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Face Recognition Using Singular Value Decomposition along with Seven State HMM

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***Abstract*— This paper presents a new approach using Hidden Marko Model as classifier and Singular Values Decomposition (SVD) coefficients as features for face recognition. As face is a complex multi-dimensional structure and needs good computing techniques for recognition and it is an integral part of biometrics. Features extracted from a face are processed and compared with similar faces which exist in database. The recognition of human faces is carried out by comparing characteristics of the face to those of known individuals. Here seven state Hidden Markov Model (HMM)-based face recognition system is proposed. A small number of quantized Singular Value Decomposition (SVD) coefficients as features describing blocks of face images. SVD is a method for transforming correlated variables into a set of uncorrelated ones that better expose the various relationships among the original data item. This makes the system very fast. 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.**

***Index Terms*— Face Recognition, Singular Value Decomposition and Hidden Markov Model**

I. INTRODUCTION

FACE recognition is one of the major topics in the image processing and pattern recognition due to the new interests in, security, smart environments, video indexing and access control .Face recognition is a challenging area in the real time applications. It also stands high in researcher's community. It is useful in finding out exact identity of any person by performing face recognition technique which is integral part of biometrics. Person can be recognized even though there is a variation in person's face due to ages and distractions. In face recognition features are extracted and it is matched with existing data and depending on result of matching, identification of human being is traced. Face recognition techniques have two categories, one is based on the face representation which uses appearance-based, which requires large set of training samples, by using statistical analysis techniques it is easy to analyze the Characteristics of a face out of all existing face images and the other type is based on feature based, which uses geometric facial features (mouth, eyes, brows, cheeks etc.), and geometric relationships between them. The features which are extracted from face are processed and compared with similar faces available in the existing database, if it matches then that person is recognized otherwise unrecognized. If any person's face image is not recognized then that image is stored in database for next recognition procedure [1]-[5].

Face recognition using HMM and SVD coefficient shows an approach using one dimensional Discrete HMM as classifier and Singular Values Decomposition (SVD) coefficients as features for face recognition. Here seven states used in HMM to take into account maximum face regions [6]-[7]. In HMM, the state is not directly visible, but output, dependent on the state, is visible. Each state has a probability distribution over the possible output tokens.

Singular value decomposition is a method for transforming correlated variables into a set of uncorrelated ones that better expose the various relationships among the original data items. It is a method for identifying and ordering the dimensions along which data points exhibit the most variation. This shows that once identified where the most variation is, it's possible to find the best approximation of the original data points using fewer dimensions. These are the basic ideas behind SVD: taking a high dimensional, highly variable set of data points and reducing it to a lower dimensional space that exposes the substructure of the original data more clearly and orders it from most variation to the least.

Hence, it shows that SVD is a good method for data reduction.Therefore the sequence of tokens generated by an HMM gives some information about the sequence of states. This approach gives good accuracy with increasing speed .To obtain result of face recognition a collection of set of face images is required. These face images become the database of known faces. So need to determine whether or not an unknown face matches any of these known faces. All face images must be of the same size (in pixels), must be gray scale, with values ranging from 0 to 255. The most useful face sets have multiple images per person. This sharply increases accuracy, can call the collection of faces as “face space” [8]-[9].

A successful face recognition system depends heavily on the feature extraction method. One major improvement of our system is the use of SVD coefficients as features instead of gray values of the pixels in the sampling windows, blocks. After learning process, each class (face) is associated to a HMM. For a K-class classification problem, it finds K distinct HMM models. Each test image experiences the block extraction, feature extraction and quantization process as well. Indeed each test image like training images is represented by its own observation vector [10]-[12].

II. FACE RECOGNITION USING HMM WITH SVD COEFFICIENT

Following diagram (Fig. 1) shows flow of processing flow in face recognition:

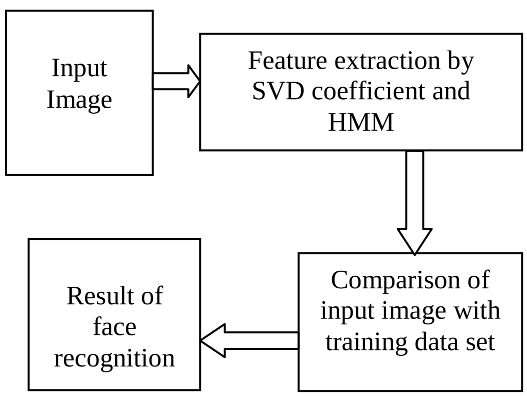

Fig. 1: Face recognition process

Face recognition using Singular value Decomposition and HMM consist of steps in which it captures the information content in an image of a face which are further useful for face recognition efficiently.In processing flow of face recognition using SVD and HMM approach, it includes extraction of face features by SVD coefficient, Seven state HMM divides face image in seven states then by using classifier, there is comparison of input image with training data set. If input image matches with training dataset image then face is said to be recognized otherwise face is unrecognized. Below diagram shows training process of a training image which includes filtering, block extraction, feature extraction and quantization.

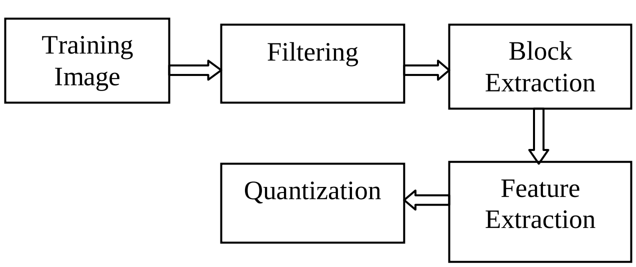

Fig. 2: The training process of a training image

Fig. 1 shows training process of a training image which consists of steps like filtering, block extraction, feature extraction and quantization. All these steps are useful in face recognition using hidden Marko model.

III. HIDDEN MARKO MODEL

Hidden Marko Models are useful in modeling one dimensional data in face finding, object recognition and face recognition. HMM is associated with non-observable hidden states and an observable sequence generated by the hidden states individually. The elements of a HMM are as N= S is the number of states in the model, where S={s1,s2,…,sN} is the set of all possible states. M = V is the number of the different observation symbols, where $V = \{v1, v2, ..., vM\}$ is the set of all possible observation symbols .HMM models are performed in the observation vectors space [13].

HMMs generally work on sequences of symbols called observation vectors, while an image usually is represented by a simple 2D matrix. The observation vector is a vector of observation symbols of length T. T is defined by user based on the in hand problem.

$A = \{aij\}$ is the state transition probability matrix, where:

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

$$0 <= a_{ij} <= 1$$

$$\sum_{j=1}^{N} a_{ij} = 1, 1 \leq i \leq N \qquad (1)$$

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

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

$$= \{\pi_1, \pi_2, \pi_{3,\dots\dots\dots}, \pi_N\}, \qquad (2)$$

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

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

$\pi = \{\pi_1, \pi_2, \pi_{3,\dots\dots\dots}, \pi_N\}$ is the initial state distribution, where:

$$\pi \quad i = P[q1 = si\,]$$

$$\pi_i = P[q_1 = S_i], 1 \leq i \leq N$$

So HMM is defined as follows

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

HMMs generally work on sequences of symbols called observation vectors, while an image usually is represented by a simple 2D matrix [15]-[17].

Here face image is divided into seven regions which each is assigned to a state in a left to right one dimensional HMM. In hidden Marko model probability of each subsequent state depends only on what was the previous state. HMM is a Markov chain with finite number of unobservable states.

These states has a probability distribution associated with the set of observation vectors.HMM consist of evaluation decoding and learning. It can be characterize by three steps that are, State transition probability matrix, Initial state probability distribution, Probability density function associated with observations for each of state[18]-[20].

Fig. 3: Seven regions of face coming from top to down like Hair, Forehead, Eyebrows, eyes, nose, mouth, chin in natural order

In the case of using a one dimensional HMM in face recognition problems, the recognition process is based on a frontal face view where the facial regions like hair, forehead, eyes, nose and mouth come in a natural order from top to bottom.

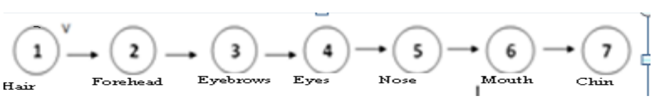

Fig. 4: A one dimensional HMM model with seven states for a face image with seven regions

IV. SINGULAR VALUE DECOMPOSITION

The Singular Value Decomposition (SVD) has been an important tool in signal processing and statistical data analysis [14]. Singular values of given data matrix contain information about the noise level, the energy, the rank of the matrix, etc.. SVD provides a new way for extracting algebraic features from an image. SVD provides a new way for extracting algebraic features from an image. A singular value decomposition of a m×n matrix X is any function of the form

$$X = U\Sigma V^T \qquad (5)$$

Where U ($m \times m$) and V ($n \times n$) are orthogonal matrix,. The columns of the orthogonal matrices U and V are called the left and right singular vectors respectively. An important property of U and V is that they are mutually orthogonal. Singular values represent algebraic properties of an image.

V. FILTERING

In this system a specific filter is used which directly affects the speed and recognition rate of the algorithm Here Order-statistic filter is used for filtering process. Most of the face recognition systems commonly use processing to improve their performance.. Order-statistic filters are nonlinear spatial filters. A two dimensional order statistic filter, which replaces the cantered element of a 3×3 window with the minimum element in the window, is used in the proposed system. It can simply be represented by the following equation.

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

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

Since HMMs require a one-dimensional observation sequence and face images are two dimensional, the images should be interpreted as a one dimensional sequence. The 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. These successive blocks are the mentioned interpretation. The number of blocks extracted from each face image is given by:

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

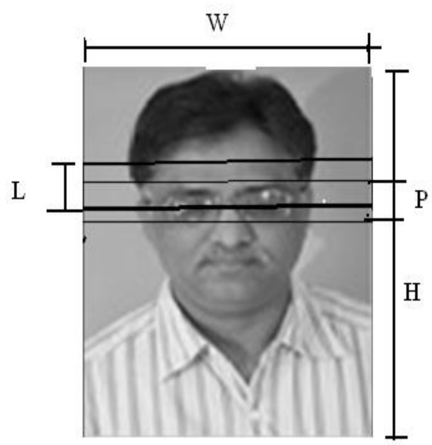

Fig. 5: The sequence of overlapping blocks

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.

In order to reduce the computational complexity and memory consumption, it is necessary to resize both face databases into 64×64 which results in data losing of images, so to achieve high recognition rate feature extraction method is necessary. A successful face recognition system depends heavily on the feature extraction method. One major improvement of our system is the use of SVD coefficients as features instead of gray values of the pixels in the sampling windows. Using pixels value as features describing blocks, increases the processing time and leads to high computational complexity. 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. It has been shown that the energy and information of a signal is mainly conveyed by a few big singular values and their related vectors. Figure shows the singular values of a 64 × 64 face image. The first two singular values are very bigger than the other ones based on the SVD theory, have more significance.

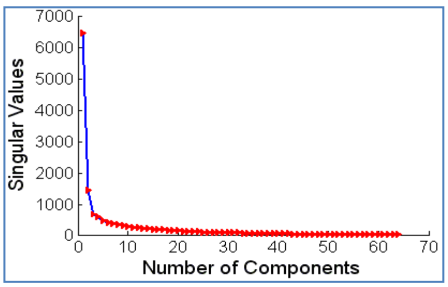

Fig. 6: SVD coefficients of a 64× 64 face image

VI. QUANTIZATION

The SVD coefficients have innately continuous values. These coefficients build the observation vectors. If they are considered in the same continuous type, it is necessary to determine infinite number of possible observation vectors that can't be modelled by discrete HMM. So quantization is important. In quantization process, used in the proposed system, consider a vector $X = (x1, x2,..., xn)$ 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.

$$\Delta_i = \frac{x_{imax} - x_{imin}}{D_i} \tag{8}$$

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

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

At last each quantized vector is associated with a label that here is an integer number. Considering all blocks of an image, the image is mapped to a sequence of integer numbers that is considered as an observation vector. After representing each face image by observation vectors, they are modelled by a 7-state HMM shown in Fig. 6.

VII. 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. Each test image experiences the block extraction, feature extraction and quantization process as well. Here each test image like training images is represented by its own observation vector. Here for an incoming face image, simply calculate the probability of the observation vector (current test image) given each HMM face model. A face image *m* is recognized as face *d* if:

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

The proposed recognition system tested on the ORL face database and some personal database. The database contains 10 different face images per person of 40 people with the resolution of 112× 92 pixels.

VIII. RESULT

This directory contains a set of faces taken between April 1992 and April 1994 at the Olivetti Research Laboratory, IIT face image database And also some individuals. There are 10 different images of 40 different persons. There are images taken at different times, varying lighting slightly, and facial expressions. All the images are taken against a dark homogeneous background and the subjects are in up-right, frontal position. The size of each image is 92x112, 8-bit grey levels. The images are organized.A fast and efficient system was presented. Images of each face were converted to a sequence of blocks. Each block is featured by a few number of its SVD parameters. Each class has been associated to hidden Markov model as its classifier. The evaluations and comparisons were performed on the face image data bases It process approximately having a recognition rate of 100%, the system is very fast. This was achieved by resizing the images to smaller size and using a small number of features describing blocks.

Following Fig. 7 shows results of face recognition with showing test image matching with recognised image.

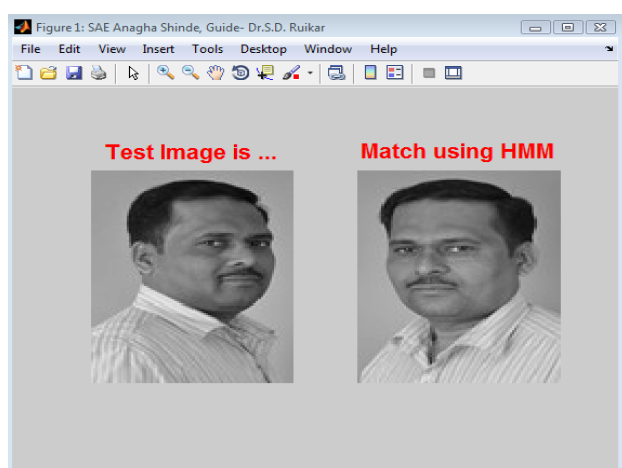

Fig. 7: Test image and recognized image from the training data base

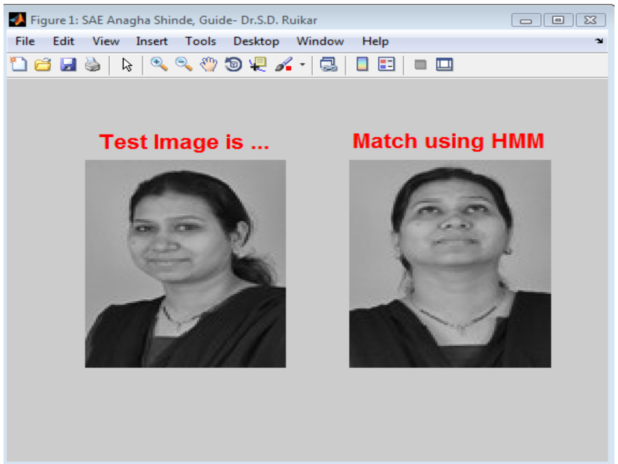

Fig. 8: Test image and recognized image from the training data base

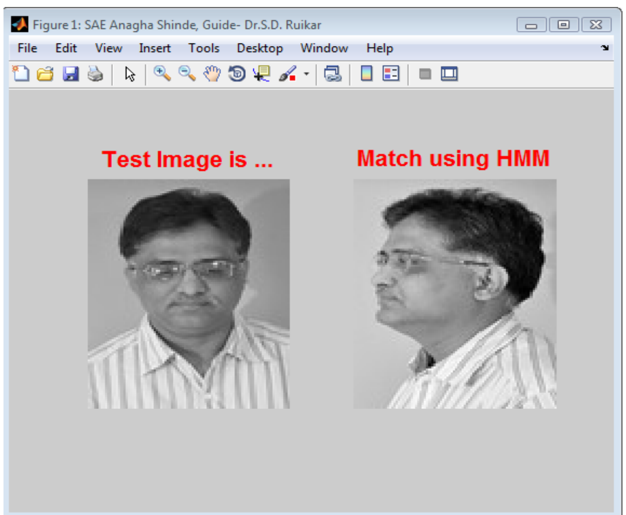

Fig. 9: Test image and recognized image from the training data base

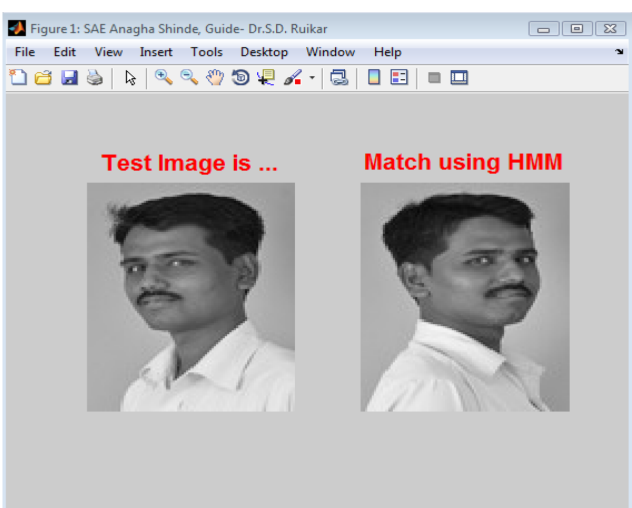

Fig. 10: Test image and recognized image from the training data base

IX. CONCLUSION

Face recognition applications such as information security, Access management, Biometrics, personal security, and Entertainment. A fast and efficient system is presented. Images of each face are converted to a sequence of blocks. Each block featured by a few number of its SVD parameters. Every class is associated to hidden Markov model as its classifier. The evaluations and comparisons are performed on face image data bases ORL IIT face database images and some other individuals. The system recognition rate is approximately 99.99 %,. It is achieved by resizing the images to smaller size and using a small number of features describing blocks.. It is obvious that if the minimum distance between the test image and other images is zero, the test image entirely matches the image from the training base.

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