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Applying Hidden Markov Model for Face Recognition using Singular Value Decomposition

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***Abstract*— A computer based system used to detect and recognize the human faces is called face recognition system. In the recent time face recognition system has gained enormous popularity as it provides security using biometric technique as compared to password or key based security. In the last few years various techniques (methods) are developed to achieve high success rate of accuracy in the identification and verification of individuals for authentication in security systems. Face recognition systems are generally trained with a database of existing face images to become familiar with the given set of faces. Many reported methods rely heavily on training database size and representativeness. But collecting training images covering, for instance, a wide range of viewpoints, different behaviour is time consuming and expensive. Therefore we require an efficient and effective face recognition system that recognizes the face accurately and in cost effective manner. In this paper we develop a hybrid approach of face recognition system consisting of Hidden Markov Model (HMM) and Singular Value Decomposition (SVD).**

***Keywords*— Face Recognition, Hidden Markov Model, Singular Value Decomposition**

I. INTRODUCTION

Face recognition & identification system [1, 2] is a computer-based system that not only identifies the face from the given database but also recognizes it to perform necessary operations. In the last few years various techniques (methods) are developed to achieve high success rate of accuracy in the identification and verification of individuals for authentication in security systems. Face recognition systems are generally trained with a database of existing face images to become familiar with the given set of faces. Many reported methods rely heavily on training database size and representativeness. But collecting training images covering, for instance, a wide range of viewpoints, different behaviour is time consuming and expensive. Therefore we require an efficient and effective face recognition system that recognizes the face accurately and in cost effective manner.

In this paper we develop a hybrid approach of face recognition system consisting of Hidden Markov Model (HMM) and Singular Value Decomposition (SVD). Singular Value Decomposition extracts the various features of face as coefficient values.

On the other hand Hidden Markov Model [3] acts as classifier i.e., it identify the face using the coefficients values extracted by SVD.

The proposed method is compared with the existing techniques. The proposed approach has been examined on ORL database and some personal database. The results show that the proposed method is the fastest one, having good accuracy.

II. ARCHITECTURE OF FACE RECOGNITION SYSTEM

In this section we outline the basic architecture of a face recognition system based on Gonzalez's image analysis system [4] and Costache's face recognition system [5]. The functional block diagram of face recognition system is shown in Figure 1 below.

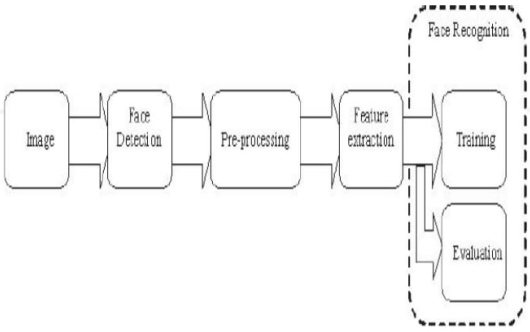

Figure 1: The functional block diagram of a face recognition system

1. Face detection block: The first phase of face recognition system face detection block. The face is detected from the image supplied to it. It is one of the important phase of Face recognition system because the accuracy of future phases is depend upon the how accurately it detect the phase from the given image. [6, 7].

2. Pre-processing block: The second phase of face recognition system is to perform some pre-processing tasks on the face detected from the previous phase. Some pre-processing tasks that performed on the face detected from detection phase are:

- To normalize the image size to the size on which we want to operate face recognition.

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- To perform histogram equalizer concept to improve the quality of image. This is generally done on the image that is too dark or too bright.
- To clean the image without losing information for the images obtained from the camera.
- To outline the portion of face only we need to remove the background of the image.

3. Feature extraction block: In this step the features used in the recognition phase are computed. In this phase features of face are extracted by computing the distances between important points in a face, and the recognition 'algorithm' matched these distances [34]. The recognition algorithm used for above task is called ED (Euclidian distance) [8].

4. Face recognition block: This phase consists of 2 separate stages: a *training process & testing or evaluation process.* In the training process, the system receives some set of face images from the database & unique features of each image are extracted for testing. In testing or evaluation process the features of test image are extracted and compared with the features of image obtained in the training process. The face image where maximum features are matched are extracted from the database and result is shown to the user.

III. Proposed Work

Many large-scale identification applications, such as law enforcement, driver license or passport card identification have only one face image per person. Keeping only one sample per person in the database has several advantages. It reduces storage and computation cost, particularly when the number of people managed by the system is very large. Thus the 'one sample per person' problem, which in this dissertation is called the one sample problem, needs to be carefully addressed. The one sample problem is defined as follows: "Given a stored database of faces with only one image per person, the goal is to identify a person from the database later in time in any different and unpredictable poses, lighting, etc. from just one image" [9].

Given its challenge and significance for real-world applications, this problem is rapidly emerging as an active research sub-area of face recognition. Finding effective algorithms that deal with this problem is the goal of this dissertation. In order to achieve the goal of building a system recognizing face images, we need a model that can capture selective spatial information. In this dissertation, a Hidden Markov Model (HMM) [10] framework is employed.

In this framework, the assumptions are formulated as probabilities and inference corresponds to finding the probability of hypotheses given observations. In the context of face recognition, we first extract observations from given face images.

We can use observation sequences extracted from samples or 'training' images to 'train' HMMs. For each person in the recognition system, we must build a model λ_r, where $r \in \{1, \ldots, R\}$, R is the number of possible persons. Each model is based on an HMM that is trained so as to best describe given observation sequences, i.e. to optimize the likelihood of the training set. For each unknown face image x, which is to be recognized, the processing must be carried out as follows:

- Extract observation sequence O from x
- Calculate model likelihoods for all possible models, $P(O \mid \lambda_r)$, $1 \le r \le R$
- Select the subject whose model likelihood is highest, i.e.

$$r^* = \underset{1 \le r \le R}{\operatorname{argmax}} [P(O \mid \lambda_r)]$$

The label r* is the best interpretation for the query face image x.

Following diagram (Figure 2) shows flow of processing flow in face recognition:

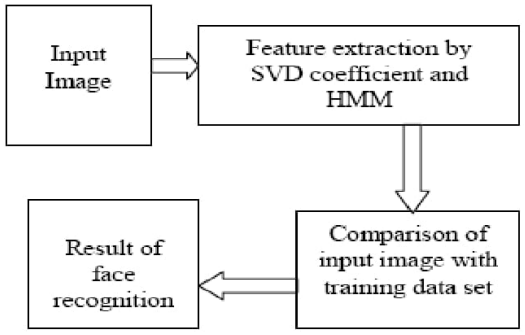

Figure 2: Face recognition process

In this paper we develop a hybrid approach of face recognition system consisting of Hidden Markov Model (HMM) and Singular Value Decomposition (SVD). Singular Value Decomposition extracts the various features of face as coefficient values. On the other hand Hidden Markov Model [3] acts as classifier i.e., it identify the face using the coefficients values extracted by SVD.

Figure 3 below shows training process of a training image which includes filtering, block extraction, feature extraction and quantization.

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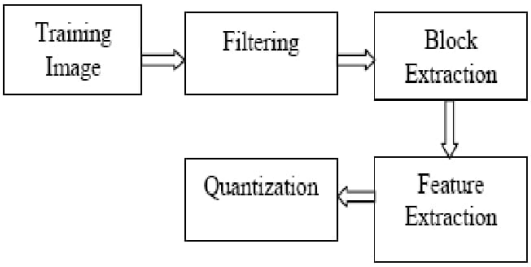

Figure 3: The training process of a training image

Figure 3 shows training process of training image which consists of steps like filtering, block extraction, feature extraction and quantization. All these steps are useful in face recognition.

A. Hidden Marko Model (HMM)

We can use Hidden Marko Models for face recognition system. HMM is associated with non-observable hidden states and an observable sequence generated by the hidden states individually. The N elements of a HMM are represented by S number of states in the model, where S = $\{s_1, s_2 \ldots, s_N\}$ is the set of all possible states. HMMs normally work on series of symbols called observation vectors. The observation vector is a vector of observation symbols of length *T*. *T* is defined by user based on the in hand problem. $A = \{a_{ij}\}$ is the state transition probability matrix, where:

$$a_{ij} = P[q_{t+1} = S_j | q_t = S_j], 1 \le i, j <= N$$

$$0 <= a_{ij} <= 1$$
$$\sum_{j=1}^{N} a_{ij} = 1, 1 \le i \le N \quad (1)$$

$B = \{b_j(k)\}$ is the observation symbol probability matrix, where

$$b_j(K) = P[O_t = V_k \mid q_t = S_j], 1 <= J \le N, 1 \le K \le M$$

$$= \{\pi_1, \pi_2, \pi_3, \ldots\ldots\ldots, \pi_N\}, \quad (2)$$

$$\pi_i = P[q_1 = S_i], 1 \le i \le N \quad (3)$$

$$\lambda = (A, B, \pi)$$

$\pi = \{\pi_1, \pi_2, \pi_3, \ldots\ldots\ldots, \pi_N\}$ is the initial state distribution, where:

$$\pi\ i = P[q1 = si]$$
$$\pi_i = P[q_1 = S_i], 1 \le i \le N$$

So HMM is defined as follows

$$\lambda = (A, B, \pi) \quad (4)$$

Here face image is divided into seven regions which each is assigned to a state in a left to right one dimensional HMM.

B. Singular Value Decomposition (SVD)

The Singular Value Decomposition (SVD) has been an important tool in signal processing and statistical data analysis [11]. Singular values of given data matrix contain information about the noise level, the energy, the rank of the matrix, etc. SVD provides a noval technique for extracting algebraic features from an image. A singular value decomposition of a m × n matrix X is any function of the form

$$\mathbf{X} = \mathbf{U\Sigma V^T} \quad (5)$$

Where U ($m \times m$) called left singular vector and V ($n \times n$) called right singular vector are orthogonal matrix.

C. Filtering

A specific filter called order-statistics filter is used which directly affects the speed and recognition rate of the face recognition system. Most of the face recognition systems commonly use filter processing to improve their performance. It can simply be represented by the following equation.

$$\hat{f}(x, y) = \min(s, t) \in S_{xy} \{g(s, t\} \quad (6)$$

In this equation, $g(s, t)$ is the grey level of pixel (s, t) and S_{xy} is the mentioned window.

"All the face images are two dimensional while HMMs require a one-dimensional observation sequence therefore images should be interpreted as a one dimensional sequence". We can generate observation sequence is generated by dividing each face image of width *W* and height *H* into overlapping blocks of height *L* and width *W*. The technique is shown in Figure 4 below.

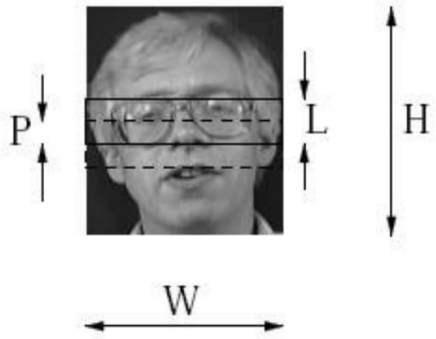

Figure 4: The sequence of overlapping blocks

These successive blocks are the mentioned interpretation. The number of blocks extracted from each face image is given by:

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$$T = \left[\frac{H-L}{L-P} + 1\right] \quad (7)$$

A high percent of overlap between consecutive blocks significantly increases the performance of the system which increases the computational complexity. This experiment showed that as long as P is large ($P \leq L - 1$) and $L \approx H$ /10, the recognition rate is not very sensitive to the variations of L.

This process computes SVD coefficients of each block and uses them as our features. The problem of feature selection is as there is given a set of d features; select a subset of size m that leads to the smallest classification error and smallest computational cost. This procedure selects features from singular values which are the diagonal elements.

D. Quantization

Inheritably all the SVD coefficients have continuous values which help to build the observation vectors. If they are considered in the same continuous type, then we need to determine infinite number of possible observation vectors. This infinite number is not model by discrete HMM. So quantization is important. In quantization process, consider a vector $X = (x_1, x_2, \ldots, x_n)$ with continuous components. Suppose x_i is to be quantized into D_i distinct levels. So the difference between two successive quantized values will be as equation x.

$$\Delta_i = \frac{x_{imax} - x_{imin}}{D_i} \quad (8)$$

x_{imax} and x_{imin} are the maximum and minimum values that *xi* gets in all possible observation vectors respectively.

$$x_{iquantized} = \left[\frac{x_i - x_{imin}}{\Delta_i}\right] \quad (9)$$

E. Face Recognition

After learning process, each face class is associated to a HMM. For a K-class classification problem, it finds K distinct HMM models. "The block extraction, feature extraction and quantization process are performed for each test image". Each test image is represented by its own observation vector like training images. A face image m is recognized as face d if:

$$P\left[O^{(m)}|\lambda_d\right] = max_n\, P\left(O^{(m)}|\lambda_n\right) \quad (10)$$

The proposed recognition system tested on the ORL face database and some personal database.

IV. Conclusion

In the recent time face recognition system has gained enormous popularity as it provides security using biometric technique as compared to password or key based security. In the last few years various techniques (methods) are developed to achieve high success rate of accuracy in the identification and verification of individuals for authentication in security systems. Face recognition systems are generally trained with a database of existing face images to become familiar with the given set of faces. In this paper we develop a hybrid approach of face recognition system consisting of Hidden Markov Model (HMM) and Singular Value Decomposition (SVD). Singular Value Decomposition extracts the various features of face as coefficient values. On the other hand Hidden Markov Model [3] acts as classifier i.e., it identify the face using the coefficients values extracted by SVD.

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