeited. Fingerprints or handprints require physical contact, and they also can be counterfeited and marred by artifacts. Human iris on the other hand as an internal organ of the eye and as well protected from the external environment, yet it is easily visible from within one meter of distance makes it a perfect biometric for an identification system with the ease of speed, reliability and automation [2].

2. Related Work and Contribution

Recognition of eyes has obtained increasing attentions in recent years. Most studies were based on extracting some recognizable features in the frequency domain, since they are more robust than the features of the time domain. Literatures states there are different recognizable features are adopted or suggested. In the following sections we describe the head research lines and our contribution in the field of study:

2.1. Related Work

+ Corresponding author. Mobile: + (+9647901545198);
E-mail address: (khamail_abbas@yahoo.com).

A study of a human recognition by use of biometrics known as Iris Recognition is provided. Based on the technology invented by Dr. John G. Daugman, an attempt of implementing a workable system was made. Although the attempt did not succeed in every aspect, "Iris Recognition" is forecast to play a role in a wide range of other applications in which a person's identity must be established or confirmed [3]. A wide variety of systems requires reliable personal recognition schemes to either confirm or determine the identity of an individual requesting their services. The purpose of such schemes is to ensure that the rendered services are accessed only by a legitimate user and no one else. Examples of such applications include secure access to buildings, computer systems, laptops, cellular phones, and ATMs. In the absence of robust personal recognition schemes, these systems are vulnerable to the wiles of an impostor. Biometric recognition or, simply, biometrics refers to the automatic recognition of individuals based on their physiological and/or behavioral characteristics. It detects Irises based on the principal Component technique analysis. The Principal Component Analysis (PCA) is one of the most successful techniques that have been used in image recognition and compression.

2.2. Contribution

In this paper, we propose a new framework to discover the relational rules for the eye recognition based on eigen problem . The recognition process utilizes the mean reduced eyes to produce the Eigeneye basis for the eye space. Image's eigenvalues and eigenvectors are computed, using covariance matrix algorithm. The least square criterion is then utilized to determine the similarity between the existed (in Database file) eyes with a new eye's images. A threshold value is designed to differentiate between existed and non-existed stored eye's images.

(1) **(2)** **(3)** **(4)** **(5)**

Fig.1: Training set of five eye images, each of 100×100 pixels size.

3. The Recognition Methodology

Suppose you have M iris images of the training set are submitted to a eyes detection algorithm. All eyes images must be in same size (e.g. n × n pixels). These images are firstly arranged in an array, as column vectors, each of N×1 dimension (N= n × n). This arrangement occurs by taking every row of the trained images and concatenating them, each one after to the other; as given by**:**

$$\begin{bmatrix} \textbf{Image}_1 & \textbf{Image}_2 & \textbf{Image}_3 & . & . & . & \textbf{Image}_M \\ \Gamma_{1,1} & \Gamma_{1,2} & \Gamma_{1,3} & . & . & . & \Gamma_{1,M} \\ \Gamma_{2,1} & \Gamma_{2,2} & \Gamma_{2,3} & . & . & . & \Gamma_{2,M} \\ \Gamma_{3,1} & \Gamma_{3,2} & \Gamma_{3,3} & . & . & . & \Gamma_{3,M} \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ \Gamma_{N,1} & \Gamma_{N,2} & \Gamma_{N,3} & . & . & . & \Gamma_{N,M} \end{bmatrix} \tag{1}$$

Thus, the average face "Ψ" of all training set plus the test image can be represented by [5]:

$$\Psi_{N,1} = \frac{1}{M+1}\begin{bmatrix} \sum_{k=1}^{M+1}\Gamma_{1,k} \\ \sum_{k=1}^{M+1}\Gamma_{2,k} \\ \sum_{k=1}^{M+1}\Gamma_{3,k} \\ . \\ . \\ . \\ \sum_{k=1}^{M+1}\Gamma_{N,k} \end{bmatrix} \qquad (2)$$

This column vector image "$\Psi_{N,1}$" can easily be retransformed into 2D image space "$\Psi(n,n)$" by inserting it in an empty array of size n × n pixels. ***Fig.2*** shows the average of the training set, shown in ***Fig.1***.

Figure.2: The average eye of the training set shown in fig.1.

Once calculating the "Ψ" average eye, a new "Φ" group of images is set up, obtained from the difference between each image of the training set and the average eyes; i.e.

$$\Phi_i = \Gamma_i - \Psi \qquad for \quad i = 1,2,....,M \qquad (3)$$

Each Φ_i , (referred as ***eigeneye***), will go far away from the average eye, as shown in ***figure.3***.

(1) (2) (3) (4) (5)

Fig.3: Mean reduced (eigeneye) of the 5 training set of images, shown figure.1

From the group of "Φ_i" images, the covariance matrix "***Cov***" can be computed as:

$$Cov = \Phi^T \Phi \qquad (4)$$

Where: "T" represents matrix transposition.

Table-1: The elements of the symmetric covariance matrix for the tested set of eigeneyes for red band.

Eigeneyes	$eigeneye_1$	$eigeneye_2$	$eigeneye_3$	$eigeneye_4$	$eigeneye_5$
1	7.6856	-0.1395	-2.8035	-2.1445	-2.5982
2	-0.1395	5.1610	- 1.7851	- 2.0547	-1.1817
3	-2.8035	-1.7851	6.2417	-1.9245	0.2714
4	-2.1445	-2.0547	-1.9245	8.6295	-2.5059
5	-2.5982	-1.1817	0.2714	-2.5059	6.0144

Table-2: The elements of the symmetric covariance matrix for the tested set of eigeneyes for green band.

Eigeneyes	$eigeneye_1$	$eigeneye_2$	$eigeneye_3$	$eigeneye_4$	$eigeneye_5$
1	0.7762	0.0346	0.2179	0.3174	0.2063
2	0.0346	0.5872	0.0616	0.3351	0.1559
3	0.2179	0.0616	0.7406	0.3788	0.0824
4	0.3174	0.3351	0.3788	1.1243	0.0930
5	0.2063	0.1559	0.0824	0.0930	0.5376

Table-3: The elements of the symmetric covariance matrix for the tested set of eigeneyes for blue band.					
Eigeneyes	$eigeneye_1$	$eigeneye_2$	$eigeneye_3$	$eigeneye_4$	$eigeneye_5$
1	0.8492	-0.0600	-0.2636	-0.3217	-0.2039
2	-0.0600	0.6742	-0.0366	-0.4218	-0.1559
3	-0.2636	-0.0366	0.9530	-0.5321	-0.1207
4	-0.3217	-0.4218	-0.5321	1.3526	-0.0770
5	-0.2039	- 0.1559	-0.1207	-0.0770	0.5576

As an example, for the set of eigeneye show in ***Fig.3***, the covariance matrix (size 10×10) is symmetric around the diagonal, as shown in table-1 below

The eigenvalues "λ" and eigenvectors "V" of a square symmetric matrix ***Cov*** are, respectively, scalars and nonzero vectors that satisfy the following matrix product formula:

$$[Cov][V_i] = \lambda_i [V_i\} \ , \quad for \quad i = 1,2,....,M \qquad (5)$$

Computation of the eigenvalues and eigenvectors can be performed by fast algorithm following the procedures given in [6]. As an example, the eigenvalues and the eigenvectors for the set of eigeneyes shown in fig.3 are:

Table4: eigenvectors for tested eye of red band

Eigenvectors	$eigeneye_1$	$eigeneye_2$	$eigeneye_3$	$eigeneye_4$	$eigeneye_5$
1	- 0.4472	-0.6618	- 0.3550	0.4032	0.2710
2	-0.4472	-0.1772	- 0.2443	-0.6168	-0.5731
3	-0.4472	0.5257	- 0.0677	0.5875	-0.4170
4	- 0.4472	- 0.1637	0.8754	0.0421	0.0718
5	-0.4472	0.4769	- 0.2084	- 0.3317	0.6474

Table -5:eigenvalues for tested eye of red component

Eigenvalues	λ_1	λ_2	λ_3	λ_4	λ_5
	0.0000	1.1218	1.0818	0.6176	0.5520

Table-6: eigenvectors for tested eye of green band

Eigenvectors	$eigeneye_1$	$eigeneye_2$	$eigeneye_3$	$eigeneye_4$	$eigeneye_5$
1	0.4472	0.1429	0.7661	0.4389	-0.0085
2	0.4472	0.2863	0.1256	- 0.7744	-0.3202
3	0.4472	0.4521	-0.5940	0.4292	-0.2421
4	0.4472	-0.8311	- 0.1385	-0.0509	-0.2959
5	0.4472	-0.0502	-0.1593	-0.1446	-0.8667

Table -7: eigenvalues for tested eye of green component

Eigenvalues	λ_1	λ_2	λ_3	λ_4	λ_5
	0.0000	1.4861	1.0051	0.6278	0.6467

Table-8: eigenvectors for tested eye of blue band

Eigenvectors	$eigeneye_1$	$eigeneye_2$	$eigeneye_3$	$eigeneye_4$	$eigeneye_5$
1	- 0.4472	-0.2797	-0.7378	0.3209	0.2729
2	-0.4472	-0.0866	0.2929	-0.5081	-0.6698
3	-0.4472	0.3321	-0.5531	- 0.6170	-0.0555
4	- 0.4472	0.8502	0.0479	- 0.1817	0.2048
5	-0.4472	0.0545	-0.2553	-0.5476	0.6572

Table-9:eigenvalues for tested eye of blue band

Eigen values	λ_1 0.0000	λ_2 1.8381	λ_3 1.1443	λ_4 0.7271	λ_5 0.6772

If a new eye image to be verified is entered with the training set, the matrix in ***eq.(1)*** becomes:

$$\begin{bmatrix} \textbf{Image}_1 & \textbf{Image}_2 & \textbf{Image}_3 & \cdot\ \cdot\ \cdot & \textbf{Image}_M & \textbf{Image}_{M+1} \\ \Gamma_{1,1} & \Gamma_{1,2} & \Gamma_{1,3} & \cdot\ \cdot\ \cdot & \Gamma_{1,M} & \Gamma_{1,M+1} \\ \Gamma_{2,1} & \Gamma_{2,2} & \Gamma_{2,3} & \cdot\ \cdot\ \cdot & \Gamma_{2,M} & \Gamma_{2,M+1} \\ \Gamma_{3,1} & \Gamma_{3,2} & \Gamma_{3,3} & \cdot\ \cdot\ \cdot & \Gamma_{3,M} & \Gamma_{3,M+1} \\ \cdot & \cdot & \cdot & \cdot\ \cdot\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot\ \cdot\ \cdot & \cdot & \cdot \\ \Gamma_{N,1} & \Gamma_{N,2} & \Gamma_{N,3} & \cdot\ \cdot\ \cdot & \Gamma_{N,M} & \Gamma_{N,M+1} \end{bmatrix} \qquad (6)$$

Suppose an existed image within the trained set has been selected to be verified, as illustrated in ***Fig.4.***

(1) (2) (3) (4) (5)

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Figure.4: The Training set of eyes images plus an existed test eyes to be verified.

Following the same procedures being done for the trained set (mentioned above), the eigenvectors for the new set of images will be:

Table-10:eigenvectors for tested eye of red band

Eigen vector	**Eigeneye$_1$**	**Eigeneye$_2$**	**Eigeneye$_3$**	**Eigeneye$_4$**	**Eigeneye$_5$**	**Eigeneye$_6$**
1	-0.4082	-0.4082	-0.4082	-0.4082	-0.4082	-0.4082
2	0.4956	0.1992	0.4553	-0.1731	0.4885	0.4885
3	0.5718	0.2852	-0.7535	-0.1513	0.0239	0.0239
4	-0.5049	0.8432	-0.0402	-0.1427	-0.0777	-0.0777
5	-0.0762	0.0359	-0.2381	0.8718	-0.2967	-0.2967
6	-0.0026	-0.0026	-0.0026	-0.0026	0.7045	0.7045

As it is obvious, the similarity between the verify eye and the trained set can be represented by the minimum distance test (i.e. utilizing the Mean-Square-Error "MSE" criterion), given by:

$$Min\{MSE_K\} = Min\{\sum_{i=}^{M}(V_{K,i} - V_{M+1,i})^2\}, \quad \text{for } K = 1,2,.......,M \qquad (7)$$

The *Min{MSE}* between trained eigeneyes and the verifying eigeneyes is, obvious, between V_5 and V_6; i.e. $Min\{MSE_K\}=MSE_5$, as listed below:

Let us now examine a different scene for an existed eyes, as illustrated in ***Fig.5*** below;

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Figure.5: The Training set of iris images plus a verify existed eyes of different scene put lenses

Once again, the eigenvectors of the new set of images are:

The *MSE* between trained eigeneyes and the verifying eigeneyes, respectively by substituting (*M=5, 4, 3, 2, and 1*) in eq.(7) are as listed below:

Table-12: eigenvectors for tested eye of red band

Eigenvectors	$eigeneye_1$	$eigeneye_2$	$eigeneye_3$	$eigeneye_4$	$eigeneye_5$	$eigeneye_6$
1	0.4795	0.1991	-0.2025	0.4810	-0.4780	-0.4791
2	0.5861	0.2858	-0.1658	-0.7393	0.0071	0.0261
3	0.5051	-0.8406	0.1648	0.0420	0.0415	0.0873
4	0.0654	-0.0701	-0.8585	0.2311	0.3350	0.2970
5	-0.4082	-0.4082	-0.4082	-0.4082	-0.4082	-0.4082
6	-0.0221	0.0217	-0.0263	0.0151	-0.7006	0.7122

Table-13: eigenvectors for tested eye of green band

Eigenvectors	$eigeneye_1$	$eigeneye_2$	$eigeneye_3$	$eigeneye_4$	$eigeneye_5$	$eigeneye_6$
1	-0.1513	-0.2925	-0.4563	0.8245	0.0550	0.0205
2	-0.7544	-0.2290	0.3262	-0.0730	0.3741	0.3561
3	0.2370	-0.1227	-0.6204	-0.3842	0.4460	0.4442
4	0.4301	-0.8247	0.3657	-0.0132	0.0238	0.0183
5	-0.4082	-0.4082	-0.4082	-0.4082	-0.4082	-0.4082
6	-0.0114	-0.0134	-0.0063	0.0186	-0.7006	0.7131

Table-14: eigenvectors for tested eye of blue band

Eigenvectors	$eigeneye_1$	$eigeneye_2$	$eigeneye_3$	$eigeneye_4$	$eigeneye_5$	$eigeneye_6$
1	0.3013	0.3076	0.3363	-0.8336	-0.0709	-0.0406
2	0.6192	0.2442	-0.2261	-0.7393	-0.4662	-0.4556
3	-0.4320	0.1769	0.7012	0.2378	-0.3444	-0.3394
4	-0.4151	0.8049	-0.4210	-0.0272	0.0396	0.0188
5	-0.4082	-0.4082	-0.4082	-0.4082	-0.4082	-0.4082
6	-0.0157	0.0027	-0.0141	0.0145	-0.7005	0.7131

Table-15:eigenvalues for tested eye of red band

Eigen values	λ_1 1.4415	λ_2 1.0885	λ_3 0.6008	λ_4 0.7003	λ_5 0.0000	λ_6 0.0500

Table-16:eigenvalues for tested eye of green band

Eigen values	λ_1 1.4875	λ_2 1.1463	λ_3 0.8812	λ_4 0.6347	λ_5 0.0000	λ_6 0.0681

Table-17:eigenvalues for tested eye of blue band

Eigen values	λ_1 1.8386	λ_2 1.2090	λ_3 1.0116	λ_4 0.7253	λ_5 0.0000	λ_6 0.0689

Table-18:Mean square error of eigenvectors for red band

MSE/M	*MSE₁*	*MSE₂*	*MSE₃*	*MSE₄*	*MSE₅*
1	-0.0004	0.28	0.2766	-0.0019	0.0011
2	-0.56	-0.2597	-0.1397	-0.7132	0.019
3	-0.4178	-0.7533	-0.0775	0.0453	0.0458
4	0.2316	0.2269	-0.5615	0.0659	-0.038
5	0	0	0	0	0
6	0.6901	0.6905	0.6859	0.6971	0.0116

Table-19: Mean square error of eigenvectors for green band

MSE/M	*MSE₁*	*MSE₂*	*MSE₃*	*MSE₄*	*MSE₅*
1	-0.2607	-0.267	-0.2957	-0.793	-0.0303
2	-0.1636	0.2114	0.2295	-0.2837	-0.0106
3	-0.0926	0.1625	-0.3618	0.1016	-0.005
4	-0.3963	-0.7861	-0.4022	-0.0084	-0.0208
5	0	0	0	0	0
6	0.6974	0.7104	0.699	0.6986	0.0126

Table-20: Mean square error of eigenvectors for blue band

MSE/M	*MSE₁*	*MSE₂*	*MSE₃*	*MSE₄*	*MSE₅*
1	-0.1308	-0.272	-0.4358	-0.804	-0.0345
2	-0.3983	0.1271	0.0299	0.2831	-0.018
3	0.2072	0.3215	-0.1762	0.06	-0.0018
4	-0.4118	-0.8064	-0.3474	0.0051	-0.0055
5	0	0	0	0	0
6	0.7017	0.6997	0.7068	0.6945	0.0125

As it is obvious, eye_5 yields minimum MSE for the first four elements of the eigenvectors, despite the huge differences between eye_5 and the verifying eye (i.e. both belong to the same person).

MSE	*MSE₁*	*MSE₂*	*MSE₃*	*MSE₄*	*MSE₅*
1	0	0	0	0	0
2	0.0071	0.2893	0.0332	0.6616	0
3	0.5479	0.2613	0.7774	0.1752	0
4	0.4272	0.9209	0.0375	0.065	0
5	0.2205	0.3326	0.0586	1.1685	0
6	0	0	0	0	0

4. Conclusion

A very encouraging matching and verifying result has been satisfied by implementing the Eigen eyes algorithm. The result can be improved if pure eye images were adopted (i.e. eye with lences, with class, without class), and compressed image. However, certain image preprocessing operations may still required to enhance the results (e.g. image normalization, image re-centering, etc.). Although only a limited number of tests have been performed, the results show that images which contain only eyes are sufficient to obtain good results in face recognition. In fact, eyes differ considerably from person to person.

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