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Identification of Critical Bands in DCT Domain Representation for Fingerprint Recognition

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***Abstract*—The low frequency sub bands of Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) are mostly used for recognition purposes. In this paper, we propose that frequency sub bands other than low frequency sub bands contain discriminative information and can be more helpful in recognition purposes. As a result, the hypothesis was checked on the fingerprint images as fingerprint images have finer and sharper details and higher frequency sub bands contain more information which should be more helpful in recognition than the low frequency sub bands. Our proposed method has accomplished promising performance. Medium and higher frequency sub bands outperform low frequency sub bands outperforms low frequency sub bands in terms of recognition rates.**

Keywords; fingerprint recognition, Frequency bands, discrete cosine transform, feature extraction.

I. Introduction

Fingerprint recognition systems have become very significant nowadays as they are being used in many applications such as electronic personal identification card, computer network logon and e-commerce. It is also being used by law enforcing people and pattern recognition researchers worldwide. Fingerprints have gained widespread importance due to their uniqueness, stability and inseparability from the host. Many algorithms for fingerprint recognition are present. The popular ones are based on the minutiae pattern of the fingerprint and are called minutiae-based approaches [1], [2]. These approaches use lots of preprocessing in order to reliably extract the minutia features [3]. The falsely extracted minutiae will degrade the performance gravely [4]. Another class for fingerprint matching which does not use the minutia features is called as image based method. In the image based approach, recognition is done by matching directly the fingerprint images [5] or by matching the features of the fingerprint image which can be extracted through certain filtering and transformation algorithms [6]. The image based approaches use little preprocessing as compared with the minutia based approaches but they have some limitations if the images are scaled or rotated with some angles. In this paper, we propose an image based fingerprint recognition system but the main goal is the identification of the most informative frequency bands which can be more helpful in fingerprint recognition.

Low frequencies from the DCT and DWT transform have been used in many pattern recognition applications. In [7] for text capture application; the DCT coefficient matrix is partitioned into three regions: low, medium and high frequencies. The medium frequency components outperformed the low frequency components in this text capture application. Dabbaghchian et al. [8] partitioned DCT coefficients in a similar manner for face recognition applications, and it was found that the most significant features for face recognition are present in medium frequency components. Chen et al. [9] proposed an illumination invariant face recognition system. As the low frequency components are more vulnerable to illumination variations, these were set to zero in the DCT transform matrix. Consequently it was found that medium and high frequency coefficients were more robust to illumination variations. Likewise in fingerprint images, the medium frequency components from the DWT decomposition have been used for recognition purposes [10]. This literature survey proves the use of medium and higher frequencies in other recognition applications. Fingerprint images have finer and sharper details and they contain edge information which means that the information is mostly placed in the medium and higher frequency sub bands. As a result, using medium and higher frequency sub bands should yield better recognition rate than the low frequency sub-bands.

II. Background

In this section we give an overview of DCT and how we have used it in our algorithm. Then a little discussion on the classifier i.e., LDA is carried out. The database used in this work is also introduced briefly in this section.

A. *Discrete Cosine Transform (DCT)*

The Discrete Cosine Transform (DCT) is one of the most popular tools used in image analysis research. DCT converts an image into its equivalent frequency coefficients. It is commonly used in image reconstruction, image compression and filtering applications. The number of frequency components generated in the DCT domain corresponds to the dimensionality of the input signal. For a two dimensional image signal of dimensionality MxN, the output of the DCT transform is a matrix of the same order MxN.

The two-dimensional DCT y [u, v] of a matrix x [m, n] of dimension MxN is given by:

$$r[u]r[v]\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}x[m,n]\cos[\pi(2m+1)u/2M]\cos[\pi(2n+1)v/2N]$$

The coefficients r[u] and r[v] are defined as:

$$r[u]=\left\{\sqrt{\frac{1}{M}}\right. \qquad \text{for } u=0$$

$$=\left\{\sqrt{\frac{2}{M}}\right. \qquad \text{for } u=1,2,...,M-1$$

$$r[v]=\left\{\sqrt{\frac{1}{N}}\right. \qquad \text{for } v=0$$

$$=\left\{\sqrt{\frac{2}{N}}\right. \qquad \text{for } v=1,2,...,N-1$$

The DCT distributes the frequency information in the image as shown in Figure 1.

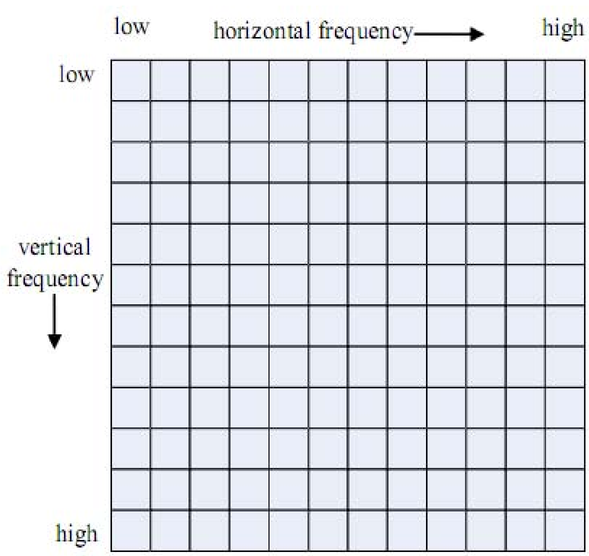

Fig.1. Frequency coefficients distribution by DCT

It places the low frequency coefficients in the upper left corner and the high frequency coefficients are placed in the bottom right of the transform matrix. The DCT transform of an image places the spatial frequency information in ascending order of frequency, as shown in Figure 2.

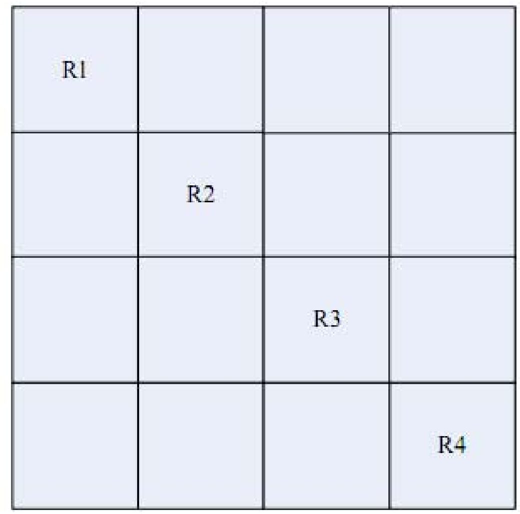

Fig.2. DCT based 4 frequency regions

The regions R1 to R4 above contain the horizontal and vertical components in order of increasing frequency. Further subdivision yields additional sub-bands as shown in Figure 3.

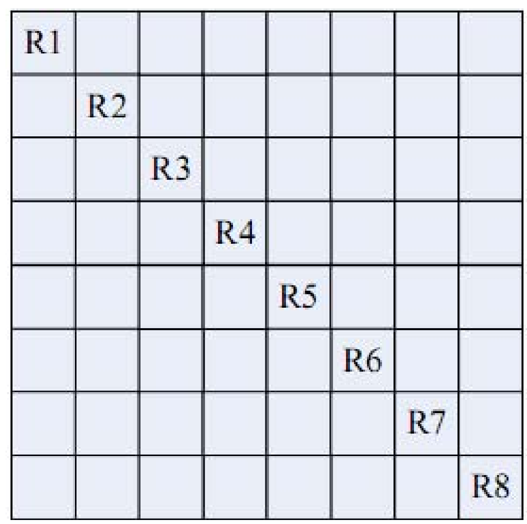

Fig.3. DCT based 8 frequency regions

B. *Linear Discriminant Analysis (LDA)*

LDA is a well known method in statistical pattern recognition literature. LDA transforms the data in such a manner so as to maximize the discrimination between members of different classes while minimizing the discrimination between members of the same class. A detailed survey on different types of dimensionality reduction techniques can be found in [12].

C. *Database*

To evaluate the algorithm, we used the subset B of database FVC 2000 [11] which consists of four collections.

Each subset is 10 fingers wide and 8 impressions per finger deep (80 fingerprints in all).

III. METHODOLOGY

For identification of critical bands in the fingerprint images, we have used a simple approach (see Figure 4).

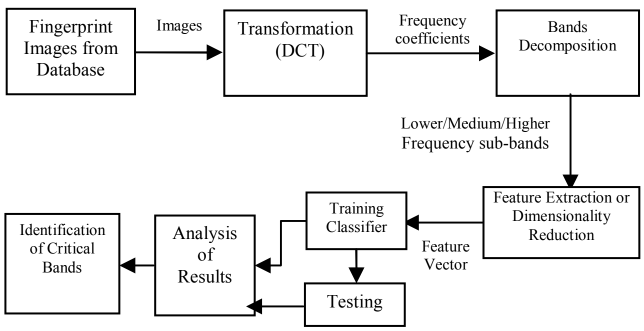

Fig.4. Schematic diagram of the approach

First, fingerprint images are taken from the database and some preprocessing like image enhancement, if needed, is done on the images. The next step transforms the image into frequency bands. In this step we applied discrete cosine transform (DCT) to transform the images into frequency components. The next step is the bands decomposition in which these frequency components are sub divided into lower, medium and higher frequency subbands. Once the frequency sub division is accomplished, in the next step, these frequency bands are given as input observations to the feature extraction part namely Linear Discriminant Analysis (LDA). The next step trained the system for which we used the dataset from [11]. Once the system is trained, the system is then extensively tested and evaluated. In the last step, the most informative frequency bands are identified.

IV. EXPERIMENTS & RESULTS

In this section, we evaluate our algorithm on the database taken from [11]. We have used both the four and eight frequency bands to test our assumption.

A. Experimentation Setup

To evaluate the performance, LDA was used as a classifier. In the database, each individual had 8 images per finger; hence we used 6 images of each individual as the training set, whereas the remaining 2 images from each individual were used for testing.

B. Experiments using four frequency bands

To evaluate the performance of our algorithm, first we used four frequency bands of the DCT transform space, as shown in Figure 3. As the images are of the size 300x300 each of these regions is of dimension 75x75. The comparison of the results of different bands (R1, R2, R3, and R4) can be seen in Figure 5. R1 (lower frequency) has outperformed in this case due to low level of sub division of the image, as each area is quite huge i.e., 75x75 pixels.

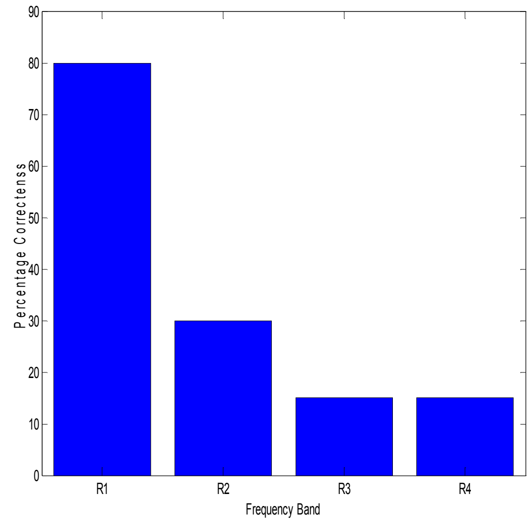

Fig.5. Recognition performance of DCT based 4 frequency regions

C. Experiments using eight frequency bands (DB1)

Now we check the performance using eight frequency bands on the database DB1. Each of these regions is of dimension 37x37. The comparison of the results of different bands (R1, R2, R3, and R4) can be seen in Figure 6. In this case, R2 (Medium Frequency) has performed better than any of the other regions. Due to higher level of subdivision each region is 37x37 pixels, which is relatively smaller than the previous case and the medium frequency subbands have shown better recognition rate.

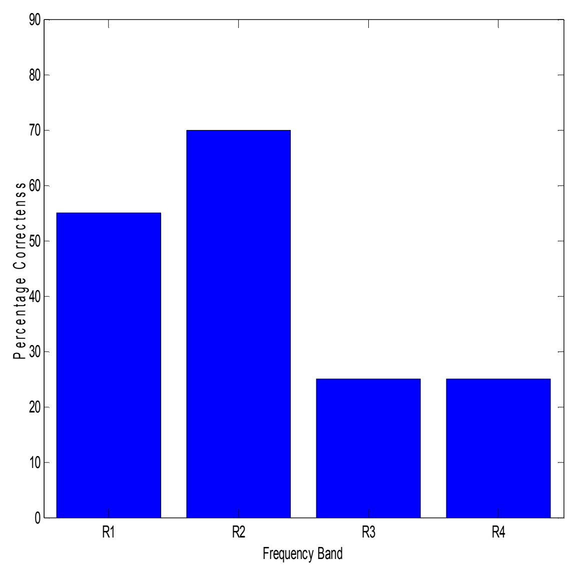

Fig.6. Recognition performance of DCT based 8 frequency regions (DB1)

D. *Experiments using eight frequency bands (DB2)*

To compare the two databases DB1 and DB2, we check the performance using eight frequency bands on the database DB2. The results are shown in Figure 7. Even using DB2, the medium frequency subbands have clearly surpassed the recognition rates of other frequency bands.

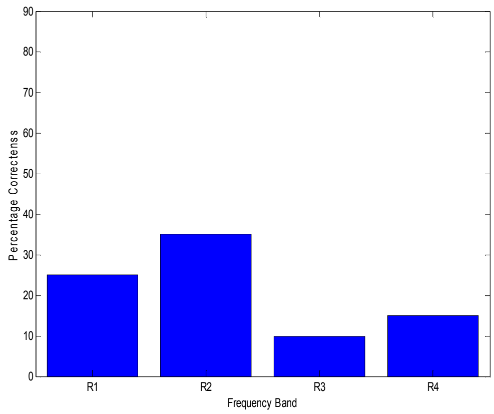

Fig.7. Recognition performance of DCT based 8 frequency regions (DB2)

E. *Experiments comparing Horizontal & Vertical Components*

To compare the horizontal and vertical components, now we check the performance using eight frequency bands on the database DB1. The result is shown in Figure 8. This result shows that horizontal frequency components contain more discriminative information than the vertical frequency components in fingerprint images.

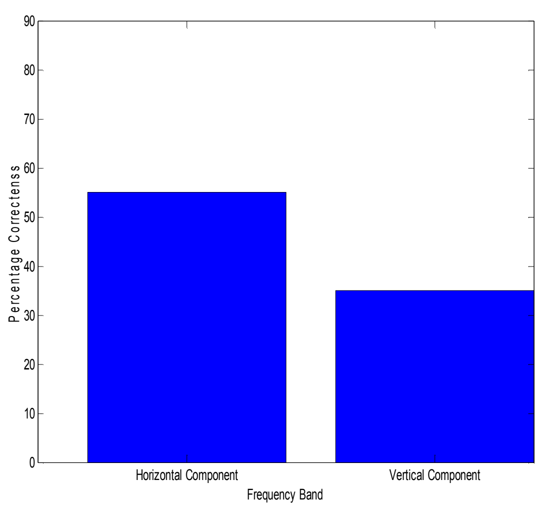

Fig.8. Comparison of Recognition performance of Horizontal & Vertical Components of DCT

As we can see from the above results that medium frequency subband has outperformed other bands in terms of recognition performance. This suggests that medium frequency sub bands have got discriminative information which can be useful in recognition procedures.

V. Conclusions

As fingerprint images have finer and sharper details, the middle frequency sub bands contains more information in these kinds of images, so mid frequency sub bands seem to be more helpful in recognition than the low frequency sub bands. In this paper, we propose that frequency sub bands other than low frequency sub bands also contain discriminative information and can be more helpful in recognition purposes. Moreover, as the lower frequency bands are more susceptible to intensity of background, the mid frequency bands are unaffected by the background variation.

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