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Artificial Neural Network for Face Detection and Recognition

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Abstract

Detection of face and its recognition in the field of pattern recognition and computer vision has gained an increasing interest over recent decades. It is because of its many applications in a variety of fields such as security systems, videoconferencing, and identity verification. But, for machines like computer, it is very difficult to make distinguish between the faces of different kinds and recognizing them. The objective of this paper is to introduce the Neural Network based algorithm that simplifies the task of recognizing and detecting face. Under Neural Network, this paper has focused on implementation of Haar Filter to detect the face in the captured face image. Also, this paper explains artificial neural network approach in combination with PCA algorithm for recognition of human face. Mapping of Haar filter in face image extracts the facial information and with that facial information, Eigen Face Vector is produced. Then a matching technique is applied to find a match between the new face and all the known faces in the database. And the result of comparison distinguishes any face to be known or unknown.

Keywords: ***Neural network, Haar filter, Facial features, PCA, Eigen face***

1. Introduction

Face is the most important attribute in human beings which is used for its identification and for conveying emotions in its social life. Human can easily recognize the face that had been seen if the face is remembered. Despite of large variations in visual stimulus due to changing conditions and distraction such as beard, glasses or changes in hairstyle,

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human can easily recognize the face. This is owing to the high level of adaptive nature, interconnectivity, learning skills as well as generalization of human nervous system which is composed of interconnected neurons [1].

In case of computer, detection and recognition of face is one of the most challenging problems. It is because, in computers there doesn't exits a nervous system like humans and is not capable of adaptive nature. Also, computer requires more complex algorithms for interconnectivity between its various components [1-3]. Moreover, computer needs system software for detection and recognition of human face. That is why, detection and recognition of face for machines like computer is very much difficult.

Face detection system includes separating image windows into two classes: first containing faces and another having the background [4]. It is challenging as commonalities exist between faces, they can change in terms of skin color, pose, age, and facial expression. Another problem might be differing image quality, lightening conditions, geometries and partial occlusion as well as disguise. An appropriate face detector should detect any face under any lighting conditions, upon any background [5,6]. Some of these effects can be avoided by ensuring a consistent background and uniform lightening conditions. This statement is suitable for some applications such as the automated separation of nuts from screws on a production line. For a number of applications this is inappropriate and system must be designed to categorize images subjected to a diversity of impulsive conditions. And these systems take complex algorithm for face detection.

There are many face detection techniques to locate a human face in a scene [7]. Some of them are template matching method which operates by performing direct correlation of segments, Eigen face approach that applies Karhonen-Loeve transform for feature extraction, and feature based method which employs knowledge about facial information to detect face. A number of algorithms execute the face detection task as a binary pattern-classification task.

In face recognition process, face of an individual is recognized by comparing an image against the images of all stored in the database. The related task of face detection has direct relevance to face recognition because image must be analyzed and faces identified, Like face detection methods, there are a number of methods that can be used for recognition of face. Some of them are Eigen face approach which recognizes the face by computing Eigen vector of the faces and then associating the facial information into the Eigen vector, template matching method which employs the concept of template for recognition of face, Neural Network which operates on constructing the artificial neuron that collects facial information through training and then use the training information to test the recognition process.

This paper explains detection of human face using Haar Filter. For detecting a face, Haar filter is mapped into the face image and during mapping the filter checks for the presence of facial features like Eye, Nose and Mouth. The filter returns 1 if it detects facial features otherwise it returns to 0. The neural network is trained to identify the face in the face image. Then, to extract the face region, various pre-processing activities are applied. This paper also explains recognition of face using PCA algorithm. For recognition of human face, first, an Eigen Face vector is created using the

facial information that is extracted during detection phase. Then, PCA algorithm maps the facial information extracted from captured image into an Eigen Face vector created form gallery of face image. The result of mapping discovers the new face image. Then the presence of this new image is checked into face database. If similar image is present in the face database, the captured face is treated as identified face or else the face is unknown.

2. Description Of the System

The system is based on using neural network for detection of face and extracting the facial information and performing mathematical operations on the values corresponding to them for recognition of face. And for this, a very simple methodology is employed. Haar filter is used as a Neural Network based filter to detect face in the captured face image. Haar filter is mapped into the face image. During mapping, the filter checks if there is presence of facial features or not. The neural network is trained accordingly to detect the face in the face image. After that, the face section is extracted from the image by applying different pre-processing activities. Using this facial information, an Eigen Face vector is created. And for recognition of face in the captured face image, PCA algorithm is implemented. PCA algorithm maps the facial information extracted from captured image into an Eigen Face vector created form gallery of face image. The result of mapping discovers the new face image. Then the presence of this new image is checked into face database. If any equivalent image is present in the face database, then the captured face is treated as known face otherwise the face is unknown (Fig. 1).

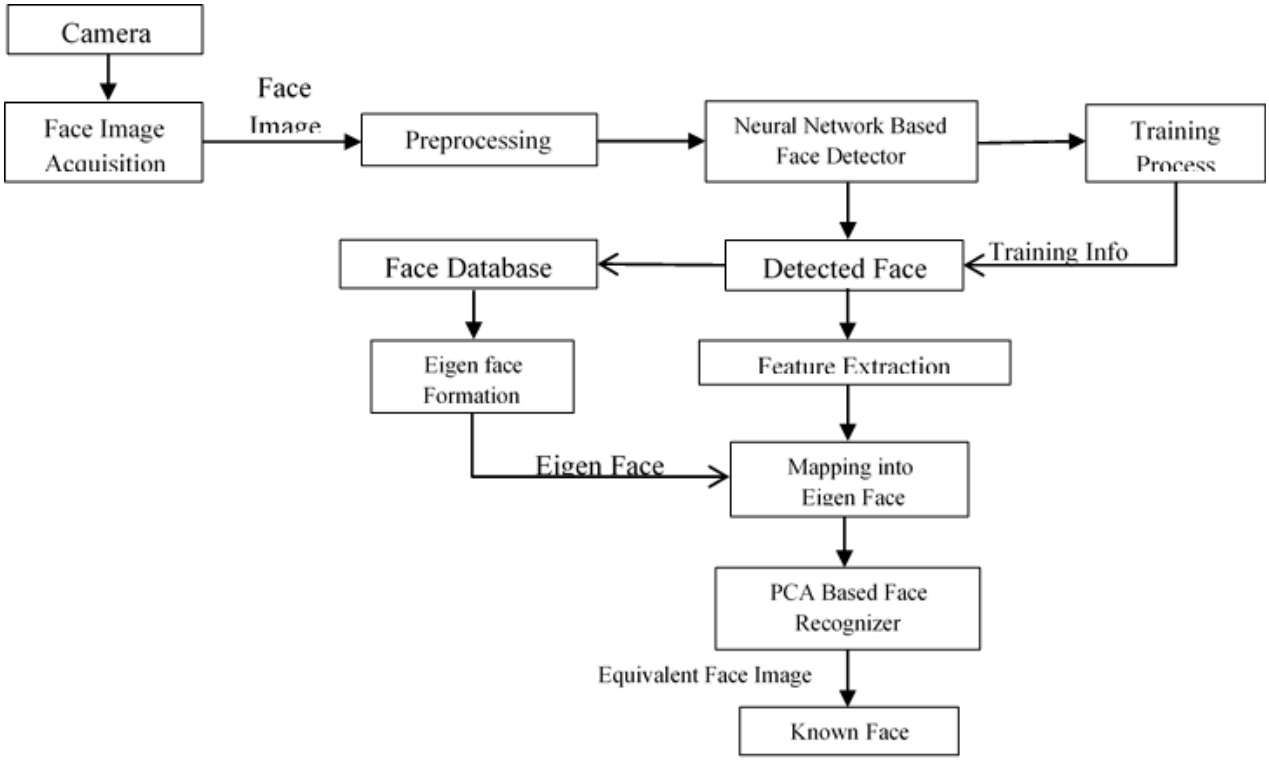

Fig. 1. Block diagram of FDRS based on ANN.

2.2 Face image acquisition

In this, a digital image of an object is captured andis converted into digital image. Output of image acquisition process is a face image which is set for preprocessing. The input to the face recognition system is an image which contains many other objects along with the facial images. So, this needs the assistance of certain face detection techniques.

2.2.1 Preprocessing

Prior to the image is presented to the system, it should be standardized so that it is well-suited with the system parameters. Following are the major tasks in preprocessing.

- ***Size Normalization***
  Changing the size of acquired image into default size so that the face recognition system can operate.
- ***Histogram Equalization***
  This preprocessing task improves the images quality by enhancing the quality of image but only in the case if the image is too dark or too bright.
- ***Median Filtering***
  Median filter can be used for cleaning noises in the images without losing information.
- ***High Pass Filtering***
  High pass filtering emphasizes the detail of an image such as contours which can dramatically improve the edge detection performance.
- ***Background Removal***
  Face backgrounds are removed for dealing primarily with facial information itself. This is especially important for the face recognition systems where entire information contained in the image is used.
- ***Edge detection***
  Face edge detection technique is applied to find various face features that are required before representing and segmenting an image.

2.3 Face detection

For the purpose of face detection, Haar filter is used. The Haar filter feature's value which are calculate as a weighted sum of two components: the pixel sum over the black rectangle and the sum over the whole feature area (all black and white rectangles). The computed feature value is then used as input to a very simple decision tree classifier that usually has just two terminal nodes, that is:

$$f_i = \begin{cases} +1, & if\ x_i \geq t_i \\ -1, & \text{if } x_i < t_i \end{cases}$$

Where +1 means the face and -1 means non face. t denotes the threshold and the data is denoted by x.

Neural network is used to train the classifier so that it can easily detect the face. The network learns to detect the face by propagating the signals through the network. The inputs and outputs are computed by using a feed forward network, then error values are calculated and the calculated error value are made propagated back through the network to adapt the weights during trainings (Fig. 2).

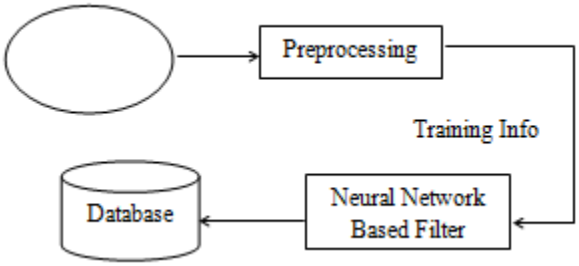

Fig. 2. Block diagram of the training phase of system.

2.4 Face database

Face database is a database of identified faces. The Eigen face configuration transforms the face image to the subspace to compare the input image to the image stored in the face database. The face database can be updated, after the classification of faces, by adding a face classified as “unknown", to the database. This process adds learning capability to the system.

2.5 Eigen face formation

Eigen face of the input image is formed for projecting the image into the subspace spanned by the Eigen vectors. Eigen face vector is a face vector which is produced by acquiring the common features of the face image stored in face database. This is done by following the steps of PCA as discussed below in "calculating Eigen face" section.

2.6 Feature extraction

It is carried out by taking the facial characteristics such as mouth, eyes, nose, ears etc. There are two methods to represent facial features: First is the local facial features such as nose, eyes and mouth are located; the second is the entire facial features as expressing with a rectangle area containing eyes, mouth and nose. Eyes and mouth was considered in this system.

The algorithm is described below:

1. Divide the face column wise into two identical parts.
2. For each row ‘r’ follow steps 3 and 4.
3. The first black pixels met on both sides are considered as (x1, y1) and (x2, y2) respectively.
4. Determine the distance between points using the formula:
   Distance = Sqrt[(x2 – x1)^2) + ((y2 – y1)^2]

5. From step 4, two non-zero distance values to eyes and mouth are obtained.
6. Locate the maximum of the distances for each non-zero set. They signify the distance between the mouth end points and eyeballs
7. By the pixels to that maximum distance, estimate the following:

- Distance from the right eyeball to the left eyeball.
- Distance from the right mouth end point to left mouth end point.
- Distance from the left eyeball to the left mouth end point.
- Distance from the right mouth end point to right eyeball.
- Distance from the right mouth end point to the left eyeball.
- Distance from the left mouth end point to right eyeball.

8. The six values calculated above are provided as the inputs to the neural network identifier

2.7 PCA based face recognizer

The PCA based face recognizer recognizes the face. The PCA algorithm maps the facial information extracted from captured image into an Eigen Face vector created form gallery of face image. The result of mapping discovers the new face image. Then the presence of this new image is checked into face database. If any equivalent image is present in the face database, then the captured face is treated as known face otherwise the face is unknown (Fig. 3).

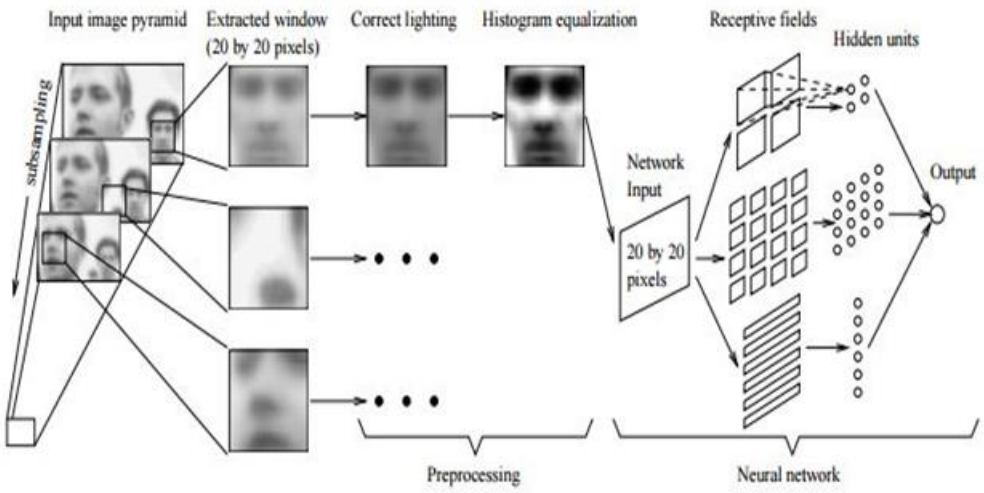

Fig. 3. Illustration of the training process.

2.8 Principle component analysis (PCA)

PCA is a statistical technique to find a pattern in high dimensional data. The holistic approach uses the entire face region as input data. The main standard of PCA is derived from the information theory that breaks facial images into small sets of feature images known as Eigen faces. Eigen faces are known as PCA of original training set of face images.

The approach of using PCA for face recognition is to articulate the large 1D vector of pixels constructed from 2D facial image. This is known as Eigen space projection. Eigen space is estimated by identifying the eigenvectors of the covariance matrix.

2.9 Mathematics of PCA

A 2D facial image is represented as 1D vector by concatenating every row (or column) into a long thin vector. Let's suppose we have M vectors of size N (= rows of image × columns of image) representing a set of sampled images. pi's represent the pixel values.

$$Xi = \left[p1 \ldots pn \right] T \ , \ i \ = \ 1, \ 2, \ \ldots , M \qquad (1)$$

The images are mean centered by subtracting the mean image from every image vector. Let m denote the mean image.

$$m = \frac{1}{m} \Sigma_{i=1}^{M} x_i \qquad (2)$$

And suppose wi is defined as mean centered image

$$Wi \ = \ xi \ - \ m \qquad (3)$$

The goal is to locate a set of ei's having the largest projection onto each of the wi's. The objective is to find M orthonormal vectors ei for which the quantity

$$\Delta i = \frac{1}{m} \Sigma_{i=1}^{M} (e \frac{t}{i} w_n) \qquad (4)$$

is maximized with the orthonormality restraint

$$e_i^t ek = \delta ik \qquad (5)$$

It was illustrated that the ei's and Λi's are provided by the eigen vectors and eigen values of the covariance matrix.

$$C \ = \ WWT \qquad (6)$$

Where W is a matrix composed of the column vectors wi placed side by side.

The size of C is N × N could be high. Images of size 64 × 64 generate the covariance matrix of size 4096×4096. It is not feasible to solve for the eigenvectors of C. A theory in linear algebra mentions that the vectors ei and scalars λi can be obtained by solving for the eigenvectors and eigenvalues of the M × M matrix WTW. Let di and μi be the eigenvectors and eigenvalues of WTW, respectively.

$$WTW \ di \ = \ \mu i \ di \qquad (7)$$

By multiplying left to both sides by W

$$WWT\ (W\ di)\ =\ \mu i(W\ di) \qquad (8)$$

It means that the first M − 1 eigen vectors ei and eigen values λi of WWT are provided by Wdi and μi. Wdi requires to normalize to be equal to ei .M, the rank of the covariance matrix cannot go beyond M− 1 (The −1 come from the subtraction of the mean vector m).

The eigen vector related to the highest eigen value decrease in exponential manner, it means roughly 90% of the total variance is contained in the first 5% to 10% of the dimensions.

3. Experimental Result

3.1 Training process

The neural network-based classifier for detection of face using Haar filter is trained to produce an output of 1 for the face examples, and -1 for the non-face examples. To detect faces anywhere in the input, the filter can be used in each location in the image. In order to detect faces higher than the window size, the input image is sub-sampled by a factor of 1.2, and the filter is used at each scale. A preprocessing step is applied to a window of the image in training process. The preprocessing initially attempts to balance the intensity values across the window. The preprocessed window is then passed through a neural network. The network gets as input a 20x20 pixel region of the image, and creates an output ranging from 1 to -1, notifying the presence or absence of a face.

For training the neural network, the sample of 100 face images were divided into 10 parts say 10 folds., in each fold there are different numbers of images of different people with different expressions and illumination conditions. The features from each of the images from all folds were recognized and separate as true features detected and false detected. Table given below shows the result of training process (Table 1).

Table 1. Training Result.

Folds	No of training images	Correct	Wrong
Fold 1	10	8	2
Fold 2	10	9	1
Fold 3	10	8	2
Fold 4	10	10	0
Fold 5	10	10	0
Fold 6	10	8	2
Fold 7	10	9	1
Fold 8	10	9	1
Fold 9	10	10	0
Fold 10	10	8	2

Mean Correct = (8+9+8+10+10+8+9+9+10+8)/10 = 8.9 = (8.9 / 10) * 100 = 89%

Mean Error = (2+1+2+0+0+2+1+1+0+2) / 10 = 1.1 = (1.1 / 10) * 100 = 11%

After the first epoch, the mean accuracy of the testing process is found to be 89% and the mean error is found to be 11%.

3.2 Testing

For testing the system, a set of images that are completely distinct from the training set images were taken. And the system was tested with different test cases.

3.3 Test case 1 (Different position of face)

For the test to detect the face, six images of face with different position as shown in the figure given below are chosen and inputted (Fig. 4).

Fig. 4. Different orientations of fingerprint sample.

3.3.1 Test Result 1

Total number of face position = 6

Face detected = 5

Not detected = 1

Accuracy (%) = (5/6)*100 %

=83.33%

Error (%) = (1/6)*100 %

= 16.67 %

3.4 Test Case 2 (Full frontal display as shown in Fig. 5)

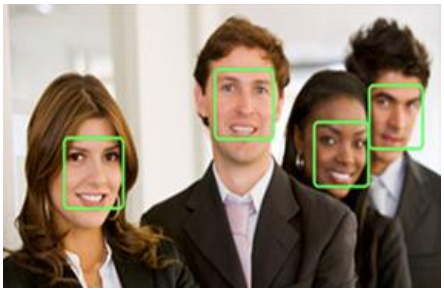

Fig. 5. Full frontal display of different face.

3.4.1 Test result 2

Total number of face position = 4

Face detected = 0

Accuracy (%) = (5/5)*100 % = 100%

Error (%) = (0/5)* 100% = 0 %

4. Discussion

The task of detecting face in an image and recognizing the face for machines like computer can be done by the implementation of algorithm based on neural network based Haar classifier and Eigen face vector. Implementation of these algorithms can provide nearly about 84% of accuracy. Thus, this system can be used for different applications such as video surveillance, face image database management etc.

5. Conclusion

In conclusion, this system detects the face by extracting facial information such as eye, nose, mouth etc. and recognizes the individuals face by comparing this facial information with those already stored in database. For this, the system had used Back-propagation algorithm in Neural Network. This system first trains the classifier by using gallery images in order to recognize face.

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Authors Biography

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Dr. Gajendra Sharma received the degree of Masters of Engineering in Electronics and Communication in 1997 from Moscow Technical University of Telecommunication and Informatics, Russia. He completed doctoral degree in Information Systems Engineering from the Harbin Institute of Technology, China. During the following years, he was employed in different IT companies and corporate organizations in Nepal as a professional engineer. He completed postdoctoral research on technology philosophy (e-government and ethics) from Dalian University of Technology, China coordinating with Delft University of Technology, Netherlands. Currently, he is working with Kathmandu University, Nepal. He worked with Liaoning Technical University, China at the department of Information Systems as an Associate Professor from 2011-2014. His research and teaching interests include information systems, e-commerce (including e-business), strategic management of information technology (IT), IT adoption, design and evaluation of IT infrastructure, strategic management of IT as well as e-governance and ethics. Moreover, he has research interest on public administration, conflict management and emergency management. He published research papers in some of the top-tier information systems and IT journals such as *Information Systems Frontiers, Internet Research, Information Technology and People, Telecommunications Policy, International Journal of Web Based Communities and Electronic Commerce Research*. He is a reviewer and technical editor of a number of peer-review journals relating to information systems and IT.

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