World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:2, No:7, 2008

A New Approach to Face Recognition Using Dual Dimension Reduction

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Open Science Index, Computer and Information Engineering Vol:2, No:7, 2008 publications.waset.org/4885/pdf

***Abstract*—**In this paper a new approach to face recognition is presented that achieves double dimension reduction, making the system computationally efficient with better recognition results and out perform common DCT technique of face recognition. In pattern recognition techniques, discriminative information of image increases with increase in resolution to a certain extent, consequently face recognition results change with change in face image resolution and provide optimal results when arriving at a certain resolution level. In the proposed model of face recognition, initially image decimation algorithm is applied on face image for dimension reduction to a certain resolution level which provides best recognition results. Due to increased computational speed and feature extraction potential of Discrete Cosine Transform (DCT), it is applied on face image. A subset of coefficients of DCT from low to mid frequencies that represent the face adequately and provides best recognition results is retained. A tradeoff between decimation factor, number of DCT coefficients retained and recognition rate with minimum computation is obtained. Preprocessing of the image is carried out to increase its robustness against variations in poses and illumination level. This new model has been tested on different databases which include ORL , Yale and EME color database.

***Keywords*—**Biometrics, DCT, Face Recognition, Illumination, Computation, Feature extraction.

I. Introduction and Related Work

FACE recognition has been studied for over 20 years in computer vision [1]. Since the early of the 1990s, the subject has become a major issue, mainly due to the important real-world applications of face recognition like smart surveillance, secure access, telecommunication, digital libraries and medicines [2]. Faces are very specific objects whose most common appearance (frontal faces) roughly look alike but subtle changes make the faces different.

Face recognition techniques have been divided into two main approaches: a) Global approach b) Component based approach. In global approach, the input to a classifier is a single feature vector that represents the whole face image. Several classifiers have been proposed in the literature e.g. minimum distance classification in the eigenspace [3] based on PCA, the independent face space based on ICA, the discriminative subspace based on LDA [3], neural networks [4], and probabilistic matching based on intrapersonal/ extra personal image difference [5]. The global techniques work well for classifying frontal views of face. For all the global techniques an alignment stage needs to be added before classifying the face. In [6] the correspondences between two face images are first built by labeling some key points and then an affine transform is computed to warp an input image into a reference face image. Active morphable model is adopted in [7] to match the input face with the reference face. Active shape models are used in [8] to align the input face with the model face.

For the component-based algorithms, the main idea is to compensate for pose changes by allowing a flexible geometrical relation between the components in the classification stage. In [9] face recognition was performed by independently matching templates of three facial regions (eyes, nose and mouth). The configuration of the components during classification was unstrained since the system did not include a geometrical model of the face. A similar approach with an additional alignment stage was proposed in [10]. In [11] a geometrical model of a face was implemented by a 2-D elastic graph. The recognition was based on wavelet coefficients that were computed on the nodes of the elastic graph. In [12] a window was shifted over the face image and the DCT coefficients computed within the window were fed into a 2-D Hidden Markov Model.

In this paper, an effort has been made to investigate the double dimension reduction through decimation algorithm and DCT, whose combination leads to improved recognition results with reduced computation. In this technique of face recognition, preprocessed normalized images are first exposed to decimation algorithm and then DCT is applied on decimated images to extract coefficients of low to high frequencies against each image which are used for training of the system. Later on recognition is performed by projecting a test image to the subspace of dimensionally reduced images. Euclidean distance is criterion used to obtain the best match. Results have been obtained by using ORL, Yale and EME color database.

Manuscript received Mar 28, 2005. This work was supported in part by the College of Eelectrical and Mechanical Engineering and National University of Sciences and Technology Rawalpindi Pakistan.

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Open Science Index, Computer and Information Engineering Vol:2, No:7, 2008 publications.waset.org/4885/pdf

II. Overview of System and Motivation

Some of the previous techniques have achieved successes in constrained scenarios; the general task of face recognition still poses a number of challenges with respect to the changes in resolution, illumination, facial expression and pose. Therefore currently researchers pay more attention to the study of the robustness against the changes in pose, illumination, expression and resolution of face images. In proposed model first of all the preprocessing (discussed in section III) of images is carried out. Then decimation algorithm is applied (discussed in section IV&V) , DCT of decimated face image (discussed in section VI) is computed and coefficients of maximum variance are retained for training (discussed in section VII) and later on a test image is exposed to system for recognition (discussed in section VIII) .Results are discussed in section XI using three different databases. Main parts of the model are shown in Fig. 1.

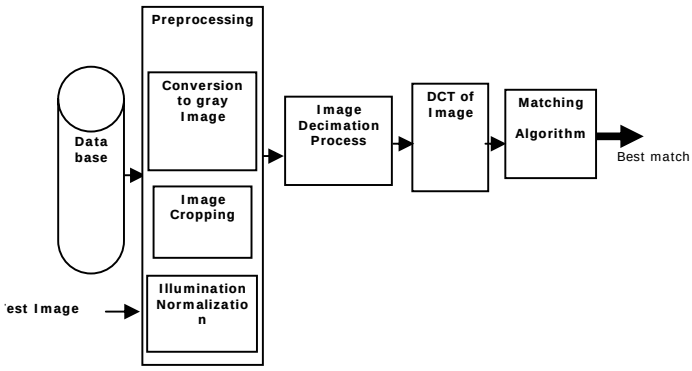


Fig. 1 Model of the System

III. Pre-Processing

A. Conversion to Gray Scale Image

To avoid computation intensive processing of colored images in three planes of Hue, Saturation and Value, the colored images of database and test images are converted to gray scale images using expression shown below:

$$Y = 0.3R + 0.59G + 0.11B \quad (1)$$

The weights are used to compute gray scale image because for equal amount of color, eye is most sensitive to green, red and then blue [13],[14].

B. Illumination Normalization

Scene illumination is one of the most important factors that determine success or failure for many imaging and machine vision applications. From theory of the illumination-reflectance model, an image can be expressed in terms of its illumination and reflectance components. Most algorithms of face detection presume that the illumination variation is uniform or lighting must be controlled. Unfortunately, the illumination components of an image vary a great deal, often more than the reflectance component. The non-uniform illumination will change the rules of human face gray level distribution.

Physiologically the response of cells in the retina of eye is nonlinear with respect to the intensity of the incoming image, which can be approximated as a logarithmic function of the intensity. In this model logarithmic transformation is applied on those images which have shadow and non uniform / poor illumination. Logarithmic function can extend low gray level and compress high gray level, which can improve the illumination deficient in essence as shown in Fig. 2.



Fig. 2 (a) Poorly Illuminated Image (b) After log transformation

Eyes, nose, lips, chin and surrounding area of face image contribute maximum in face recognition. So scale normalization of face images of data sets is carried out by using the cropping phenomena which eliminate the unnecessary information from image and retain face only. Fig. 3 shows the original image and the cropped image.

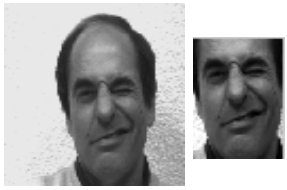


Fig. 3 Original Image and Cropped Image

IV. Decimation Algorithm (DA)

In most pattern recognition systems it is always required to have optimal image resolution which provides best recognition results [15]. Decimation algorithm is a novel form to obtain desired resolution in all images of database which provides best recognition results. Decimation factor (L) which is used to obtain images with varying resolution can be calculated as:

$$L = M / N \quad (2)$$

Where M = order of original image matrix
N = order of desired decimated image matrix
L = arbitrary down scale decimation factor:

V. Structure of Decimation Algorithm

In this algorithm the sub sampling under the best circumstances is harmless to image as it scans through lines of pixels, averaging together pair of pixels or group of pixels according to value of L. The resulting image is a reduced size mirror of the original image faithful in tonality to the original image but smaller in size. The sliding mask shown in Fig. 4 is

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applied to achieve the decimation, the mathematical model of decimation process [16] is:

$$A_{mxn} = \frac{\sum_{i=0}^{W-1}\sum_{j=0}^{H-1}\left[\sum_{m=i\times\mu_w}^{i\times\mu_w+(\mu_w-1)}\sum_{n=j\times\mu_h}^{j\times\mu_h+(\mu_h-1)} O_{ixj}\right]}{L\times L} \quad (3)$$

$$\mu_w = \frac{W}{L} \,\&\, \mu_h = \frac{H}{L}$$

Where W = Width of the original image
H = Height of original image

μ_w = Ratio between actual width of image and desired width

μ_h = Ratio between actual height of image and desired height.

1	**1**	**1**
1	**1**	**1**
1	**1**	**1**

Fig. 4 Decimation mask of 3 x 3

The size and movement of mask depends upon the value of L. As value of decimation factor is varied, a Gaussian pyramid [17] as shown in Fig. 5 is achieved which is used to obtain optimal resolution for best recognition rate with minimum computation.

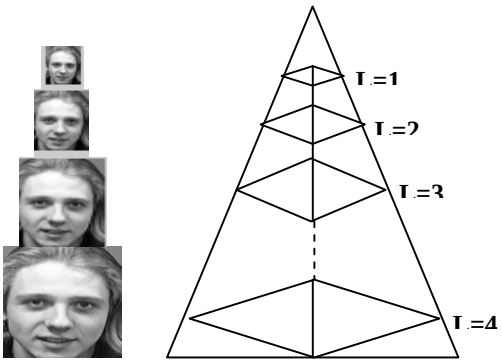


Fig. 5 Gaussian pyramid

Decimation algorithm [16] was applied on ORL, YALE and EME database to evaluate the effect of varying image resolution on recognition process. The results shown in figure 6 reflect that at one particular resolution level the optimal recognition is obtained.

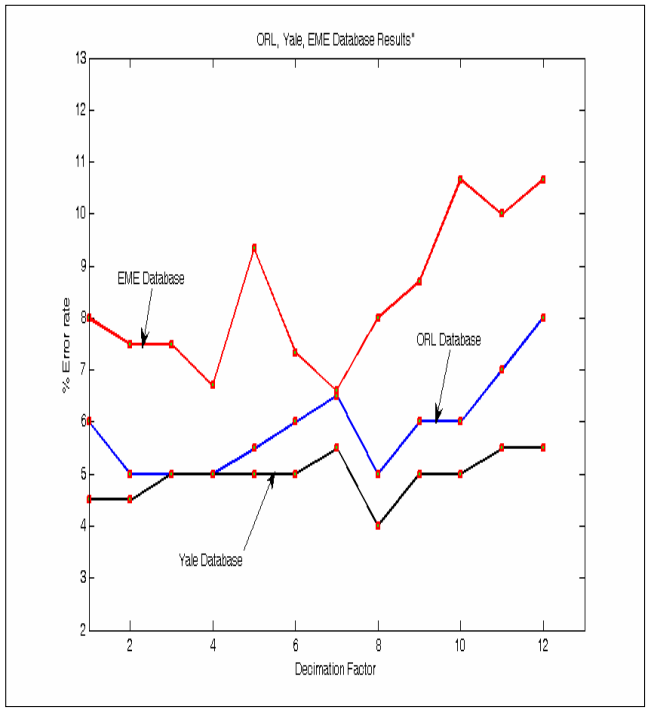


Fig. 6 Recognition results of ORL, YALE, EME color Database by using Decimation Algorithm only

VI. DCT of Image

In pattern recognition techniques to make the model computationally efficient, dimension reduction is as important as the class separation in applications like face recognition. The discrete cosine transform (DCT) helps to separate the image into parts (or spectral sub-bands) of differing importance (with respect to the image's visual quality). The DCT is similar to the discrete Fourier transform: it transforms a signal or image from the spatial domain to the frequency domain and represents an image as a sum of sinusoids of varying magnitude and frequencies In proposed model of face recognition dimension reduction is achieved firstly through decimation algorithm and then DCT is applied which exhibits large variance distribution in a small number of coefficients [18] and much of the signal energy lies in low frequencies; these appear in the upper left corner of the DCT.

The equation of DCT for a two dimensional image is :

$$F(u,v) = \left(\frac{2}{N}\right)^{\frac{1}{2}}\left(\frac{2}{M}\right)^{\frac{1}{2}}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\Lambda(i).\Lambda(j).\cos\left[\frac{\pi.u}{2.N}(2i+1)\right]\cos\left[\frac{\pi.v}{2.M}(2j+1)\right].f(i,j)$$

DCT of the normalized decimated face image is computed and a certain subset of low-to-mid frequency coefficients having the highest variance is retained as a feature vector which describes face.

VII. System Training

Five out of 10 images of database are used for training of model. Images are preprocessed, decimated and their DCT is

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computed. A feature vector containing 8 x 8 subset of DCT coefficients is retained and stored against each face image.

VIII. Recognition

The DCT of preprocessed, decimated test image is obtained and an 8 x 8 subset of coefficients is retained. Feature vector of test image is compared with feature vector of images obtained during the training of the system. Euclidian distance criterion is used to get the best match.

IX. Experiments and Results

Three sets of experiments are presented to evaluate this new approach. The model is tested on a 2.6GHZ Pentium IV computer with 512MB RAM and MATLAB image processing tool was used for coding. First experiments were carried out on ORL and YALE databases containing gray scale images and later on model are also tested on EME database of color images of different resolutions and constraints.

A. Olivetti Research Laboratory Face Database

The ORL database contains 400 images of 40 individuals, 10 images were taken for each individual and few constraints on facial expression and pose were imposed. Furthermore captured images were subjected to illumination variations. It is expected that this is a more difficult database to work with. There are variations in facial expressions (open / closed eyes, smiling / non- smiling) and facial details (glasses / no glasses). In proposed face recognition model, 5 for each individual of ORL database were selected randomly to train the system. The remaining 200 samples were used as test images. Error rate is computed by varying the value L while keeping 8x8 DCT coefficients constant throughout, results are shown in Fig. 7.

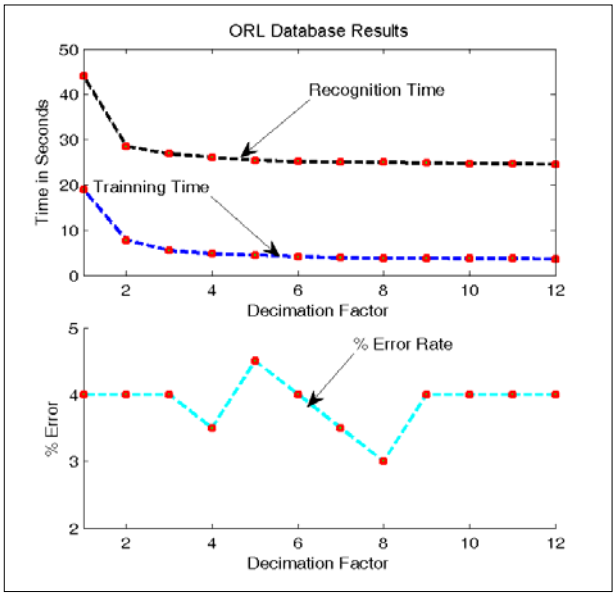


Fig. 7 (Upper) Decimation factor, vs Training time& Recognition time (Lower) Decimation factor vs Error rate of ORL Database

B. Color Face Database

In the second set of experiments, 15 sets of color images of different individuals with 10 varying poses, sizes and intensity level were taken [19]. These images were obtained with different facial expressions and occlusions. Results with various values of L and its effect on error rate are shown in Fig. 8.

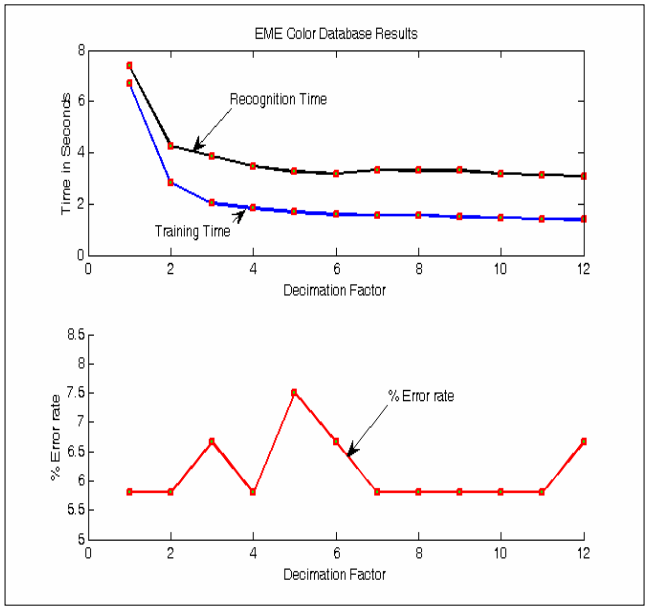


Fig. 8 (Upper) Decimation factor, vs Training time& Recognition time (Lower) Decimation factor vs Error rate of EME Color Database

C. Yale Dataset

The Yale database contains 165 gray scale images in GIF format of 15 individuals. There are 11 images per person one per different facial expression or configurations: center-light, with or without glasses, sad, happy, sleepy, surprise and wink. Results with various values of L are shown in Fig. 9 which reflects that value of L=8 Provides best recognition rate of 96.5%.

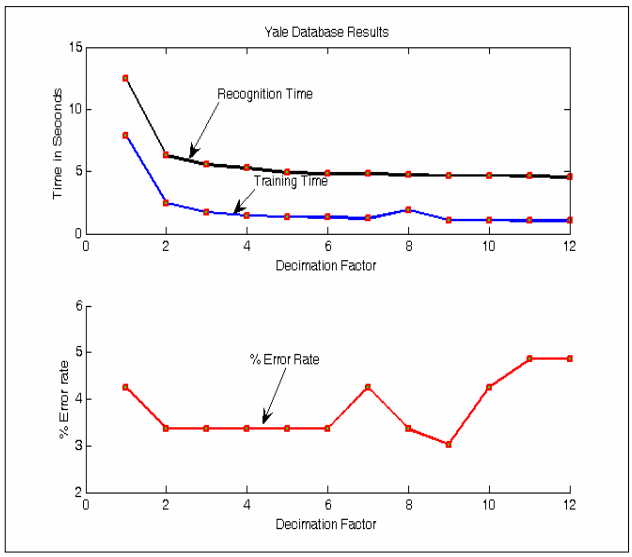


Fig. 9 (Upper) Decimation factor ,vs Training time& Recognition time (Lower) Decimation factor vs Error rate of YALE database

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X. Comments

Decimation algorithm is applied to three different databases having images with different constraints. Experiments using Gaussian pyramid of different image resolution values and keeping DCT subset of 8 x 8 coefficients are carried out. Results reflect that a trade off between image resolutions, recognition error rate and computation time exists in each dataset. Different databases are used to evaluate the proposed model on images acquired under maximum constrained environments. Computation time and recognition rate vary with respect to number of training images. For comparison and standardization, five images of each person have been used for training purpose and it is found that results are much better than other techniques. The comparison of results of proposed double dimension model with other dimension reduction techniques like DFT, NMF, PCA and LDA is also carried out and its recognition rate with computational speed were much better.

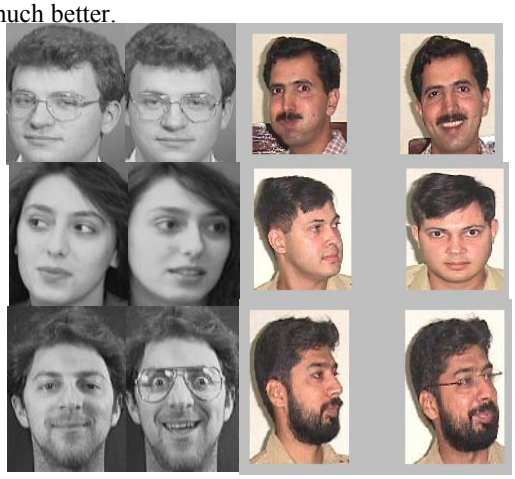


Fig. 10 Few Recognition Results

XI. Conclusion

Real time security and surveillance due to certain limitations and restrictions (like constrained environment, speed of system and its accuracy) have made this area of research more attractive and challenging for biometric researchers. Proposed system of face recognition using decimation algorithm in conjunction with DCT has been developed to overcome these limitations up to a certain extent and success rate has improved besides enhancing speed. Results have been obtained by using five images as a standard for training purposes. Variations in number of training images affect both the success rate and speed of CPU. The proposed technique performed much better compared to other technique of face recognition like PCA, LDA, ICA, NMF and ect. The proposed model significance is two fold (1) dimension reduction up to an effective and suitable face image resolution(2) appropriate DCT coefficients are retained to achieve best recognition results with varying image poses, intensity and illumination level.

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