

Eigenface approach based human face recognition

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المستخلص

ينتاول هذا البحث مبدا تقريب محول ايكن للوجه لكشف وتحديد وجه الانسان . وفي هذا التقريب يتم استخلاص ميزات من صورة الوجه مقللا تأثير تباين الاضاءة والخلفية, ويعامل الوجه كمجموعة من المعلومات ذات بعدين أخذا حقيقة ان صورة الوجه عادة ما تكون منتصبة وقائمة بشكل عادي ومتمركزة في منتصف الصورة, وهكذا يمكن وصفها كمجموعة صغيرة من خصائص ثنائية الرؤية, وصور الوجه المستخدمة للتدريب والاختبار انتقيت بعناية من قاعدة المعلومات ORL لصور الوجوه للحصول على اقل تغيير لتعابير الوجه. ويعتبر تقريب محول ايكن للوجه المقترحة طريقة ملائمة للاستخدام في كشف وتحديد الوجوه لكونها بسيطة وسريعة وقابلة للتعلم بكفاءة.

Abstract

This paper describe the principle of eigenface approach to detection and identification human face. In this approach, the features extracted from face images are individual, hidden, light insensitive, and effective to recognition. Wherever approach treats the face recognition as two dimensions recognition problems, taking advantage of the fact that faces are normally upright and thus may be described by a small set of two characteristics view. The face images for training and testing are selected carefully from Olivetti and Oracle Research Laboratory (ORL) face database in order to have minnum pose variation. The eigenface approach is proposed seems to be an adequate method to be used in face recognition due to its simplicity, speed, and learning capability.

1-Introduction

Face recognition plays an important role in biometrics base personal identification[1]. Abiometrics is, "Automated methods of recognizing an individual based on their unique physical or behavioral characteristics." The process of facial recognition involves automated methods to determine identity, using facial features as essential elements of distinction[2,3]. The important fact which is considered is that although these face images have high dimensionality, in reality

they span very low dimensional space. So instead of considering whole face space with high dimensionality, it is better to consider only a subspace with lower dimensionality to represent this face space. The Eigenface approach gives us efficient way to find this lower dimensional space. This method was originally suggested by Alex P. Pentland and Matthew A. Turk from MIT in 1991[4]. Eigenfaces are the Eigenvectors which are representative of each of the dimensions of this face space and they can be considered as various face features. Any face can be expressed as linear combinations of the singular vectors of the set of faces, and these singular vectors are eigenvectors of the covariance matrices. The Eigenvectors with higher Eigenvalues represent most significant directions which should be considered in the lower dimensional subspace. The lower Eigenvalues can be neglected as they do not provide significant information about face variation. So it means that all images projected in this direction lie close to each other and so do not represent much face variation. The eigenvectors in some sense represent the features of face. The eigenvectors with higher eigenvalues are the directions in which we can get maximum variation and this corresponds to important features of face which are primarily required for Face recognition. The eigenvectors with lower eigenvalues can be neglected as these are the directions in which there is no significant information and the small face variations are mainly due to noise in face images. So this eigenface approach helps in extracting various useful features essential for face recognition[5]. Some of the limiting factors of this approach are the background, difference in illumination, imaged head size, and head orientation. To solve some of these problems we could identify the location of the head and zoom until it observe most of the face[6]. In the final, the Face recognition is an important research problem spanning numerous fields and disciplines. This because face recognition, in additional to having numerous practical applications such as bankcard identification, access control, Mug shots searching, security monitoring, and surveillance system, is a fundamental human behaviour that is essential for effective communications and interactions among people[7].

2-Human face database creation

The Olivetti and Oracle Research Laboratory (ORL) Human face database is used in order to test the approach 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. The images are greyscale and original size of each image is 112x92 pixels[8]. Fig.(1) shows example for 10 individuals 5 images per personal from the ORL database for human face images.

3-Algorithm of eigenface approach:

The algorithm for the facial recognition in spatial domain using eigenfaces is described in Fig.(2). The original images of the training set are transformed into a set of eigenfaces E . Afterwards the weights are calculated for each image of the training set and stored in the set W .

For an unknown image X , the weights are calculated for that image and stored in the vector W_x . The W_x is compared with the weights of the training set W . It is compared using distance measures, which is calculated using Euclidean distance. If this average distance exceeds some threshold value θ , then the weight vector of the unknown image W_x lies too far apart from the weights of the faces. In this case, the unknown X is considered to be not a face. Otherwise if X is actually a face, its weight vector W_x is stored for later classification. The optimal threshold value θ is determined empirically[2].

4-The eigenface approach technique:

Suppose the training set consists of M human face images $I_i(x,y)$ be a $N \times N$ grey image in two two-dimensional spatial domain, and the face images must be centered and of the same size.

1- Represent every image I as a vector Γ_i :

$$I = \begin{bmatrix} X_{11} & \cdots & X_{1N} \\ \vdots & \ddots & \vdots \\ X_{N1} & \cdots & X_{NN} \end{bmatrix} \quad (1)$$



Fig.(1) Example from ORL human face database

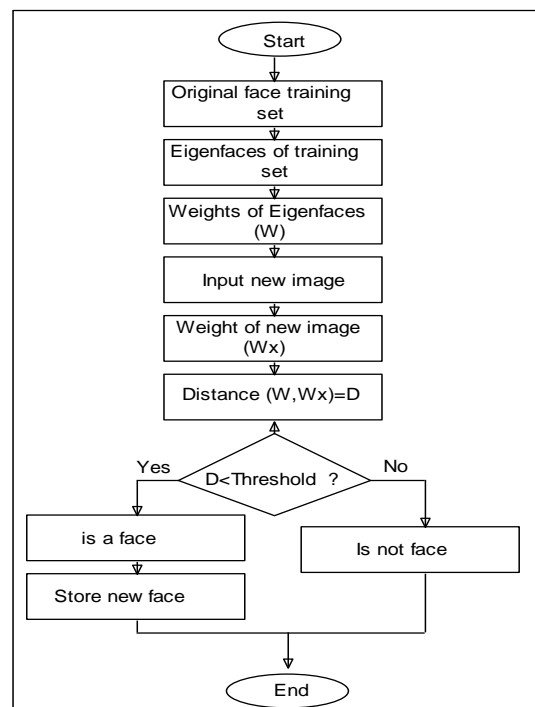


Fig.(2) High- Level functioning principle of the Eigenface _ based facial recognition algorithm

since

$$\Gamma_i = [x_{11} \ x_{12} \ \dots x_{1N} x_{21} \ \dots x_{NN}]^T \quad (2)$$

Γ_i is an $N^2 \times 1$ vector.

From training face images I_i :

$$I_i = \{I_1, I_2, \dots, I_M\} \quad (3)$$

Obtain:

$$\Gamma = \{\Gamma_1, \Gamma_2, \dots, \Gamma_M\} \quad (4)$$

Γ is an $N^2 \times M$ matrix.

2- Compute the mean face Ψ as:

$$\Psi = \frac{1}{M} \sum_{i=1}^M \Gamma_i \quad (5)$$

3- Calculate the difference vector Φ_i between input image and the mean face as:

$$\Phi_i = \Gamma_i - \Psi \quad (6)$$

4- Compute the covairance matrix C as:

$$C = \frac{1}{M} \sum_{i=1}^M \Phi_i \Phi_i^T = AA^T \quad (7)$$

5- Compute the eigenvectors and eigenvalues of C as[4]:

Let:

$$C = AA^T \quad (8)$$

$$L = A^T A \quad (9)$$

$$L_{n,m} = \Phi_m^T \Phi_n \quad (10)$$

$$u_l = \sum_{k=1}^M v_{lk} \Phi_k \quad \text{and } l=1, 2, \dots, M \quad (11)$$

where L is a $M \times M$ matrix, v are M eigenvectors of L and u are eigenfaces. The covariance matrix C is calculated using the formula $C=AA^T$, the original (inefficient) formula is given only for the sake of explanation of A . The advantage of this method is that one has to evaluate only M

numbers and not N^2 . Usually, $M \ll N^2$ as only a few principal components (eigenfaces) will be relevant. The amount of calculations to be performed is reduced from the number of pixels ($N^2 \times N^2$) to the number of images in the training set (M).

6- The associated eigenvalues allow one to rank the eigenfaces according to their usefulness. Usually, it use only a subset of M eigenfaces, the M' eigenface with the largest eigenvalues.

7- Each face (minus the mean) Φ_i in the training set can be represent as a linear combination of the best M' eigenvectors. Whenever the normalized training face of Φ_i is represent in this basis by a vector[4]:

$$\Omega_i = [w_1^i \quad \dots \quad w_{M'}^i]^T \quad (12)$$

5-Classifying the faces:

The process of classification of a new (unknown) face Φ_{new} to one of the classes (known faces) proceeds in two steps.

First, the new image is transformed into its eigenface components. The resulting weights form the weight vector Ω_{new}^T

$$w_{\text{new}} = u_k^T (\Gamma_{\text{new}} - \Psi) \quad k=1,2, \dots, M' \quad (13)$$

$$\Omega_{\text{new}} = [w_1 \quad w_2 \quad \dots \quad w_{M'}]^T \quad (14)$$

Second, classification is performed by comparing the feature vectors of the face library members with the feature vector of the input face image. This comparison is based on the Euclidean distance between the two members to be smaller than a user defined threshold θ_k . This is given as [1]:

$$\frac{\|\Omega_{\text{new}} - \Omega_i\|}{\|\Omega_i\|} \leq \theta_k \quad (15)$$

If the comparison falls within the user defined threshold, then face image is classified as “known”, otherwise it is classified as “unknown” and can be added to face library with its feature vector for later use, thus making the system learning to recognize new face images.

6-Results

The training set and new unknown face images are selected carefully from the ORL database in order to have minimum pose variation. This database consists of four classes, each class represents one distinct person. In every class, there are three face image as shown in Fig.(3). Top three rows of them are randomly selected for training and bottom row shows the images for testing. So, there are totally nine face images for training and three face images for testing. The image format has been transformed to Joint Photographic Experts Group (JPEG) format because

its easy to process. The normalize of the training face images shown in Fig.(4). This is done to reduce the error due to lighting conditions and background while Fig.(5) shows the mean image which assist to find the difference between the input face image and the mean image. In Fig.(6) shows the eigenfaces for training faces sorting as descending form of eigenvalues. The first image to be recognized was taken from the training set. which is the first face image in the fourth row of Fig.(3). The result is showing in Fig.(7) and Fig.(8) which observe ,how the maximum Euclidean distances increases as imperfections are added as shown in table(1). This distance tells us how close the input image to the images on our training set and the maximum Euclidean distance for a face is approximately 15000 and the minimum is around 12000. Based on these distances we can make a decision of whether the face is a known face, an unknown face, or not a face at all. The second face image is outside our training set and how the error increases as imperfections are added as showing in Fig.(9) and Fig.(10). The third face image is unknown face as showing in Fig.(11) and Fig.(12) shows the observed the result. The image can be determined to be a face because the max value is within the 15000 range. Something that may look contradictory is that the maximum Euclidean distance is less than the one obtained using an image from the training set. On the other hand, the minimum value is higher as expected. Any decision that can take has to be made based on minimum and maximum distance.



Fig.(3) The training and testing images

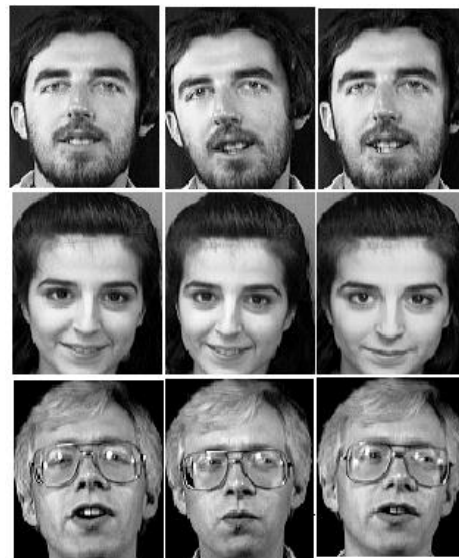
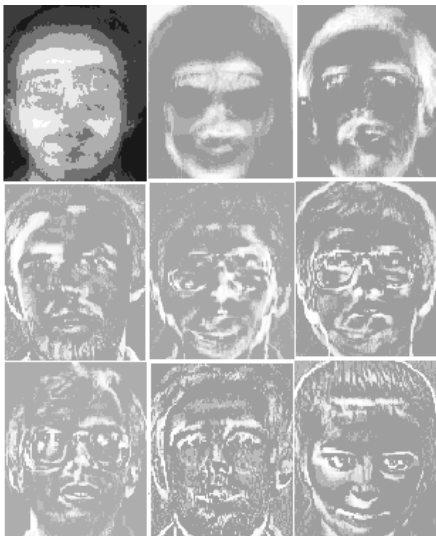


Fig.(4) Normalized training images



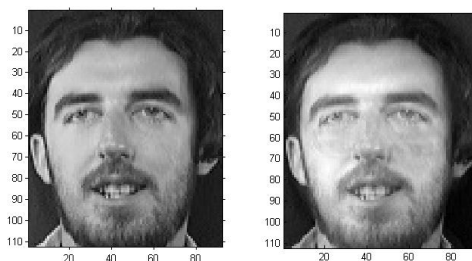
Fig.(5) The mean image



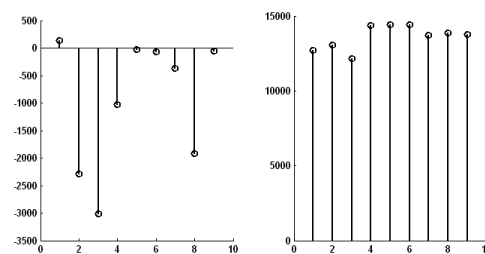
Test face image	Min Euclidean distance	Max Euclidean distance
First	12162	14428
Secnd	12799	15062
Third	12694	13248

Fig.(6) The eigenfaces for training images

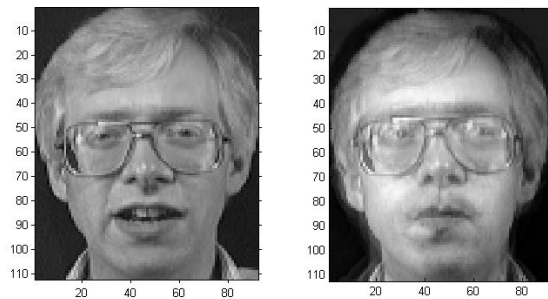
Table(1) Face image Euclidean distance



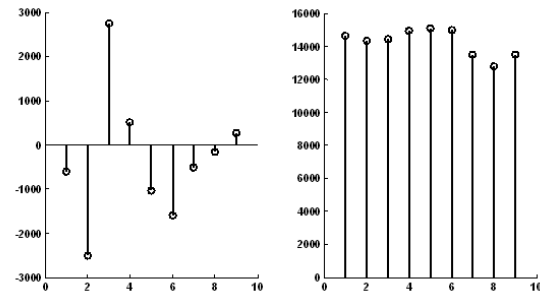
-a-
Fig.(7) a- First image test
b- Reconstructed image



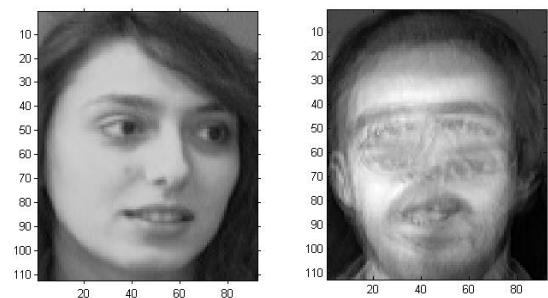
-a-
Fig.(8) a- Weight of first image test
b- Euclidean distance for first image test



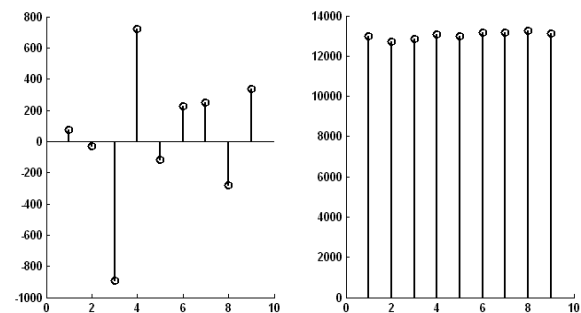
-a-
Fig.(9) a- Second image test
b- Reconstructed image



-a-
Fig.(10) a- Weight of second image test
b- Euclidean distance for second image test



-a-
Fig.(9) a- Third image test
b- Reconstructed image



-a-
Fig.(10) a- Weight of third image test
b- Euclidean distance for third image test

7-Conclusion

The Eigenface approach for Face Recognition process is fast and simple which works well under constrained environment. It is one of the best practical solution for the problem of face recognition. The recognition is performed by assigning weight vectors to face images, according to their contributions to the face space spanned by the eigenfaces. This approach excels in its speed, simplicity and learning capability.

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