IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 3, Issue 6, January 2015)

PCA, DCT and DWT based Face Recognition System using Random Forest Classifier

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Abstract – **Face recognition plays an important role in biometrics base personal identification. The need for reliable recognition and identification of interacting users is obvious. The biometrics recognition technique acts as an efficient method and wide applications in the area of information retrieval, automatic banking, and control of access to security areas and so on. The proposed method is based on Principal Component Analysis (PCA) of image in DCT domain with a combination of details of DWT.**

This approach reduces the storage requirement and computation time while preserving the data. The proposed scheme exploits feature extraction capabilities of the Discrete Wavelet Transform Decomposition and invokes certain normalization techniques that increase its robustness to variations in facial geometry and illumination. Traditionally, to represent the human face, PCA is performed on the whole facial image. Random Forest Classifier is used to classify the features and the similarity measure is done by Euclidian Distance. Experimental results show that the proposed method is effective and possesses several desirable properties when it compared with many existing algorithm. The approach PCA-DCT-hybrid DWT is evaluated on MATLAB using ORL face database. Compared to previous methods the proposed method improves feature extraction and retrieval rate.

Keywords – **DCT, DWT, Euclidian Distance, ORL Face Database, PCA and Random Forest Classifier.**

I. INTRODUCTION

During the past two decades, Face recognition [1] bound its importance as the necessity of security levels increasing. This makes the researchers to work for an efficient system of face recognition. The methods of face recognition is mainly divided into two major categories, appearance based (PCA, LDA, IDA etc.,) and feature based, in which the former one is more popularized.

In general face images are captured with very high dimensionality, which is above 1000 pixels. As dimensionality increases the complexity also increases which makes difficult to recognize faces based on the original images. This makes the feature extraction as an important step and base to the face recognition. In holistic based face recognition method, PCA shows prominent results and an Eigen face method, projects the image data into a subspace based on the variance between data. Also, some of the frequency domain methods have been adopted in face recognition such as Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). Here features are extracted by first transforming images (spatial domain) into frequency domain. Since frequency domain methods are data independent (basis vectors are constant) and also they require only low frequency components which contain the most information to represent the image, these are more efficient than PCA and LDA.

Here we go through a combination of frequency and spatial domains for feature extraction. Frequency domains such as DCT and DWT reduce the redundant data and make the input into an efficient form. Features are extracted by Linear Discriminant Analysis of image in DCT domain, there by calculating the DWT details of transformed image coefficients. Since the DCT only reduces the correlated data in blocks, using DWT after DCT reduces the redundant data between blocks also.

II. PCA MODULE

This is the module which contains the implementation of PCA.

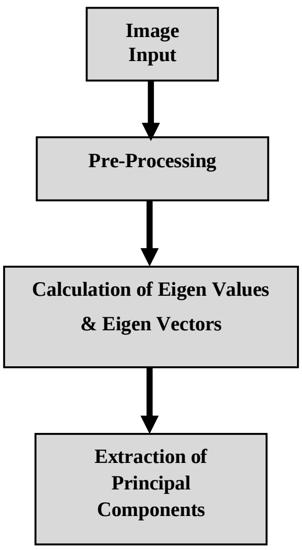

Figure 1: Flow diagram of PCA module

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The extracted images stored in the fdata.dat file forms the dataset for the PCA. Depending upon the No. of images stored say ‘n’, a matrix ‘ A ’ is formed of size 25600×n. The flow diagram of PCA is shown in Figure 1. The following steps are carried out:

i. *Center data:* Each of the training images is centered by subtracting the mean image from each of the training images. The mean image is again a column vector such that each entry is the mean of all corresponding pixels of the training images.
ii. *Covariance matrix:* Now the centered training images in the matrix ‘A’ is multiplied with its transpose to form a covariance matrix L.

$$L = A^T A \text{............ n×n Matrix} \quad (1)$$

iii. *Computing the Eigen Faces:* The ‘n’ Eigen faces are computed using the equation:

$$V = A * V * (\text{abs(D)})^{-0.5} \quad (2)$$

iv. *Projecting of Training Images and Test Images:* Each of the centered training images (X_i) is projected onto the eigenspace. The dot product of the image with each of the ordered eigenvectors is calculated to project an image onto the Eigen space,

$$\tilde{x}^i = V^T \bar{x}^i \quad (3)$$

III. Discrete Cosine Transform (DCT)

A DCT is a Fourier related transform similar to Discrete Fourier Transform (DFT) but using only real numbers (since Fourier transform of real and even function is real and even). The DCT is a very popular transform function used in signal processing. It transforms a signal from spatial domain to frequency domain. Due to good performance, it has been used in JPEG standard for image compression. DCT has been applied in many fields such as data compression, pattern recognition, and image processing, and so on. Two dimensional discrete cosine transform (2D-DCT) is defined as:

$$F(jk) = a(j)a(k)\sum_{m=0}^{N-1}\sum_{n=0}^{N-1} f(mn)\cos\left[\frac{(2m+1)j\pi}{2N}\right]\cos\left[\frac{(2n+1)k\pi}{2N}\right] \quad (4)$$

The corresponding inverse transformation (IDCT) is defined as:

$$f(mn) = \sum_{m=0}^{N-1}\sum_{n=0}^{N-1} a(j)a(k)F(jk)\cos\left[\frac{(2m+1)j\pi}{2N}\right]\cos\left[\frac{(2n+1)k\pi}{2N}\right] \quad (5)$$

The DCT can not only concentrate the main information of original image into the smallest low frequency coefficient, but also it can cause the image blocking effect being the smallest, which can realize the good compromise between the information centralizing and the computing complication. So it obtains the wide spreading application in the compression coding.

DCT-based watermarking is based on two facts. The first fact is that most of the signal energy lies at low-frequencies sub band which contains the most important visual parts of the image. The second fact is that high frequency components of the image are usually removed through compression and noise attacks. The watermark is therefore embedded by modifying the coefficients of the middle frequency sub band so that the visibility of the image will not be affected and the watermark will not be removed by compression.

IV. Discrete Wavelet Transform (DWT)

Discrete Wavelet transform (DWT) is a mathematical tool for hierarchically decomposing an image. It is useful for processing of non-stationary signals. The transform is based on small waves, called wavelets, of varying frequency and limited duration. Wavelet transform provides both frequency and spatial description of an image. Unlike conventional Fourier transform, temporal information is retained in this transformation process. Wavelets are created by translations and dilations of a fixed function called mother wavelet. This section analyses suitability of DWT for image watermarking and gives advantages of using DWT as against other transforms.

The DWT is nothing but a system of filters. There are two filters involved, one is the “wavelet filter”, and the other is the “scaling filter”. The wavelet filter is a high pass filter, while the scaling filter is a low pass filter. DWT includes many kinds of transforms, such as Haar wavelet, Daubechies wavelet, and others. Figure 2 shows the workflow of DWT.

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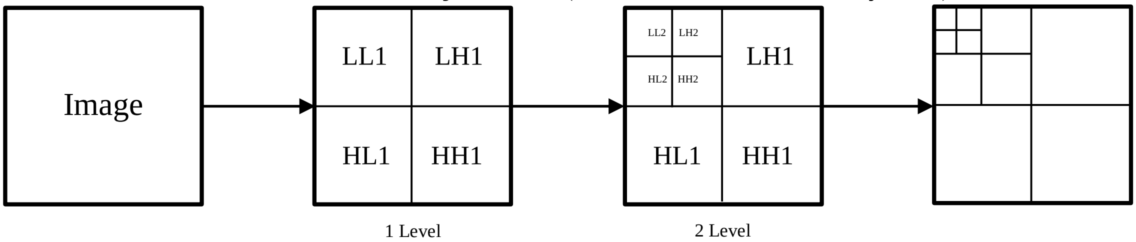

Figure 2: The workflow of discrete wavelet transform

After applying a 1-level DWT on an image, we get the approximation sub-band LL, the horizontal sub-band LH, the vertical sub-band HL, and the diagonal sub-band HH. Moreover, if we want to apply a 2-level DWT on the image, we just simply apply another 1-level DWT on the approximation sub-band LL. After applying a 2-level DWT, we also get the approximation sub-band LL2, the horizontal sub-band LH2, the vertical sub-band HL2, and the diagonal sub-band HH2 of the approximation sub-band LL other than sub-bands LH, HL, HH.

An advantage of DWT over other transforms is it allows good localization both in time and spatial frequency domain. Because of their inherent multi-resolution nature, wavelet coding schemes are especially suitable for applications where scalability and tolerable degradation are important. Applying IDWT to LL, HL, LH, and HH, we can get four different frequency's images that are low frequency image, middle-low frequency image, middle high frequency image, high frequency image separately.

Characteristics of DWT

- Wavelet Transform is computationally efficient and can be implemented by using simple filter convolution.
- With multi-resolution analysis, image can be represented at more than one resolution level. Wavelets allow image to be described in terms of coarse overall shape and details ranging from broad to narrow.
- Magnitude of DWT coefficients is larger in the lowest bands (LL) at each level of decomposition and is smaller for other bands (HH, LH, and HL).
- The larger the magnitude of wavelet coefficient, the more significant it is.
- Watermark detection at lower resolutions is computationally effective because at every successive resolution level, less no. of frequency bands are involved.
- High resolution sub bands help to easily locate edge and textures patterns in an image.

Advantages of DWT

The suitability of wavelet transform for image watermarking can be considered because of following reasons:

- Wavelet transform can accurately model HVS than other transforms like Discrete Cosine Transform (DCT). This allows higher energy watermarks in regions where HVS is less sensitive. Embedding watermark in these regions allow us to increase robustness of watermark, with no much degradation of image quality.
- Wavelet coded image is a multi-resolution description of image. Hence an image can be shown at different levels of resolution and can be sequentially processed from low resolution to high resolution. The advantage of such approach is that the features of an image that might go undetected at one resolution may be easy to spot at another.
- Visual artefacts introduced by wavelet coded images are less evident compared to DCT because wavelet transform doesn't decompose image into blocks for processing. At high compression ratios, blocking artefacts are noticeable in DCT as against wavelet transformed images.
- DCT is full frame transform. Hence, any change in the transform coefficients affects entire image except if DCT is implemented using a block based approach. However DWT has spatial frequency locality. It means it will affect the image locally, if watermark is embedded.
- Another advantage is that current image compression standard JPEG 2000 is based on wavelet transform.

V. Proposed Methodology

The block diagram for proposed method of hybrid face recognition is as shown in Figure 3. A combination of DCT, DWT and PCA is used for feature extraction of images. Images are finally retrieved by comparing the features extracted from query and database with random forest classifier.

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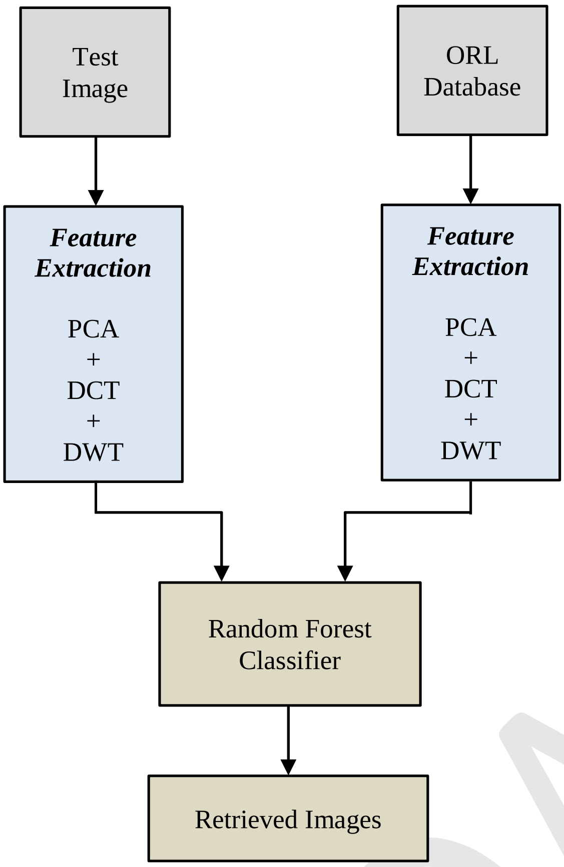

Figure 3: Proposed architecture of Face recognition system

The proposed algorithm was tested in order to determine the performance and efficiency of the system. There were two stages in the process: the first is the training stage, done to obtain Eigen-faces of the database images and second is testing stage, done to test images of different orientations whether it match with the database images.
In addition, both stages have three steps:

- For each image presented above, wavelet decomposition was performed according to level (level 1, 2 and 4) to reduce the size of the original image and only the low-band wavelet was taken as the approximation image.
- Next, PCA was performed on this approximation image to obtain its Eigen-faces and were then stored in the database as training images.
- Eigen-faces of the testing and database images were compared to find the best match. System performance was measured in percentage considering the accuracy of matching images with those in the database. The accuracy of the system was measured based on the levels of the wavelet decomposition and the number of Eigen-faces that each image has in the database.

Feature Extraction

Before finding the projection result, the within class scatter matrix and between class scatter matrix are transformed in DCT domain using orthogonal matrix Q, i.e.

$$\overline{S_b} = Q^T S_b Q \tag{6}$$

$$\overline{S_w} = Q^T S_w Q \tag{7}$$

Now these transformed matrices are taken as input to the DWT. A wavelet function called "Haar" which is very simple and orthogonal is used in DWT [2]. In DWT, decomposition of matrices makes the output with four details, out of which most of the information in approximation details (smooth information), except the sharp edge information. To maintain the data efficient, instead of using all four sub bands the diagonal details which contain the sharp edge information is merged with approximation details.

The new modified/transformed with-in class and between-class scatter matrices are used for further procedure in PCA [3] for feature extraction. Finally a projection matrix with Eigen vectors [4] correspond to highest Eigen values [4] is obtained.

Similarity Measure

Similarity measure is the step done after extracting features. The similarity between the test image and images in database can be obtained by simply measuring the distance. The distance is measured with Euclidian distance.

Random Forest Classifier

Random forests are recently proposed statistical inference tools, deriving their predictive accuracy from the nonlinear nature of their constituent decision tree members and the power of ensembles. Random forest committees provide more than just predictions; model information on data proximities can be exploited to provide random forest features. Variable importance measures show which variables are closely associated with a chosen response variable, while partial dependencies indicate the relation of important variables to said response variable.

Random Forest [5] uses decision tree as base classifier. Random Forest generates multiple decision trees; the randomization is present in two ways:

1. Random sampling of data for bootstrap samples as it is done in bagging and,

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2. Random selection of input features for generating individual base decision trees.

Strength of individual decision tree classifier and correlation among base trees are key issues which decide generalization error of a Random Forest classifier [5].
Random Forest is a classifier consisting of a collection of tree-structured classifiers {h(x, Θ_k) k=1, 2, ….}, where the {Θ_k } are independent identically distributed random vectors and each tree casts a unit vote for the most popular class at input x.

Random Forest generates an ensemble of decision trees. To achieve diversity among base decision trees, Breiman selected the randomization approach which works well with bagging or random subspace method. To generate each single tree in Random Forest Breiman followed following steps: If the number of records in the training set is N, then N records are sampled at random but with replacement, from the original data, this is bootstrap sample. This sample will be the training set for growing the tree. If there are M input variables, a number m<<M is selected such that at each node, m variables are selected at random out of M and the best split on these m attributes is used to split the node. The value of m is held constant during forest growing. Each tree is grown to the largest extent possible. There is no pruning.

In this way, multiple trees are induced in the forest; the number of trees is pre-decided by the parameter N_{tree}. The number of variables (m) selected at each node is also referred to as m_{try} or k in the literature. The depth of the tree can be controlled by a parameter node size (i.e. number of instances in the leaf node) which is usually set to one.

Once the forest is trained or built as explained above, to classify a new instance, it is run across all the trees grown in the forest. Each tree gives classification for the new instance which is recorded as a vote. The votes from all trees are combined and the class for which maximum votes are counted (majority voting) is declared as classification of the new instance. Here onwards, Random Forest means the forest of decision trees generated using this process.

In the forest building process, when bootstrap sample set is drawn by sampling with replacement for each tree, about 1/3rd of original instances are left out. This set of instances is called OOB (Out-of-bag) data. Each tree has its own OOB data set which is used for error estimation of individual tree in the forest, called as OOB error estimation. Random Forest algorithm also has in-built facility to compute variable importance and proximities [5]. The proximities are used in replacing missing values and outliers.

Illustrating Accuracy of Random Forest:

The Generalization error (PE*) of Random Forest is given as,

$$PE *= Px, y\ (mg(X,Y)) < 0 \qquad (8)$$

Where $mg(X,Y)$ is Margin function. The Margin function measures the extent to which the average number of votes at (X,Y) for the right class exceeds the average vote for any other class. Here X is the predictor vector and Y is the classification.

VI. Simulation And Results

Proposed research work used ORL image database. The images were taken at different times, lighting and facial expressions. The faces are in an upright position in frontal view, with a slight left-right rotation.

Figure 4: Test Images of ORL data base

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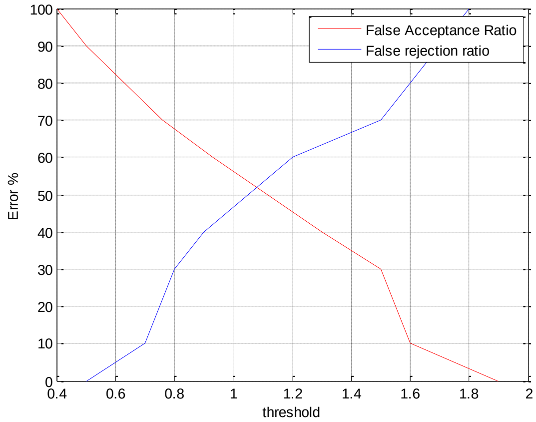

Figure 5: Comparison between FAR and FRR

Table 1: Comparative analysis of accuracy in face recognition under different face orientation

Methods	**Face orientation same (accuracy)**	**Face orientation slightly different**	**More different**
PCA	98%	62%	48%
PCA+DCT	100%	78%	67%
PCA+DCT+DWT	100%	89%	78%
PCA+DCT+DWT+RF (proposed method)	100%	100%	96%

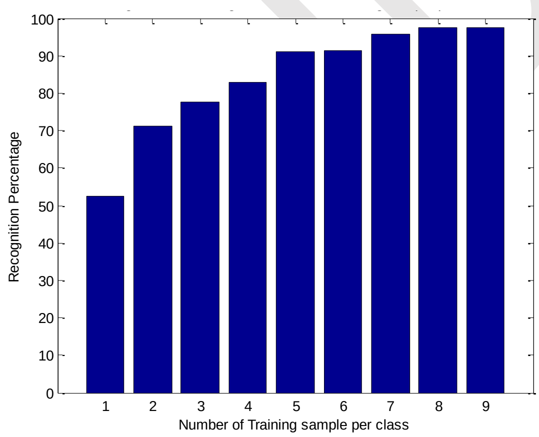

Figure 6: Graph between Recognition percentage and number of training samples per class

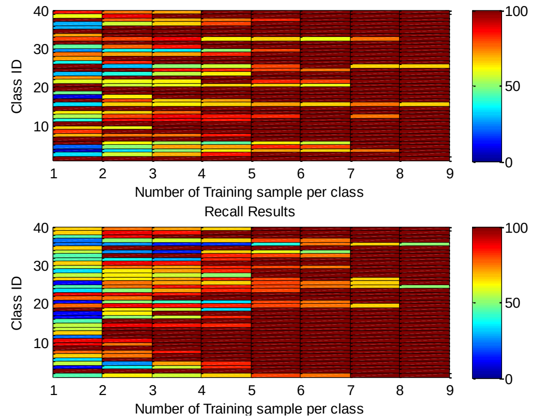

Figure 7: Precision result

VII. CONCLUSION

A number of different cases have been observed in this research work. The results shown here are obtained by using the ORL database having 400 images with each image size of 112×92. The number of features is taken constant throughout all the methods. There are 40 persons, 10 images per each person. A hybrid technique of feature extraction of face recognition using PCA+DCT+DWT for robust and reliable face recognition system. In comparison with the traditional use of PCA, the proposed method gives better recognition accuracy and discriminatory power; further, the proposed method reduces the computational load significantly when the image database is large.

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