Fingerprint Verification Based On Dual Transformation Technique

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Abstract

The Fingerprint is used to authenticate a person for multiple applications. In this paper, we propose Fingerprint Verification Based on Dual Transformation (FVDT). The Fingerprint image size of 300*480 is segmented into four cells of each size 150*240. The DCT is applied on each cell to convert from spatial domain to frequency domain. One level DWT is applied on DCT coefficients to derive four sub bands such as LL, LH, HL and HH. The directional information features and the centre area features on LL sub bands are computed. The final feature vector set is formed by concatenating directional information features and centre area features. The matching between database fingerprint and test fingerprint is based on ED, SVM and RF. It is observed that TSR and FRR values are improved in the case of proposed algorithm compared to the existing algorithm.

Keyword: ***Fingerprint, Directional Information Features, Centre Area Features, FRR, TSR.***

1. INTRODUCTION

The Biometrics is an automated method of recognizing a person and the term is derived from the greek word *bio* (life) and *metric* (measurement). The biometric parameters are broadly classified as Physiological characteristics of a person such as face, fingerprint, palmprint, Iris, DNA etc. and behavioral characteristics of human being like signature, voice, keystroke, gait etc. The biometric system is a pattern recognition model which acquires biometric data from an individual and processes the data to generate features, and then compared with the database template using matching algorithm. The biometric identification is more secure compared to the traditional methods such as PIN, smartcard for verifying a person. Some of the biometric applications are financial transaction, access to computer, access to confidential documents.

The fingerprint is widely used biometric compared to other biometric parameters, since it is unique part of the body of a person and it works even for non cooperative persons. The disadvantages are (i) User acceptance is not guaranteed due to temporary or permanent injury to fingerprint. (ii) Due to disortion on fingerprint or dirt the success rate of a person is reduced and (iii) Malicious fingerprint is produced with the help of special material to match with some person. The different techniques used to identify a person with fingerprint are (i) Minutiae based technique: Ridge ending and ridge bifurcation are minutiae of fingerprint and represented by location (x, y) and orientation Ɵ. The preprocessing on fingerprint is required to extract a true minutia which is time consuming, but accuracy rate of recognition is high. (ii) Image based technique : The fingerprint preprocessing is optimal and the spatial domain fingerprint image is processed to generate features using mean, standard deviation, variance, energy, gradient, directional features etc. (iii) Transformed domain technique – The fingerprint is converted into frequency domain using Fast Fourier Transform (FFT), Discrete Cosine Transform (DCT), Dual Tree Complex Wavelet Transform (DTCWT), Discrete Wavelet Transform (DWT), Principal Component Analysis, Singular Value Decomposition (SVD). The features are generated using transformed domain coefficients. (iv) Multiple Feature Fusion Technique – The feature are created using fusion of minutiae features, ridge features, image based features and transformed domain feature. (v) Multiple Classifier Technique – The test fingerprint features are compared with features in the database using multiple classifiers such as Euclidean Distance (ED), Hamming Distance (HD), Support Vector Machine (SVM), Neural Network (NN), and Random Forest (RF), etc.

Contribution: In this paper, the Fingerprint is segmented and DCT is applied on each segmented region. The DWT is applied on DCT coefficients to get low and high frequency components. The directional information features and centre area features are computed and concatenated to get final features. The ED, SVM and RF are used to verify test fingerprint with database fingerprint.

Organization: The paper is organized into the following sections. Section 2 is an overview of related work. The FDVT model is described in Section 3. Section 4 is the algorithm for FDVT system. Performance analysis of the system is presented in Section 5 and Conclusions are contained in Section 6.

2. RELATED WORK

Honglie Wei and Danni liu [1] have proposed a fingerprint matching technique based on three stages matching including local orientation, local minutiae structure

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and global structure matching. Mohammad Sadegh Helfroush and Mohsen Mohammadpour [2] have proposed image based Fingerprint Verification method. The verification is achieved with the fusion of spectral and directional features and does not need any reference point to be detected. The spectrum of the fingerprint is divided into sectors with equal number of pixels and for each sector the average and the standard deviation is calculated. The resulting feature vector is used to calculate the distance measure of two fingerprints. The similarity of the Block directional Field (BDF) of two fingerprints is assigned a value. Ujjal Kumar Bhowmik et al., [3] proposed the smallest minimum sum of closest Euclidean distance (SMSCED) corresponding to the rotation angle is extracted, to reduce the effect of non linear distortion for fingerprint verification. The overall minutiae patterns of the two fingerprints are compared by the SMSCED between two minutiae sets.

Vasileios K. Pothos et al., [4] proposed the generic transform domain image classification method. The fingerprint image is decomposed using Gabor filter and at every pixel the information is extracted in vectorial form. Only multivariable fingerprint spectral distribution is employed to reduce the redundancy. Multiscale vectorial representation allows the inclusion of higher order dependencies among image pixels that describe in a unique way for every fingerprint. Dale and Joshi [5] presented a fingerprint matching scheme based on transform feature. The scheme uses Discrete Cosine Transform (DCT), Fast Fourier transforms (FFT) and Discrete Wavelet Transform (DWT), to create feature vector. Fingerprint image of size 64*64 is cropped around a core point and transform is applied on cropped image. The transform coefficients are arranged in specified manner and are used to obtain feature vector in standard deviation. The final matching is based on the minimum Euclidian distance between two feature vectors. Avinash Pokriyal and Sushma Lahri [6] explained the relationship between the order of Pseudo Zernika moments (PZM) and accuracy rate. The order of PZM is high it carry more descriptive information and order of 40 to 45 of PZM s is good for extracting features from fingerprint image. It is used to de-noise and extract ridges.

Esla Timothy Anzac et al., [7] proposed authentication system that uses PRNs and fingerprints to generate revocable and privacy preserving templates. It uses pseudo random numbers and fingerprints to generate revocable and privacy preserving biometric templates.

3. MODEL

The definitions of performance parameters and the proposed FVDT model for fingerprint recognition based on Directional Information, Centre and Edge Features of DWT (FVDT) is discussed in detail.

3.1 Definitions

3.1.1 False Rejection Rate (FRR):

It is the measure of the biometric security system that incorrectly reject an access attempt by an authorized user. A FRR is the ratio of the number of false rejections to the total number of identification attempts is given in the Equation 1.

$$\text{FRR} = \frac{\text{Number of rejected persons}}{\text{Total number of persons}} \qquad \text{------(1)}$$

3.1.2 Total Success Rate (TSR):

It is the rate at which match occurs successfully.

$$\text{TSR} = \frac{\text{Number of matched persons}}{\text{Total number of persons}} \qquad \text{----------(2)}$$

3.1.3 Gradient:

Gradient is a directional change in the intensity or colour in an fingerprint image. It can also be used to extract directional information from fingerprint images

3.1.4 Variance:

The variance for a block indicates how much each individual element in the block deviates from the sample mean. It gives better result as compared to standard deviation.

3.2 Proposed FVDT model

Fingerprint recognition system based on directional Information, Centre Area Features, DCT and DWT is as shown in the Figure 3.

3.2.1 Fingerprint Database

Fingerprint images are considered from the data base of FVC 2004 [8]. The fair and distinct fingerprint image databases DB1, DB2, DB3 and DB4 are created with different scanners and time as shown in the Figure 1. Each data base has 110 fingers with 8 samples per finger leading to 880 fingerprint images. DB3 data base is considered to test our algorithm and it is decomposed into two parts viz., DB3_A and DB3_B having first 100 fingers and last 10 fingers respectively. The source data base consists of DB3_A with first seven samples of every fingerprint constituting 700 samples. The test fingerprint data base consists of DB3_A with the last eighth sample of each fingerprint leads to 100 fingerprint samples. An eight fingerprint samples of a Person in DB3_A database is

Figure 1. Fingerprint image samples

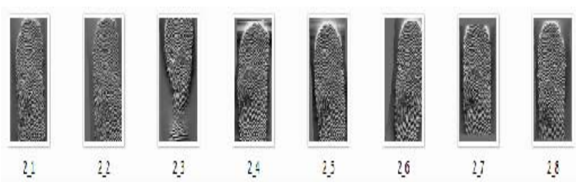

Figure 2. A sample of finger print of DB3_A

shown in the Figure 2. Using the source data base and test data base, FRR can be calculated. The DB3_B data base is considered for second test data base having 80 samples which are used to compute FAR.

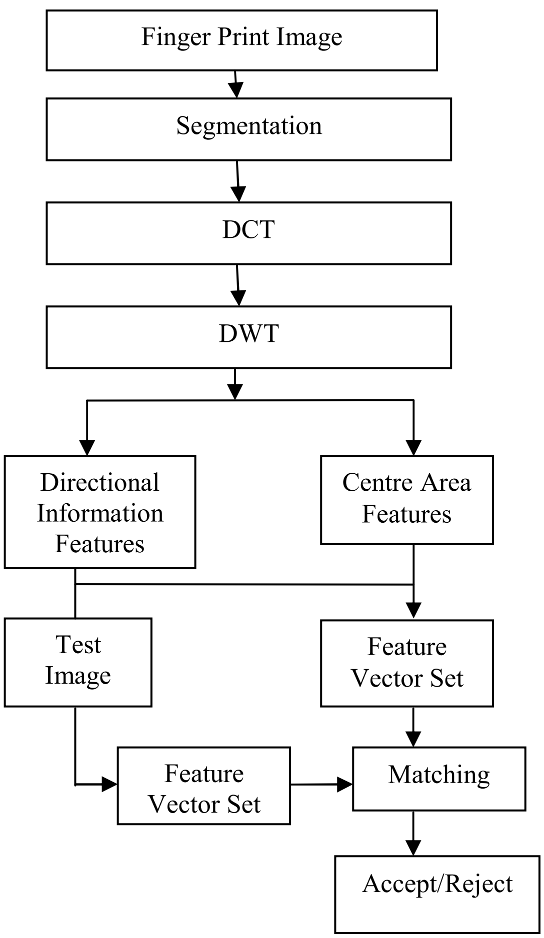

Figure 3: Block Diagram FVDT

3.2.2 Segmentation

This function divides the two-dimensional matrix into adjacent sub matrices. The original fingerprint size of 300×480 is converted into four sub cells of each size 150×240 is shown in the Figure 4. The final features of each cell are compared between Test-image and database image to get better performance results.

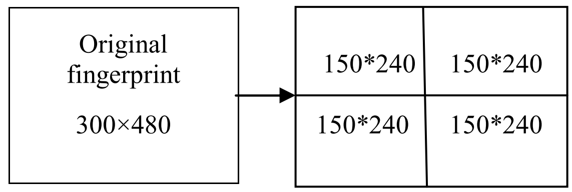

Figure 4. Segmentation

3.2.3 Discrete Cosine Transform (DCT)

Fingerprint representation in DCT is a sum of sinusoids of varying magnitudes and frequencies. Each cell is converted into DCT co-efficient and few DCT co-efficients has significant information of an image. DCT is used to convert spatial domain image into frequency domain image which differentiate whole image into high and low frequency components. The DCT is used in data compression as reconstruction of original image from frequency domain is possible with few DCT coefficients.

3.2.4 Discrete Wavelet Transform (DWT)

The one level Daubechies wavelet is applied for DCT of segmented portion of Fingerprint and features are extracted from LL, LH, HL and HH sub bands for the verification of fingerprint. LL sub band gives significant information, LH sub band represents vertical information, HL gives horizontal details and HH gives diagonal details of DCT coefficients in the fingerprint image. L = Low and H = High

3.2.5 Directional Information Features

The LL sub band of the DWT is considered for directional information features. The gradient of LL is computed using LH and HL sub bands ie., the gradient G_{mn} and corresponding angle θ_{mn} at the position (m,n) is computed using Equations 3 and 4 respectively.

$$G_{mn} = \left(|G_{mn}^{x}| + |G_{mn}^{y}|\right) \qquad \text{------(3)}$$

$$\theta_{mn} = \tan^{-1}\left(G_{mn}^{x} / G_{mn}^{y} \right) \qquad \text{------(4)}$$

The quantities G_{mn}^{x} and G_{mn}^{y} represent the components of G_{mn} in horizontal and vertical directions, respectively. The coherence is determined using gradient and angle as given in the Equation. 5 using the window size of (5 **x** 5).

$$\delta_{mn} = \frac{\sum G_{ij} \cos(\theta_{mn} - \theta_{ij})}{\sum G_{ij}} \quad \text{--------(5)}$$

Where i = 1 to 5

and j = 1 to 5

The dominant local orientation is calculated from the gradient and coherence. The dominant local orientation θ is defined in Equation 6.

$$\theta = \frac{1}{2}\tan^{-1}\frac{\sum_{m=1}^{N}\sum_{n=1}^{N}\delta_{mn}{}^{2}\sin 2\theta_{mn}}{\sum_{m=1}^{N}\sum_{n=1}^{N}\delta_{mn}{}^{2}\cos 2\theta_{mn}} + \frac{\pi}{2} \quad \text{------- (6)}$$

Where N = 8.

Thus, each 8x8 size window represents one directional information.

3.2.6 Center Area Features

The LL subband of wavelet of size 75*120 is considered for centre area features. The centre point for LL, sub band is fixed by considering the pixel with maximum variance among rows and columns.

The 16 X 16 window is considered around the centre point. The Correlation, Contrast, Homogeneity and Energy are determined for 16 X 16 windows around the centre point for LL sub band to derive the second set of fingerprint features.

Correlation: It is a measure of how correlated a pixel is to its neighbor over the whole image. The range for Gray-Level Co-occurrence Matrix (GLCM) is given by [-1 1]. Correlation is 1 or -1 for a perfectly positively or negatively correlated image. Correlation is NaN (Not-a-Number) for a constant image. It is given by the Equation 7.

$$\text{Correlation} = \sum_{i=1}^{N}\sum_{j-1}^{M}\frac{(i-\mu_i)(j-\mu_j)\,P(i,j)}{\sigma_j} \quad \text{-----(7)}$$

Where μ = mean,

σ_j= standard deviation.

Contrast: It is a measure of the intensity contrasts between a pixel and its neighbor the whole fingerprint image; it is given by Equation 8. The range for Gray-Level Co-occurrence Matrix is given by [0, (size (GLCM,1)-1)^2], Contrast is zero for a constant image.

$$\text{Contrast} = \sum_{i=1}^{N}\sum_{j=1}^{N}(|i-j|)^2 P(i,j) \quad \text{------(8)}$$

Energy: It is the sum of squared elements in the GLCM. The range for GLCM is given by [0 1] , Energy is 1 for a constant image. By using Equation 9 Energy of center area in fingerprint image is given by equation 9

$$\text{Energy} = \sum_{i=1}^{N}\sum_{j=1}^{N} P(i,j)^2 \quad \text{---(9)}$$

Homogeneity: It is a value that measures the closeness of the distribution of elements in the GLCM to the diagonal. The range for gray-level co-occurrence matrix is [0 1] , homogeneity is 1 for a diagonal GLCM. By using Equation 10 Homogeneity of center area in fingerprint image is given by Equation 10

$$\text{Homogeneity} = \sum_{i=1}^{N}\sum_{j=1}^{N} p(i,j)/(1+(i-j)) \quad \text{--------(10)}$$

3.2.7 Feature Vectors

Directional Information features and Centre Area Features are concatenated to constitute Feature Vector set to increase correct recognition rate and decrease FRR.

3.2.8 Matching

The final features of test fingerprints are compared with the final features of database fingerprints to verify a person using matching techniques such as (i) Euclidean Distance, (ii) Random Forests and (iii) Support Vector Machines.

(i) Euclidean Distance

It includes three consecutive stages viz., Euclidean Distance determination of feature vectors, the second is sum of matched dominant features and the third is match stage.

Euclidean Distance determination: The two fingers features are converted to single matrix, and a feature point of first row matched with associated feature point of second row using standard Euclidian function.

Sum of matched dominant features: Dominant features are extracted features, obtained by concatenation of correlation, energy, homogeneity and contrast of one level DWT features. Given two fingers dominant features are to be matched, choose any one feature from each finger dominant features, and calculate the similarity of the two features associated with the two referenced feature points. If the similarity is larger than a threshold, assign value one to that feature and finally get the sum of that features as value one.

Match stage: It uses the elastic match algorithm to decide whether the two fingers are matched which is based on Euclidean distance and Sum of matched dominant features.

(ii) Support Vector Machines (SVMs)

It takes a set of input data and predicts which of the possible classes the input belongs to. The input data is treated as an x-dimensional vector. It builds a model by constructing a set of hyper planes in a high dimensional space. For an x-dimensional vector, (x-1) hyper planes are created. A good separation is achieved by the hyper plane that has the largest distance to the nearest training data points of any class and is the functional margin. The larger the margin, the better is the classification

(iii) Random Forests (RF)

The training set consisting of *N* cases is sampled at random to form a new training set, which is used for growing the decision trees. If there are *M* variables, then $m<<M$ variables are selected which are used to split the node. The tree is grown without pruning. For a given input vector each tree gives its classification, this is called as voting. The forest chooses the class which has maximum number of votes. The error is calculated during the training. The feature vectors are sampled and a few vectors are left out and are called OOB (out-of-bag) data. The size of OOB data is about *N/3.* The classification error is estimated by using this OOB data. The classification error is calculated as follows:

- A prediction is obtained for each vector which is OOB relative to the i^{th} tree.
- The class winner (one with majority votes) is found from the vectors which are OOB and compared to ground-truth response.
- The ratio of misclassified OOB vectors to all vectors in the original data is equal to the classification error.

The forest error depends on two things such as: (i) The correlation between any two trees in the forest. Increasing the correlation increases the error. (ii) The strength of each individual tree in the forest. Increasing the strength decreases the error.

.4. ALGORITHMS

PROBLEM DEFINITION: The Fingerprint is verified using FVDT algorithm. The objectives are

1. To increase Total Success Rate of verification
2. To reduce False Rejection Ratio
3. Decrease number of features to reduce execution time

The dual transform i.e., DCT and DWT are applied on fingerprint to derive transform domain coefficients. The directional features and centre area features are computed on transform domain coefficients to derive features. The final feature vector is formed by concatenating two features resulting in unique features is given in the Table 1

Assumptions: The finger print database DB3_A of FVC 2004 having size of 300x480 with 512 dpi is considered for performance analysis.

Table 1: FVDT Algorithm

- Input: Finger print Database, Test Fingerprint.
- Output: Verified Finger print image

1) The database is created for 100 persons with 7 images per persons. i.e. Total number of images 100*7=700
2) The fingerprint image is segmented into Four cells of size 150×240 each
3) DCT is applied on each cell
4) DWT is applied on cell of DCT coefficient
5) Directional Information Features and Centre Area Features are derived from LL band
6) The final feature vector set obtained by concatenating of Directional Information Features and Centre Area Features
7) The final Feature Vector set for test fingerprint image is created using step2 to step6.
8) The given test image is compare with database using Euclidean Distance, Random Forest and Support Vector Machine

5. PERFORMANCE ANALYSIS

The database FVC 2004 is considered to verify the performance analysis. The database is created using different sensors and timing which leads to four types of fingerprint images DB1, DB2, DB3 and DB4. To test the proposed algorithm, DB3 set consisting of 100 person's database with 8 fingerprint samples per person results in 800 fingerprint images are considered.

Table 2: The values of TSR and FRR for different classifiers.

Methods	ED	RF	SVM
TSR	100	99	99
FRR	0	1	1

The values of TSR and FRR for different matching methods ED, RF and SVM is given in the Table 2. It is noticed that the performance is better in the case of ED matching compared to RF and SVM classifiers.

Table 3: Performance comparison between existing FRDCE and proposed FVDT method.

	Existing FRDCE [9]	**Proposed FVDT**
Number of Features	5846	556
FRR	3	0
TSR	97	100

The comparison of performance parameters such as number of features, FRR, TSR and Elapsed time for existing technique. Fingerprint recognition based on Directional, Centre and Edge features of DWT (FRDCE) [9] and the proposed technique FVDT is given in the Table 3. It is observed that the number of features in the case of proposed algorithm reduces compared to existing technique since dual transformation and no edge features are used which results in less elapsed time. The values of FRR and TSR are improved in the case of proposed technique since directional features and centre area features are computed on dual transform coefficients to obtain unique features.

6. CONCLUSION

The Fingerprint is used in almost all areas of applications. In this paper FVDT algorithm is proposed in which DCT is applied on segmented portion of fingerprint. The DWT is applied on DCT to generate four sub bands. The features such as directional information features and centre area features are computed and concatenated for verification using ED, SVM and RF. The success rate of recognition and FRR values are better in the case of proposed algorithm compared to existing algorithm.

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