

Hybrid Feature Based Face Verification and Recognition System Using Principal Component Analysis and Artificial Neural Network

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Abstract

In Human Computer Interaction (HCI), the issue of developing an automatic face verification and recognition system has been one of the most important concerns of the researchers due to its wide range of application especially in the areas where there has been a high demand for consistent identification electronic access system for an individual. This paper discusses an approach to verify the human face and recognize the person's face through a still image. The proposed method is a hybrid approach that considers the local components of the face as well as the entire face of a human being. The local facial components comprises of the lips, nose, left eye and right eye. The proposed system has been implemented using Principal Component Analysis (PCA) and the Artificial Neural Network (ANN). The system has been designed to handle the noises, illumination variations and the facial emotions to some extent. Hence, the proposed system proves to be efficient as it gives the correct recognition rate of 93.5% for ideal facial image and approximately 85% for noise affected facial image.

Keywords: Artificial Neural Network, Face Recognition, Face Verification, Feature Extraction, Gaussian Noise Human Computer Interaction, Poisson Noise, Principal Component Analysis, Salt and Pepper Noise

1. Introduction.

Face recognition system is considered to be the most commonly known Biometric system that is precisely implemented or rather used to automatically authenticate the individual's identity. Any automatic face recognition system involves Detection, Pre-processing, Feature extraction and Identification and/or Authentication¹. Any Face recognition system is highly influenced by certain challenges which increase the complexity level of the system. These are the diverse facial emotions, the cultural variety, age, sickness, various postures, shapes and size. This paper presents the findings of the Principal Component Analysis with Artificial Neural Network

(ANN) based face recognition and verification system. It has been considered that the detection of the face is already done before the recognition process is carried out.

2. Problem Formulation

An Artificial Neural Network is to be designed so that, it can recognize and classify a human face relative to the faces of the training database. Hence, the designed system classifies the face and verifies as well. Further, the face recognition system needs to solve the problem concerning with different facial expressions as well. The system must be able to know that two images of the same person with different facial expressions actually are the same person.

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Some of the additional issue that a face recognition system must solve is: makeup, posing positions, illumination conditions and effect of noise.

3. Literature Survey

Face recognition using image data (2D face recognition) is a matured field that has been researched for many decades. Researchers have shown increased interest in developing reliable and efficient face recognition techniques. The various systems compete on each other in reducing computation time while improving the correct recognition rate.

One of the commonly employed techniques involves representing the image by a vector in a dimensional space of size similar to the image. However, the large dimensional space of the image reduces the speed and robustness of face recognition. This problem has been overcome rather effectively by dimensionality reduction techniques such as the holistic features based face recognition approaches. Initially, researchers made use of Principal Component Analysis (PCA), the 2D Discrete Cosine Transform (2D-DCT) and morphable models². The de facto standard for 2D face recognition is eigenfaces which is a technique that applies PCA to an image and was introduced to the field by Turk and Pentland³. The 2D-DCT based technique proposed in⁴ models the 2D-DCT features using Gaussian Mixture Models.

In the beginning of the 1970's, face recognition was treated as a 2D pattern recognition problem⁵. The distances between important points were used to recognize known faces. E.g. measuring the distance between the eyes or other important points or measuring different angles of facial components. Kanade⁶ was one of those who actually managed to extract features automatically in a quite simple manner and to recognize faces, previous systems had a manual extraction approach. Kanade's approach was to convert a regular image into a binary image and then automatically detect the position of the eyes, mouth and nose of the face. The work done by Blanz and Vetter⁷, and Huang⁸ took face recognition to a new level. By being able to use a morphable 3D model to create synthetic images has proven to give good results. It is a very appropriate approach that solves many of the problems of the previous works.

In recent years, researchers have developed hybrid face recognition systems which take both the global features

as well as the local features of the face. Weng and Huang presented a face recognition model based on hierarchical neural network which is grown automatically and trained with gradient-descent. Good results for discrimination of ten distinctive subjects were reported⁹.

4. Basic Theory

Face recognition broadly refers to the twofold tasks of face verification and identification. These two processes are as depicted in Figure 1.

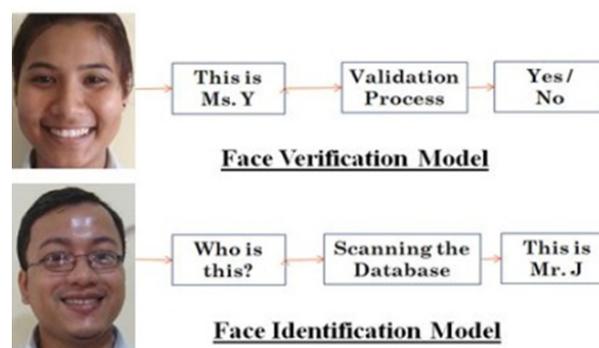


Figure 1. Block diagram of face verification and identification.

4.1 Different Approaches for Face Recognition

Various approaches for face recognition are discussed as follows:

4.1.1 Holistic Matching Methods

These methods use the whole face region as the raw input to a recognition system. One of the most widely used representations of the face region is eigen-faces which are based on Principal Component Analysis.

4.1.2 Feature-based (structural) Matching Methods

Typically, in these methods, local features such as the eyes, nose and mouth are first extracted and their locations and local statistics (geometric and/or appearance) are fed into a structural classifier.

4.1.3 Hybrid Methods

Just as the human perception system uses both local features and the whole face region to recognize a face,

a machine recognition system should use both. One can argue that these methods could potentially offer the best of the two types of methods.

4.2 Hybrid Feature Based Face Recognition

In the hybrid features approach, local as well as the global information of the face are extracted for recognition process. In this work, while retaining the principal component analysis of the whole image for global approach, the central moment, eigenvectors and standard deviation are employed for extracting the features of the eyes, mouth and nose used as the landmark segments of the face.

4.2.1 Principal Component Analysis

To find principal components using eigen faces algorithm we need to use the following methods

- First of all we need to find the linear combinations of the original variables with large variance.
- The covariance matrix C or the correlation matrix R is then calculated.
- The eigenvalues and eigenvectors of C or R is found.
- The eigenvalues are computed in descending order (from largest to smallest), $e_1, e_2, e_3 \dots e_p$.
- Finally the corresponding eigenvectors $a_1, a_2, a_3, \dots, a_p$ are found, where $a_i^T a_i = 1$ and $a_i^T a_j = 0$, thus,
- $y_1 = a_1^T x = a_{11}x_1 + a_{12}x_2 + \dots + a_{1p}x_p$ is the first principal component,
- $y_2 = a_2^T x = a_{21}x_1 + a_{22}x_2 + \dots + a_{2p}x_p$ is the second principal component,
- $y_p = a_p^T x = a_{p1}x_1 + a_{p2}x_2 + \dots + a_{pp}x_p$ is the p 'th principal component.

4.2.2 Central Moment

In image processing, computer vision and related fields, image moments are useful to describe objects after segmentation. Simple properties of the image which are found via image moments include area or total intensity, its centroid and information about its orientation¹⁰. Central moments are translational invariant. There are several types of invariance. For example, an object may occur in an arbitrary location in an image, in such case, one needs the moments to be invariant to location. For binary connected components, this is achieved simply by using the central moments¹¹.

5. Artificial Neural Network

An artificial neural network (ANN), also called as Neural Network (NN) are non-linear statistical data models of decision making tools. ANNs can identify and learn correlated patterns between input data sets and corresponding target values. In this work, we have used a multilayered General Feed-Forward Artificial Neural Network. The architecture of this class of network, comprises three components namely, weighting function, summation function and activation function as depicted in Figure 2.

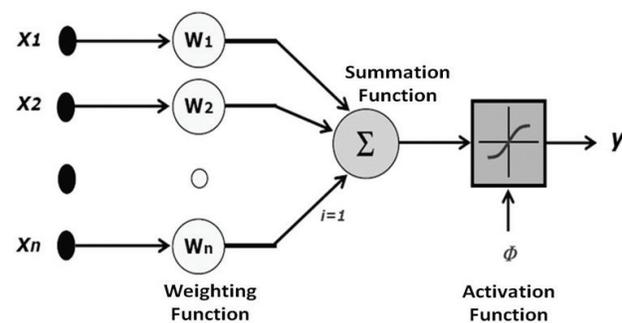


Figure 2. Multilayered general feed-forward network configuration.

6. Training Model

The block diagram of the proposed model is shown in Figure 3.

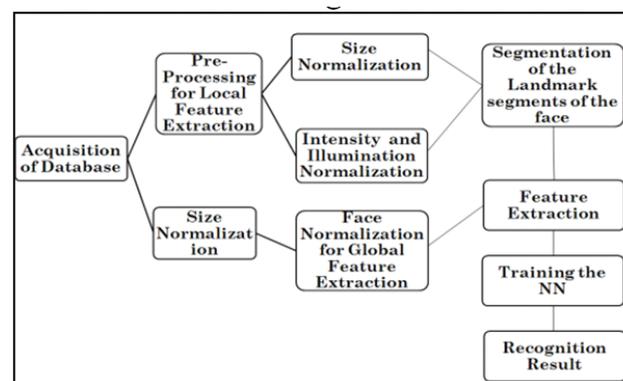


Figure 3. Block diagram of the proposed face recognition model.

6.1 Acquisition of Database

In this work, we have used our own image data base. The data base consists of 20 images of each of 8 persons totaling to 160 images. Of these, 120 images (15 images per person) are used for training while the other 40 images are used to testing the system. These images were captures at different instances of the day; with varying illumination level; varying distance from the camera; varied facial expressions. The database consists of images of both men and women. Sample of the database images of two persons with different facial expressions are given in Figure 4.



Happy Face Neutral Face Sad Face Surprise Face

Figure 4. Acquired data base sample of two persons.

6.2 Normalization and Pre-processing of Images

The different pre-processing techniques carried out are

6.2.1 Brightness Distribution

This is carried out by histogram equalization to improve the contrast in the grayscale so as to obtain a uniform histogram. The histogram equalization method also helps the image to reorganize the intensity distributions. The problem of light intensity is thus overcome (Figure 5).

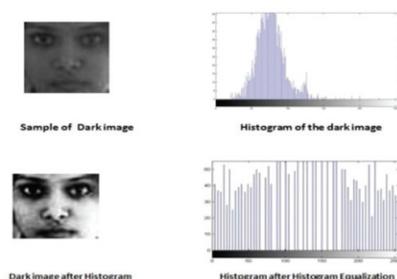


Figure 5. Histogram plot of a dark image before and after brightness distribution.

6.2.2 Noise Removal

The images of the database may be affected by noise such as Gaussian or Salt and Pepper or Poisson noise. These are removed so that the network does not get trained with unwanted noise information (Figure 6).



Figure 6. Sample of noise removal process.

6.3 Extraction of the Landmark Segments of the Face

From the pre-processed face images, the eyes, nose and mouth of the image are detected for procuring the local feature vector as shown in Figure 7.



Figure 7. Sample of Face Segmentation to extract the landmark segments of the face.

6.4 Feature Extraction

For the global facial component, the eigenvectors corresponding to the first 4 eigenvalues are considered. And for the local facial components the different feature

extraction measures are considered, these are tabulated in Table 1

Table 1. Extracted features

Sl. No.	Facial region	Extracted features
1	Right Eye	Central Eigen Vector
2	Left Eye	Moment of Covariance
3	Nose	of the Face
4	Mouth	

7. Training the Artificial Neural Network

The neural network consisted of three layers these are commonly named as the Input layer, the Hidden layer and the Output layer. The number of Hidden layer basically differs, it can be one or more than one. The specifications of the network implemented in this experiment is as mentioned in Table 2.

Table 2. Affective domain assessment method

Type: Feed Forward Backpropagation Network	
Parameters	Specifications
Number of Layers	3 (Input layer, Hidden Layer, Output Layer)
Number of Units in the Input Layer	Each Feature Matrix containing of feature vectors of 8 persons
Number of Units in the Output Layer	1 Binary Encoded matrix containing of 8 final vectors for 8 persons.
Number of Iterations	1000, 1500
Number of Validation Checks	6
Learning Rate	0.7, 0.8, 0.9
Momentum	0.5, 0.6, 0.7
Activation Functions	Log-Sigmoid and Tan-Sigmoid

8. Performance Assessment Results

The Mean Square Error (MSE) is considered for performance assessment of the classifier. The Figure 8 shows the MSE convergence curve of one such iteration carried out in the training phase of the ANN.

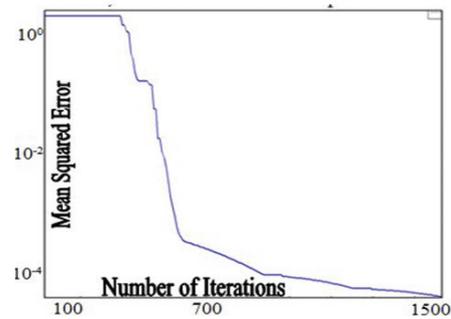


Figure 8. MSE convergence curve.

The experimental results of the MSE are tabulated in Table 3. The Table 3 shows the results obtained after performing the experiment using Log- Sigmoid as the activation function. It is very distinctly seen that the MSE convergence has performed better for a learning rate of 0.7. In addition, an optimum result has been obtained for the network when trained with a learning rate of 0.7, the momentum of 0.6 and for the iterations of 1500.

Table 3. Convergence of MSE for three different learning rates, momentum and two iterations using logarithmic sigmoid activation function

Learning rate	Momentum	MSE for different iterations	
		1000	1500
0.7	0.5	1.5×10^{-7}	1.3×10^{-10}
	0.6	1×10^{-7}	1×10^{-12}
	0.7	1.2×10^{-6}	1.2×10^{-10}
0.8	0.5	1.4×10^{-4}	1.5×10^{-7}
	0.6	1.3×10^{-5}	1×10^{-8}
	0.7	1.2×10^{-4}	1×10^{-7}
0.9	0.5	1.7×10^{-3}	1.8×10^{-6}
	0.6	1.4×10^{-5}	1×10^{-7}
	0.7	1.3×10^{-3}	1.4×10^{-6}

To ensure that the Classifier can perform better even when the images are having noises, the sample images with the noise were fed into the Neural Network to train the network. The Table 4 shows the Correct Recognition Rate (CRR) achieved by the proposed system when considered with the test images that are affected by various noises such as Salt and Pepper, Poisson, Gaussian noise etc.

Table 4. Correct recognition rate of the proposed system with the database affected by different kinds of noise

Images with noise	Correct recognition rate %
Ideal Images	93.5
Poisson	91.0
Gaussian	87.8
Salt & Pepper	78.8

9. Conclusion

In this paper, the hybrid approach was adopted to develop the face recognition and verification system. The proposed system was based on Principal Component Analysis and Artificial Neural Network. The feed forward Back propagation algorithm has proved to be quite satisfactory in its performance. The proposed system was able to tolerate the various noises with significant recognition rates. The Correct Recognition Rate of the ideal images was recorded as 93.5%. However, the system was reasonably proving better for images affected with Poisson noise with a CRR of 91 % in comparison to the other types of noise such as Gaussian and Salt and Pepper.

10. References

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