Performance Evaluation of Fingerprint Identification Based on DCT and DWT using Multiple Matching Techniques.

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Abstract

The fingerprint is a physiological trait used to identify a person. In this paper, Performance Evaluation of Fingerprint Identification based on DCT and DWT using Multiple Matching Techniques (FDDMM) is proposed. The fingerprint is segmented into four cells of each size 150*240. The DCT is applied on each cell. The Harr Wavelet is applied on DCT coefficient of each cell. The directional information features and centre area features are computed on LL sub band. The final Feature Vector is obtained by concatenating Directional Information and Centre Area Features. The matching techniques viz., ED, SVM, and RF are used to compare test image feature with database image features. It is observed that the values of TSR and FRR are better in the case of proposed algorithm compared to existing algorithm.

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

1. Introduction

The Biometrics is used to 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. Biometric system operates as verification mode or identification mode depending on the requirement. The verification mode validates a person with readymade template. The identification mode recognizes a person's identity by performing matching against multiple biometric templates. The biometrics 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.

Fingerprints have been used as most popular biometric authentication and verification measure because of high acceptability, immutability and uniqueness. Immutability refers to the persistence of the fingerprints over time whereas uniqueness is related to the individuality of ridge details across the whole fingerprint image. Fingerprint classification is an important step in any fingerprint identification system because it reduces the time taken in identification of fingerprints. Classification allows test fingerprint to be matched against a database. The disadvantages of fingerprint are (i) User acceptance is not guaranteed due to temporary or permanent injury to fingerprint. (ii) Due to distortion 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 Θ. 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 ED, SVM, 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 FDDMM model is described in Section 3. Section 4 is the algorithm for FDDMM system. Performance analysis of the system is presented in Section 5 and Conclusions are contained in Section 6.

2. Related Work

Deepak Kumar Karna et al., [1] has proposed a fingerprint recognition method based on normalized cross correlation. The method correlates the common region of two fingerprint images by the image rotation and scaling. Honglie Wei et al., [2] has proposed quadrangle based matching algorithm. The quadrangle is composed of two ridge lines that connect two minutiae points with the associated two ridge points. The line matching has been emphasized. The local quadrangle set is formed using the type, the length of the basic ridge lines and angle between the basic edge and the ridge. The fake pairs are removed by considering correlation among pairs. The fingerprint matching is done using the shrunken set. Xiao long Zheng et al., [3] has presented a minutiae scoring method which considered various aspects influencing the quality of minutiae. The image quality is described from three aspects viz., the global factor, the block image quality factor and the neighborhood detailed structure. These three factors are investigated and combined by the product rule and linear weight. The minutiae score is incorporated into fingerprint matching by checking the scores of corresponding minutiae pairs.

Chengming Wen and Tiande Guo [4] presented fingerprint matching algorithm based on convex hull matching principles. The query fingerprint is matched with the template fingerprint using local features. Using global features the matching minutiae pairs are achieved with the help of maximum weight bipartite matching model. Spurious matching is eliminated using the convex hull similarity checking process. Chengming wen et al., [5] has proposed an algorithm for one-to-one matching of minutiae points using motion coherence methods. They have used the K-plet to describe local structure. Chongwen wang and Gangyi Ding [6] has presented a fingerprint representation method, which combines adjacent features of minutiae with curvature of ridges. These features are used to identify corresponding minutiae between two fingerprint impressions by computing the Euclidean distance between vectors. Only the position and direction are used to define minutiae. The algorithm uses the curvature of ridges to alignment and delivers a matching score that expresses the degree of similarity between the two fingerprints.

Zhong Wei-bo et al., [7] used the relative topological relationship among the minutiae for the fingerprint matching. The minutiae type and the topological relationship among the minutiae and its neighbor with the absolute coordinate information gives the changeless characteristics in the fingerprint distortions. Jiong Zang et al., [8] proposed an algorithm which extracts a fingerprint reference point and reference direction based on the orientation field of the image is proposed. Then they take the reference point as the origin and the reference direction as the polar axis to establish a polar coordinate system. The fingerprint minutiae information which is constituted by minutiae point is independent of the shift and rotation of the fingerprint. Overall matching is employed here to match two fingerprint images with shift and rotation. Khuram Yasin Qureshi and Shoab A. Khan [9] proposed fingerprint matching using five neighbor of one single minutiae i.e., center minutiae. The authentication of a minutia is assured by the characteristics of its five neighbors. The characteristics are minutiae type, distance to the central minutiae, relative angle calculated by the coordinates of central point, coordinates of neighbor, direction of central point and ridge count. The special matching criteria incorporate fuzzy logic to select final minutiae for matching score calculation.

JuCheng Yang et al., [10] proposed fingerprint matching using invariant moments which are preprocessed for minutiae and the reference point determination. The reference point is then aligned. These features are invariant to translations and rotation. Anil K. Jain et al., [11] proposed algorithm to compare the latent fingerprint image with that of the stored in the template. From the latent fingerprint minutiae orientation field and quality map are extracted. Both level 1 and 2 features are employed in computing matching scores and at each feature level both quantitative and qualitative scores are computed. Xuzhou Li and Fei Yu [12] proposed fingerprint matching algorithm that uses minutiae centered circular regions. The circular regions constructed around minutiae are regarded as a secondary feature. This feature is tolerant to the linear distortion. Other features like ridge count, distance, relative angle and the minutiae type are also considered to construct the local features. The degree of similarity is obtained based on the local features matching. The minutiae pair that has the higher degree of similarity than the threshold is selected as reference pair minutiae.

Danese et. al., [13] proposed fingerprint matching in the field of embedded systems for real-time authentication. FPGA based architecture is used that employs the phase only correlation algorithm. Sevng –Hoon Chae et al., [14] used the technique of obtaining the distance between the two ridges to compare the two ridges. Initially the compare points are selected on the neighboring ridges, then the distance between the pairs of comparison points are calculated. The mean distance and the standard deviation are also determined. Jian-De Zheng et al., [15] introduced fingerprint matching based on minutiae. The algorithm uses a method of similar vector triangle. The ridge end points are considered as the reference points and the vector triangles are constructed. The fingerprint matching is performed by comparing the vector triangles.

Minakshi Gogoi and Bhattacharya [16] proposed an effective method of minutiae clustering for fingerprint verification and graph theoretic approach for fingerprint comparison. Hausdorff distance is the invariance measure of each fingerprint. Zhi Hao Lo [17] proposed an enhanced minutiae based fingerprint feature extraction approach for use in fingerprint identification system. Ramaswamy et al., [18] discussed two types of system, they are Automatic Fingerprint Authentication System (AFAS) and Automatic Fingerprint Identification System (AFIS) which are used for manual matching and classification of fingerprints

M. Rajinikannan et al., [19] described three models of minutiae detection system which differently enhances the input image for minutiae detection. FFT and Gabor filter based on frequency and orientation image enhancement technique are used. Conti et al., [20] proposed a fingerprint recognition approach which is based on core and delta points. A Pseudo singularity point is extracted . In automatic fingerprint recognition fingerprint classification and matching are the two key issues. Pseudo singularity points were detected and extracted for fingerprint recognition. Neil Yager and Ted Dunstone [21] discussed the existence of goats, lambs, wolves for biometric applications and presented methods for dealing with their existence. A differing degree of accuracy is seen within the biometric system. Goats, wolves and lambs are labels commonly applied to problem users. Mohammed S Khalil et al., [22] proposed fingerprint verification based on statistical analysis. This method incorporates two techniques detecting the reference point and analyzing the fingerprint image. A biometric fingerprint images are statistically analyzed for personal identification. A sub image of 129 * 129 was extracted from original image and transformed into co-occurrence matrix. The results have been analyzed by program for rate estimation and statistical summaries.

3. Model

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

3.1 Definitions

3.1.1 False Rejection Rate

It is the measure of the biometric security system that incorrectly rejects 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.

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

3.1.2 Total Success Rate (TSR)

It is the rate at which match occurs successfully.

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

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 FDDMM model

Fingerprint recognition system based on directional Information, Centre Area Features, DCT and DWT is as shown in the Figure 1.

3.2.1 Fingerprint Database

Fingerprint images are considered from the data base of FVC 2004[23]. The fair and distinct fingerprint image databases DB1, DB2, DB3 and DB4 are created with different scanners and time as shown in the Figure 2. 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

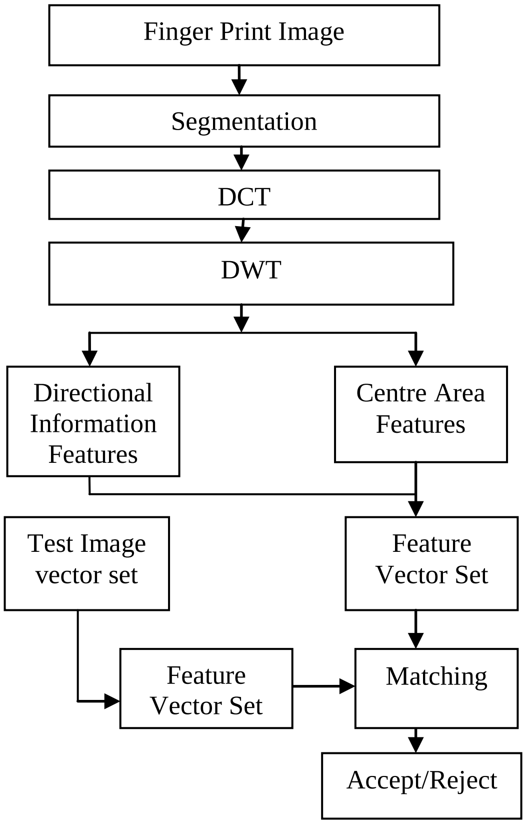

Fig 1: Block Diagram FDDMM

Fig 2. Fingerprint image samples

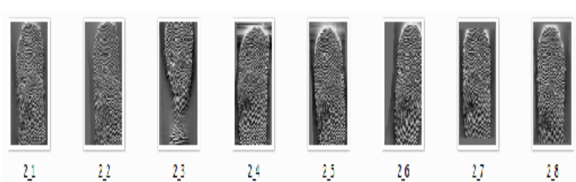

Fig 3. A sample of finger print of DB3_A

shown in the Fig 3. 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.

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.

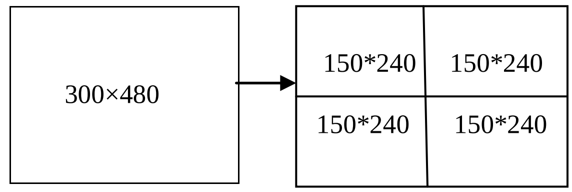

Fig 4. Segmentation

3.2.3 Discrete Cosine Transform (DCT)

Fingerprint representation in DCT [24] is a sum of sinusoids of varying magnitudes and frequencies. Each cell is converted into DCT co-efficient and few DCT co-efficient 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.

The DCT Equation is given in an Equation 3

$$Y(k) = w(k)\sum_{n=1}^{N} x(n) cos\frac{\pi(2n-1)(k-1)}{2N}$$

Where

K=1, 2, 3.....N

$$W(k) = \begin{cases} \frac{1}{\sqrt{N}} & k=1 \\ \sqrt{\frac{2}{N}} & 2 \leq k \leq N \end{cases} \quad (3)$$

The DCT has better energy compaction properties with just a few of the transform coefficients representing the majority of the energy in the sequence. The properties of the DCT make it useful in applications such as data communications, signal coding, etc.

3.2.4 Discrete Wavelet Transform (DWT)

The one level Daubechies wavelet [25] is applied on 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.

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 4 and 5 respectively.

$$G_{mn} = \left(|G_{mn}^{x}| + |G_{mn}^{y}|\right) \quad (4)$$
$$\theta_{mn} = \tan^{-1}\left(G_{mn}^{x} / G_{mn}^{y} \right) \quad (5)$$

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. 6 using the window size of (5 **x** 5).

$$\delta_{mn} = \frac{\sum G_{ij} \cos(\theta_{mn} - \theta_{ij})}{\sum G_{ij}} \quad (6)$$

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 7.

$$\theta = \frac{1}{2}\tan^{-1}\frac{\sum_{m=1}^{N}\sum_{n=1}^{N}{\delta_{mn}}^{2}\sin 2\theta_{mn}}{\sum_{m=1}^{N}\sum_{n=1}^{N}{\delta_{mn}}^{2}\cos 2\theta_{mn}} + \frac{\pi}{2} \quad (7)$$

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

3.2.6 Center Area Features

The LL sub band 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 8.

$$\text{Correlation} = \sum_{i=1}^{N}\sum_{j-1}^{M}\frac{(i-\mu_i)(j-\mu_j)\,P(i,j)}{\sigma_j} \quad (8)$$

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 9. The range for Gray-Level Co-occurrence Matrix is given by [0, (size (GLCM,1)-1)^2], Contrast is zero for a constant image.

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

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 10 Energy of center area in fingerprint image is given by equation 10

$$\text{Energy} = \sum_{i=1}^{N}\sum_{j=1}^{N} P(i,j)^2 \quad (10)$$

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 11 Homogeneity of center area in fingerprint image is given by Equation 11

$$\text{Homogeneity} = \sum_{i=1}^{N}\sum_{j=1}^{N} p(i,j)/(1+(i-j)) \quad (11)$$

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) Support Vector Machines and (iii) Random Forests.

(i) Euclidean Distance [26]

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) [27]

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) [28]

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. Algorithm

PROBLEM DEFINITION: The Fingerprint is verified using FDDMM 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. FDDMM 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 in800 fingerprint images are considered.

The values of TSR and FRR with number of features and threshold is given in the Table 2. It is seen that the values of TSR and FRR increases and decreases respectively as threshold increases. The value of threshold increases with the number of features

The values of TSR and FRR for different matching methods ED, RF and SVM is given in the Table 3. It is noticed that the performance is better in the case of ED matching compared to RF and SVM classifiers

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) [29] and the proposed technique FDDMM is given in the Table 4. 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.

Table 2: The values of TSR and FRR for different threshold values

No. of features	Threshold	TSR	FRR
200	4-5.5	0	100
	5.75	1	99
	7.75	71	29
	9	94	6
	9.25	97	3
	9.5	98	2
	9.75	99	1
	10	100	0
300	5-6.5	0	100
	6.75	1	99
	9	77	23
	10.5	98	2
	13	100	0
400	7-8	0	100
	8.5	3	97
	10.5	79	21
	12	99	1
	13	100	0
572	10-15	0	100
	16	3	97
	24	54	46
	48	98	2
	54	100	0

Table 3: The values of TSR and FRR for different classifiers.

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

Table 4: Performance comparison between existing FRDCE and proposed FDDMM method.

	Existing FRDCE [29]	Proposed FDDMM
Number of features	5846	556
FRR	3	0
TSR	97	100
Elapsed time	20 min	2 min 35 sec

6. Conclusions

The Biometrics is used in almost all areas of applications. In this paper FDDMM 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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