Face Recognition Using Facial Symmetry

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ABSTRACT
Face is the most frequently used biometric trait after fingerprint. Its applicability made it popular in different areas such as Human Robot Interaction (HRI), Security Authentication, and Surveillance to name a few. Face recognition concept is based on two major blocks, training and testing. Usually training is done offline while testing is performed in real time scenario. As the size of the database increases, the recognition rate (time taken by system to recognize) increases. The rate of recognition is directly proportional to the size of the database and the dimension of the images. Human faces have the vertical symmetry; hence we utilized this feature and proposed a half way face recognition approach. Experimental verification on both the full faces and the half faces shows that half faces are also sufficient for recognizing the person. For verifying the efficiency of the approach, we have applied PCA (Principle Component Analysis) on both, the full faces and half faces, and have found that in both the cases, accuracy is almost same. But the recognition rate of half faces is just the half of the full faces.

Categories and Subject Descriptors
I.4.7 [**IMAGE PROCESSING AND COMPUTER VISION**]: Feature Measurement– *Feature representation, Size and shape, Projections.*

General Terms
Reliability, Experimentation, Security, Verification.

Keywords
Face Recognition, PCA, Facial Symmetry.

1. INTRODUCTION
'Biometrics is defined as the measurement of life. It is composed of two words – bio means life and metric means measurement. It consists of some methods to uniquely recognize human being, based on their physiological and behavioral traits. Face recognition is the physiological biometrics technique, which does not require any direct cooperation of human being [2]. Every human being has some common physiological traits like ears, iris, face and fingerprints but due to different geometrical representation of these, they are unique for each person out of which we limit ourselves to face alone. Each human face has certain unique identification traits that make them distinguishable from others. Faces play a magnificent role in several areas like access control, surveillance and human robot interaction system etc., as they represent rich source of information. The history of the face recognition technology started from late 1960s with the development of the semi-automated system, where administrator needs to locate the feature points (eyes, nose, mouth, etc.) [8]. Later recognition is performed by calculating the distance between the reference point of probe image and feature points of gallery images. Later advancement in this direction, suggested two ways of face recognition (a) based on face geometry (b) based on template. Geometry based methods used face geometry to distinguish the person, while template based methods used image intensity matrix for comparing the images and recognizing the person [3]. Intensity matrices of faces are basically dependent on the image dimension, and the values of the matrix depend on the format of the image (like RGB, Gray, and Black & White). Therefore, processing such a big dimension matrix requires much time. Recognition is performed in real time: therefore recognition techniques should be faster and accurate.

In 1996, two researchers David O'Mara and Robyn Owens [1] found a new way which could be used for the purpose of face recognition. They proposed a concept of bilateral symmetry in digital images. With the help of a dominant hyper plane they divided the objects in the image into two parts, so that each one looked like a mirror image of the other. Later, this approach of facial symmetry was also used by Xin Chen et.al [4]. They designed a fully automatic tool based on gray level difference histogram to define the symmetry in faces, but the disadvantage of their algorithm is it cannot define the symmetry when faces are not perfectly aligned in front of the camera. Human faces are symmetrical or not still a topic of debate, because the answer varies from person to person. Due to some environmental issues or due to some diseases like craniofacial deformity, some people do not have perfect bilateral symmetry. Some Children are born with these deformities, while others acquire it by mental trauma or other diseases. Same question in this regard has been well addressed in [6]. But the successful implementation of facial symmetry in 3D faces to handle pose variations by Georgios Passalis et al. [5] motivated us to proceed in that direction. Therefore, in this paper, we have first defined the bilateral symmetry on ORL database [12], and on the basis of symmetry of the full faces, we have extracted the half faces. Later, these half faces are used for the training and testing purpose. The experimental results using the PCA on both the full faces and the half faces have strengthened our hypothesis.

This paper is structured as follows: Section 2 describes the background details of PCA and provides the pseudo code of the method. In Section 3, we proposed face recognition method using face symmetry. Section 4 shows experimental verification of our approach and the comparison of their results with full face

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recognition. In section 5, we conclude the paper with its contribution towards the face biometrics and its future prospects.

2. PCA Algorithm for Face Recognition

PCA is a mathematical tool designed by Karl Pearson in 1901 to reduce the dimension of large datasets. The primary motivation for designing this tool was to represent the whole information (Big data) within a small entity. These small entities are known as principle components. Principle components are considered to be the most promising features of the datasets.

We have presented PCA in the algorithmic way so that it would be easier to understand how it practically works when face recognition is used. The algorithm is divided into two parts (a) Training and (b) Testing. Generally testing is performed offline and testing is performed in real time scenario. The mathematics of PCA can be found in literature [9][10][11]. So we have tried to provide a practical approach towards the understating and implementation of PCA. The given algorithm is influenced by Mathew Turk and Ales Pentaln [7] who have proposed PCA for faces in early 1991. They presented both, a mathematical view and a simplified way in terms of algorithm to better understand of this technique.

2.1 PCA for training the System

Step1: Generating Face Database

For each image in N

Img=read image(ImageName);

Img_db=img;

end

Step2. Find Co-variance of the face

M=mean(Img_db);

For each image in n

Var=Img_db(i)-m;

End

$Co\_Var=Var^T * Var;$

Step4. Finding Eigen Vectors and Eigen Values

[V D]=eig(Co_Var);

Step5. Choosing Best Eigen Vectors

For i=1 to Col_Size(D)

If(D(i,i)>TH) *//TH=Threshold for selecting the*

Best_Vect=V(:,i) *// best eigen vectors*

end

Step6. Generating EigenFaces

*EigenFaces=Var * Best_Vect;*

Step7. Generating ProjectedFaces

For each image in N

$ProjectedEigenFaces = EigenFaces^T * Var(:,i);$

end

2.2 PCA for Testing the System

Step1: Reading the Test Image

Img=read image(ImageName);

Step2. Mean Allignment

Img=Img-m;

Step3. Generating ProjectTestFace

$ProjectedTestFace = EigenFaces^T * Img;$

Step4. Finding distance between ProjectedFaces and ProjectedTestFace

For each image in N

Dist=min(ProjectedTestFace, ProjectedEigenFaces(:,i));

end //Minimum distance leads to the matched image

3. Proposed Approach

The proposed model is divided into two parts: first part measures the symmetry of the face while the second part uses this feature and utilizes it into the face recognition.

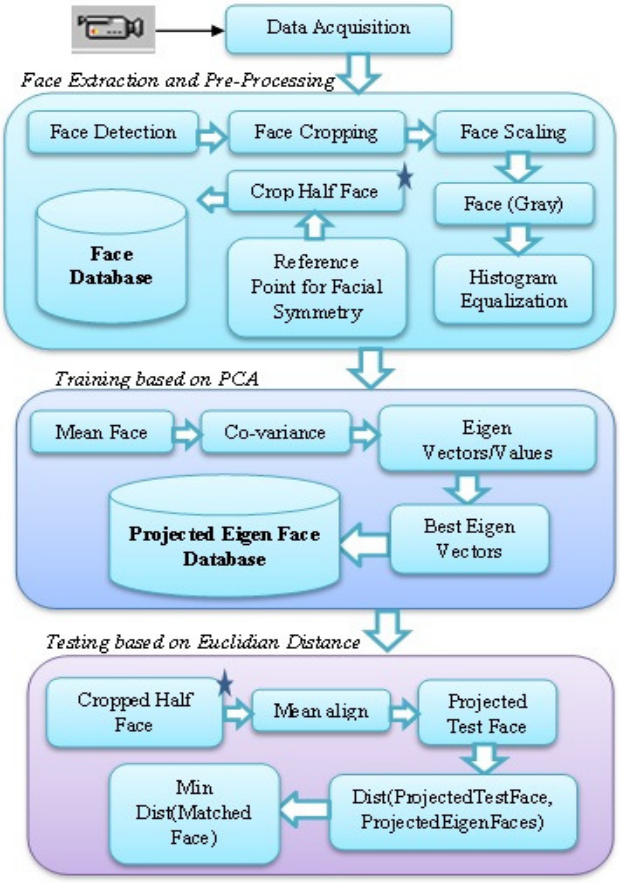

Figure 1: Description of Proposed Model

Figure 1 shows the description of our work, each block has its significance. The first block deals with the pre-processing of the face images. It detects the face from the given image (either from input image or directly from camera). Then it extracts the face and save it separately, later scaling, RGB to Gray Conversion,

Equalization all steps performed on the face. For finding the symmetry reference point should be well defined. We here defined the reference point is mid distance between two eyes. On the basis of the reference point half face is extracted from the full faces. All the left half faces are stored and a face database generated. While Section 3.1 briefly describes the face symmetry, section 3.2 describes the training and testing.

3.1 Generating Symmetrical Faces

We have followed a very simple mathematical model for finding the symmetry. We have assumed face as a rectangle/square depends on the dimension. In our experiment we have taken them as rectangle. If we vertically bisect the rectangle, it will be divided into two identical parts. Though face is not a rectangle, but if the face is symmetrical and perfectly aligned, we can apply this concept. The approach for finding the symmetry is given below.

Step1. Detecting frontal face in Image using Haar Cascade Classifier.

Step2. Crop and save the face region from the image.

Step3. Scale the faces to make them equal in dimension.

Step4. If face is in RGB convert it into the Gray.

Step5. Equalize the face using any filter (here we have used Histogram Equalization).

Step6. Face boundary is basically the rectangle of fix region. So, by dividing the rectangle, we can achieve the symmetry.

Step7. Crop and save the face region from the starting of the rectangle to the middle of the rectangle.

Figure 2: Samples of Full faces of ORL database

Figure 3: Samples of Half Faces of ORL database

Figure 2 shows some samples of full faces from the ORL database while figure 3 shows the half faces generated by using the above steps on behalf of the facial symmetry.

3.2 Training and Testing

Training start from calculating the mean of the face database

Xi represents each image in the database, while m and represents the mean and number of images. Variance is calculated by subtracted this mean from each face image in the database, variance basically describes how the data distributed along the mean.

$$m = \frac{\sum_{i=1}^{n} X_i}{n-1}$$

$$\text{Var} = \frac{\sum_{i=1}^{n}(X_i - m)(X_i - m)^T}{n-1}$$

Co-variance is calculated by

$$Co_{Var} = Var * Var^T$$

Eigen Vectors and Eigen Values are calculated on the basis of Co-variance matrix. Eigen vectors are having the same dimensions of the Co-variance matrix, while Eigen values are the same dimension but only having the diagonal values. It is widely known that best Eigen values gives the best Eigen vectors. So for choosing the best Eigen vectors we have decided the threshold. Eigen value greater than the threshold, their correspond Eigen vector selected as the best Eigen vectors. Eigen faces are generated by projected the variance (mean aligned faces) to the best Eigen factors, and the projected Eigen faces are generated by again projection of Eigen faces over the each mean aligned face.

Testing is also start with aligning the test image to the mean image of the face database. Projected test face is calculated by projecting this mean aligned face image to the Eigen faces. Recognition is performed by measuring the minimum distance between the projected test image and the projected Eigen faces. Here for the distance measurement we have used Euclidian distance, but other distance measurement techniques could also be used.

4. Experimental Setup and Result Comparisons

Our hypothesis is based on the assumption that human faces have the property of vertical symmetry. This symmetry can be defined over the system S where S'=T(S), Here T is a transformation applied on S. To evaluate the symmetrical property of an object in an image Dava O'Mara has given a very significant equation [1]. In the given equation S values lies between 0 and 1. If the value of S is zero then the object is having the perfect symmetry. As value of S increases the symmetry ratio decreases.

$$S = 1 - \frac{\sum_{\vec{p} \in Object} f(\vec{p})}{\sum_{\vec{p} \in Object} maxdiff}$$

Where

$$f(\vec{p}) = abs(I(\vec{p}) - I(\vec{p'})) \quad , \; if\ (\vec{p'}) \in Object$$
$$= maxdiff \quad , \; if\ (\vec{p'}) \notin Object$$

In the above equation $\vec{p}$ represents any point in the image and $\vec{p'}$ is the reflection through the candidate hyper plane of bilateral symmetry. *I(n)* represent the intensity value of point n, and *maxdiff* is the difference between the maximum intensity values.

From the above example, it has been proved that Symmetry is defined along a reference point. Here we have considered reference point is the mid distance between two eyes. Hence we have vertically bisected the face along the reference point. Both the two faces are almost identical in nature. The database we have taken here is the ORL database available at Cambridge University Computer Laboratory [12]. The database consists of 400 gray scale images of 40 persons. Each person is having 10 images. Training and testing is performed in the ratio of 70% and 30%, hence total 280 images are used for training and 120 images is used for the testing purpose.For the validation of our hypothesis, we have divided the overall experiment into two parts.

4.1 Verification of Face Symmetry

For the verification of our hypothesis we have applied PCA on both, the left half faces and the right half faces. Recognition is performed by measuring the Euclidian distance between the gallery image and the probe image. We have performed the training and testing in the groups of 10, 20, 30 and 40 people, the results of which have been summarized in table 1 and table 2. These tables also show the statistics of the experiment. Accuracy and the recognition rate are the two parameters of our experiment. By observing the result in table 1 and table 2, we conclude that in terms of recognition rate, they are same. But when measured in terms of accuracy, they have the slight difference in the result which is due to the alignment problem.

Table 1. Experiment performed on Left Half Face

No. Of Person	Total Images	Training (70%)	Testing (30%)	Left Half Face	
				Accuracy (%)	Time (ms)
10	100	70	30	96	1.3
20	200	140	60	93	2.6
30	300	210	90	94	4.0
40	400	280	120	93	5.3

Table 2. Experiment performed on Right Half Face

No. Of Person	Total Images	Training (70%)	Testing (30%)	Right Half Face	
				Accuracy (%)	Time (ms)
10	100	70	30	93	1.3
20	200	140	60	91	2.6
30	300	210	90	94	3.9
40	400	280	120	91	5.2

Figure 4 shows the comparison of the symmetry of the left face and the right face. From the figure below it is proved that left and right faces of a person have almost identical. This hypothesis also confirms that if human faces are symmetric in nature, then for the recognition purpose we may use half faces instead of full faces. We proceed with this idea and in the next section, verify it with our experimental results.

Figure 4: Accuracy Graph of both the Left and Right Half faces based on PCA evaluation.

4.2 Comparison Analysis between Full Face Recognition and Half Face Recognition

For verifying the efficiency of both the aspects we again implemented PCA on both the full faces and the half faces. The experimental results given below are very much promising.

Table 3. Experiment Performed on Full Faces

No. Of Person	Total Images	Training (70%)	Testing (30%)	Full Face	
				Accuracy (%)	Time (ms)
10	100	70	30	96	2.6
20	200	140	60	93	5.0
30	300	210	90	94	7.5
40	400	280	120	95	10.2

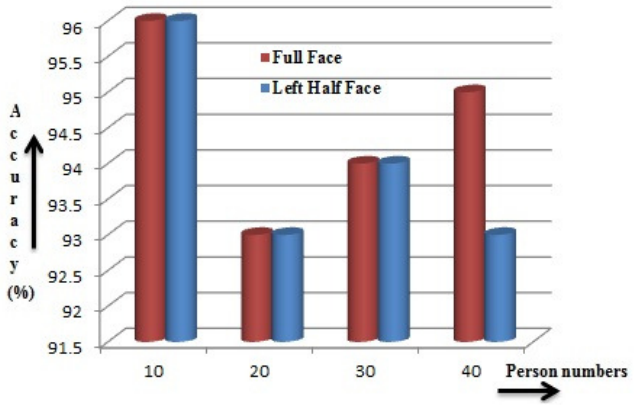

Figure 5: Accuracy Comparison Graph of Full Faces and Left Half faces based on PCA evaluation.

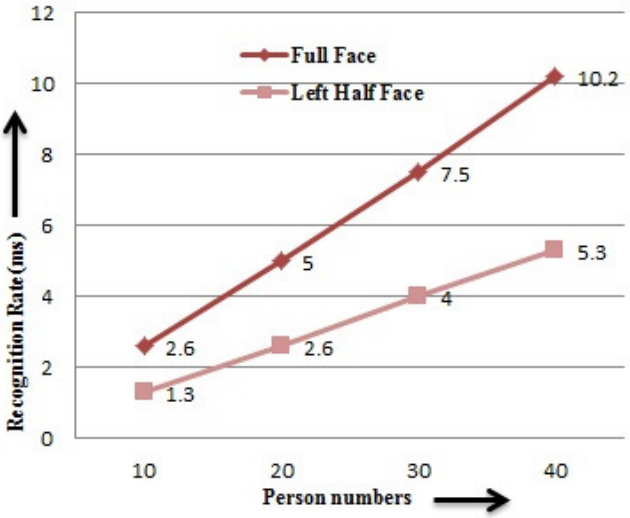

Figure 6: Recognition Rate Comparison Graph between Full Face and Left Half faces.

By comparing the accuracy and recognition from table 1 and table 3 we conclude that the recognition rate is almost similar in both the cases, while the recognition time of half faces is nearly half of that of the full faces. While figure 5 is showing the accuracy, figure 6 shows the curve of recognition rate.

5. Conclusion and Future Work

In general, recognition in real time has several challenges; time is also a big factor in this regard. Time is directly proportional to the size (dimension) of the data (images). As human faces are almost identical in nature, they have the vertical symmetry. Hence we have used only left half of the human faces for training and testing. We have tested our hypothesis on ORL database of 40 people having 400 images. Symmetry is verified on the basis of the accuracy of classification rate between the left and right portion of the face.

Experimental results of full faces and half faces shows that they are almost equal in accuracy, but recognition rate (time) based on half faces is nearly half of the time taken by the full faces. Hence it is verified that half face is also sufficient for the face recognition paradigm. This approach saves both time and resources (computation and memory). Another advantage of using the half face approach is they are invariant to facial expressions. For the better classification, faces should be aligned perfectly.

Additional classification techniques may also be considered apart from PCA. Our future work will be focused on the verification of this concept by using different classification techniques.

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