Development and Evaluation of a Hybrid Facial Recognition Technique

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Abstract— **Facial Recognition software is a fast growing industry, with developments coming its way every other day. With the rise in technology it is now more of a necessity to keep the data secure as the world is becoming entirely digitalized. To make sure the data is preserved facial recognition techniques are acquired, as they not only are faster and more secure, but have a higher accuracy rate compared to other recognitions. Many holistic and feature based techniques have been developed individually, but it is seen that the hybrid facial recognition technique combines the advantages of the individual techniques and hence gives a more precise recognition rate. This paper combines two individual approaches i.e. Karhunen Loeve technique and Hidden Markov Model to demonstrate a single code that recognizes the image based on the Eigen vector method and recall further images of the same person by using Hidden Markov Model. A simple GUI is also implemented for this code to make it more user-friendly.**

Keywords—**Facial Recognition, Hybrid, Karhunen Loeve technique, Hidden Markov Model.**

I. INTRODUCTION

Facial Recognition is emerging with every passing second and its implementation includes highly advances technologies. The requirement for security is not only left for commercial purpose but also in law enforcement methods, recognition demand has rose. The facial recognition software has a high demand due to the increased amount of security and easy access. The facial features vary from person to person; hence it belongs to each individual. Moreover there is no certain object where the face has to be placed in order to be detected such as those used for finger print recognition systems. The face can be easily spotted with the help of a CCTV camera from far away. Furthermore, facial recognition method is preferred over other security measures, such as ATM cards or keys, as it does not require the individual to carry any important accessory or which can be lost over time.

The facial recognition technique is now used worldwide in various different applications. From commercial point of view, it is implemented in private place access through face recognition, normal secure transactions in ATM machines etc. The government and other official authorities also make use of facial recognition software in law enforcement applications. This includes matching the face of a violator to the existing database, or to find a missing person. In such applications the accuracy rate has to be very high, and there are not much chances of error. According to the news [1] the FBI has launched its new biometric facial recognition software that contains photos of tens of billions of US citizens. This data base is used to scan and search for criminal offenders on daily basis. This highly advanced software detects additional features to the normal facial features, including the tattoos, piercings etc. The US government has ordered for CCTV cameras to be installed in order to be synchronizing work with this software, in order to minimize the terrorist attacks in the region and also to minimize the minute offences committed on regular basis.

Facial recognition has been under constant development, and individual as well as hybrid methods have been implemented to reach the maximum possible accurate recognition rate. The facial recognition approach usually follows the nomenclature i.e. firstly there is face detection with the help of an hardware such as camera, CCTV etc. that captures the image and electronically processes it to form the digitalized form of the image. Second step is for feature extraction from any suitable method and then later a classification is done in order to match the data from the captured image to that of an existing one. [2] The individual techniques used for facial recognition include two main kinds of approaches: Holistic Approach and Feature based approach.

The Holistic Approach usually takes the whole face as the input for detection. The face is either split into different vectors, or the distance is noted from a certain feature in order to obtain data for the particular face. Later this data is organized and send further for classification and to be matched with faces in existing database. On the other hand the feature based detection takes the particular organs from the face such as the eyes, nose or lips and determine the distances and position accurately, this data is then processed for each image and compared later to obtain the exact or closest match.

The hybrid technique used in this project includes two individual methods combined together i.e. the Karhunen Loeve technique and Hidden Markov Model. The Karhunen Loeve technique is a form of holistic approach.

II. EVALUATION OF EXISTING TECHNIQUES

The facial recognition implementation is not straight forward due to a number of hindrances coming in its way,

which includes the varying illumination levels, subjects' facial expression and different poses. Hence various different techniques have been invented previously and further research build on it, in order to improvise the techniques for higher accuracy. Since this paper proposes a hybrid approach to the existing methods, thus individual methods were studied in depth at first, and after selection of the appropriate techniques to combine, the hybrid method was generated.

A. *Holistic Methods*

The concept of holistic processing is a cornerstone of face-recognition research [4]. The Holistic method takes the complete face as the input to be processed. This holistic based approach focuses on the entire face without focusing on any one feature individually. The main examples of Holistic method include the Eigen face method, Principal Component Analysis (PCA), Fisher face, SVM, ICA etc.

Eigen face method is the most widely implemented method of the holistic approach in facial recognition software. In 1991 Turk and Pentland conducted the first ever research of Eigen faces. The image captured is processed by projecting it into different Eigen weights which are later compared with the database. The weight vector makes the test image which is compared with the existing database to find the exact match. The theorem is based on the Karhunen- Loève expansion that suggests that all the images can be represented by tiny collection of weights which can be later reconstructed into the image to be matched.

The fisher face method is one of the most frequently used methods. It is based on appearance this comes under holistic approach. It is named after the scientist R.A. Fisher in 1930 after he developed this methodology [5]. It is considered to be one of the oldest techniques of facial recognition. The ratio of the class scatter compared to the image scatter is done to obtain the exact match for this method. LDA approach is used, which has a disadvantage of high error rate due to the scatter mix being single whereas the image consists of high number of pixels. This effect is mostly seen when the illumination and posing is not correct. The fisher face method helps to overcome these problems as it utilizes the with-in class information, hence the variation and diversity within one class is lesser. This proposes a simple solution to the complex problem of lighting condition and poses in LDA [6].

Another technique is the Support Vector Machine. This technique tends to operate solely on the pattern recognition and doesn't require other data to do image processing. It has a high generalization performance, by classifying the points with the largest possible fraction with the help of a hyper plane. These points of the same class are kept on one side [7]. The distance from either plane to the hyper plane is increased. Thus hyper plane acts as a barrier which doesn't let the software to misjudge a face or recognize an image wrongly. This hyper plane not only prevents the misjudging of training set images but also the test image.

B. *Feature Based Methods*

The feature based method mainly emphasizes on the particular features of the face such as the eyes, nose, lips and their location is extracted. This method works by feeding those extracted locations and their geometrics to the classifier, which would later match the subject features to these categorized features. The main disadvantage of this method lies in the restoration process where the hidden features such as the head pose are difficult to identify i.e. the front face image as compared to side pose [8]. Thus such difficulty poses a challenge to this technique. The main methods used for features based classification are Geometrical method, HMM, and CNN techniques

Geometrical models are the most common example of the feature based method. The technique applicable in this method involves sorting out certain features and noting them down with the help of set of data. The geometrical method looks into certain features, such as the pupil in the eye and extracting its colour by the red, green, blue pixel values. Certain colour would determine the skin colour, whilst the other colours would help identify the certain feature which would later be matched with the data in the existing database. To get accurate results the average of the eye height and width is taken to minimize error and help achieve a more precise result [9].

Hidden Markov Models are set of statistical models used to characterize the statistical properties of a signal (Samaria and Harter, 1994). The HMM method is mostly implied to 1-D or 2-D images, but in order for this approach to be carried out, the mage has to be in either of these formats originally, or needs to be converted before the method is implied. The band sampling technique under HMM was implied on a face image by Yang,M. , Kriegman, D and Ahuja, N in 2002. The face images used were all in one dimension. The test image is processed under an observation sequence, and then the result obtained from it is contrasted with the HMM's pre-existing in the database. The Neural network technique is based on non-linearity as compared to the Eigen face approach. Its image extraction feature is highly competitive to the Karhunen-Loève method used by the Eigen face method. Neural network has been researched upon for years, and depending on its application, the structure of the neural network is considered. There are various methods linked to neural networks that exist today including the Convolution neural networks, multilayer perceptron etc.

C. *Existing Hybrid Methods*

As the name suggests, this method is a combination of the individual methods. The hybrid method combines both the feature based methods along with the holistic approach, to identify the face. Mostly hybrid method is implacable to 3D images, where the orientation depth of the eyeball or the curvature of the chin is taken into considerations, to enhance the matching technique. This technique has a positive edge over the other solo techniques as it categorizes the face by measuring various distances on the axis of measurement and also takes into account the depth.

In 1997 a hybrid technique was proposed which contained self-organizing map, along with CNN, neural network and local sampling technique [10]. The SOM helped in minimizing the effect on the result due to minor changes in the dimension of the input image or the invariance in the input sample. Then the CNN aids in evaluating the image by highlighting the main features, while diminishing the effects of rotation, scaling or any transformation on the input image. When the experiment was carried out on ORL database, for four hours, a success rate of 96.2% was found. It took less than 0.5 seconds for the image to be recognized amongst the four hundred images of the forty individuals.

III. Development of the Hybrid Method

A. *Karhunen Loeve technique*

The Karhunen Loeve technique is quite popular amongst the facial recognition algorithms and is widely used. This technique is popular since the initial time, i.e.1987 and has been researched over and improved a couple of times to date. The algorithm for this method is explained in depth. Firstly the matrix is identified with its i'th and j'th term. Later the commutative dot product of the vectors is used to obtain a matrix B after processing. The matrix B has similar Eigen values to the original matrix, which is shown by the characteristic polynomial. In order for facial recognition process, initially the image imported is changed to grey scale image and it is defined by a matrix h x w where h is the height of the image and w is the width. In order to process the algorithm, this matrix is changed to (w * h) x 1, by 'placing the first column on the top and each successive column below its predecessor' [3].

B. *Hidden Markov Model*

The first method used in this hybrid approach consists of a seven state HMM which is more detailed and gives accurate results. The previously used five state models included the hair, forehead, eyes, nose and mouth whereas in the seven states HMM model two more features i.e. the eyebrows and chin were added. These additional features give a higher accuracy to the algorithm, and hence improve the successful matching statistics.

The SVD coefficients used in this experiment are very less, as they are quantized and takes lesser time to process. These SVD coefficients help to generate a pattern amongst the chosen segments with the help of the matrices. A typical SVD can be generalized by the formula below:

$$X = UEV^T$$

Where U is an a×a matrix and V also a x a matrix, both of them are orthogonal to each other, and E is and a×b diagonal matrix of singular values.

C. *The Modified Hybrid Method*

Both the algorithms, i.e. the HMM and the Karhunen Loeve were used to create the hybrid method. The coding of the two methods was combined to form the hybrid method. The codes were analysed and the coding was introduced to combine both the individual methods into one. To ensure both the codes run continuously and recognize the data from each other, a special code was introduced. . A GUI was implemented to make it user friendly, in order to access data. Figure1 shows the implemented GUI.

Fig.1: The Main GUI of the program

The GUI consists of three pushbuttons, which define the functions carried out. Initially the database is loaded by using the Generate database function, which loads all the 400 images from the database. Initially the program asks if a new database is to be generated or not, and on the command of the user input, it goes back to the original GUI or loads the database. The main challenge faced in developing this program, was to design an algorithm which connects one method to the other. This was done by using the codes below:

```
imageno=strread(saved);
C = regexp(saved1, '\','split');
Q=C(1,9);
qur=char(Q);
[~, imagefolder] = strread(qur, '%c %d');
if imageno==10
imageindex = (imagefolder*imageno)
else
imageindex = ((imagefolder*10)-(10-imageno))
end
```

The MATLAB functions such as strread, regexp and char are used to interlink the various quantities with each other. This algorithm links the Hidden Markov model for recognizing a single image with the Karhunen Loeve method, which extracts the various other images of the person and displays them.

An example of the output from the project can be seen in Figure 2. The output from the coding first retrieves the exact matching image by the HMM model and later the

Karhunen Loeve method is used to extract the rest of the images of the same person. This is done by combining the codes of the individual methods, and linking them with algorithm mentioned

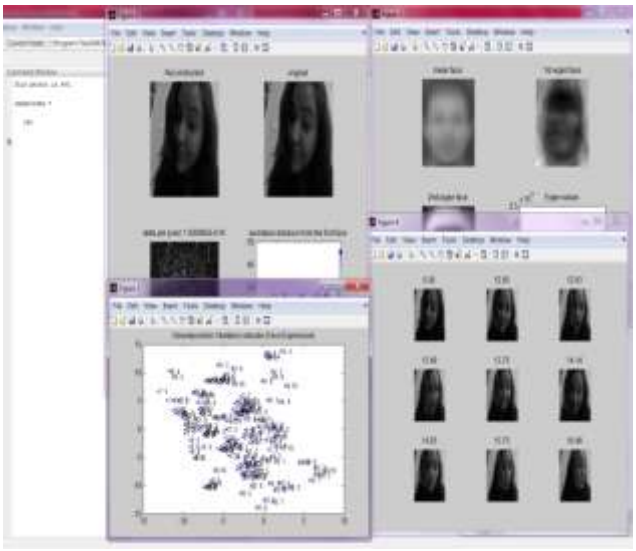

Figure 2: The output of the facial recognition program

IV. Conclusion

The testing of this project was done on the ORL (Olivetti Research Laboratory) database from United Kingdom. The database consists of forty different people each having 10 different images. Each person has ten different images in different facial expressions, as to give a highly varying database for testing.

The output of the hybrid facial recognition program gives four figures demonstrating different quantities. The figures include the closest match of the database, the mean Eigen faces, the variation in the Euclidean distance between the input image and the images pre-existing in the database and lastly it shows all the extracted images of the same person.

The hybrid facial recognition method proved to be the most accurate as well as the most informative method as compared to the individual techniques. The Hybrid technique possesses the advantages of each of the two techniques, whereas the drawbacks are over come from the other technique. In this way over all the result achieved is very accurate i.e. was able to recognize almost 99.5% of the data, with an error of less than 1%. This is highly commendable compared to the recognition rate of the each of the individual methods.

Considering only the Karhunen Loeve method, the input images all have to be in the aligned position as to give the best recognition rate. Only if all the images are aligned and positioned in a similar manner, the algorithm works efficiently and produces the desired results i.e. a higher accurate matching rate. Also it was noticed that the algorithm works best on smaller databases, and also when the size of the images were reduced by almost over 23% only then the facial recognition software was able to work successfully, with consuming lesser time as compared to larger databases.

The Hidden Markov Model proved to be a fast and efficient system, where after converting the input image to blocks in a sequence, the blocks were assigned SVD coefficients. The system proved to be very fast and the recognition rate as seen was about 96% with an error of only 4% in the results. This error was due to the large database implementation and the training images restricted to only five. Also the images were resized before the algorithm was implemented on them, which contributed to the false recognition rate. The HMM model output alone was the image index of the person based on the closest matching Euclidean distance.

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