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FAST PALMPRINT AUTHENTICATION BY SOBEL CODE METHOD

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Abstract
The ideal real time personal authentication system should be fast and accurate to automatically identify a person's identity. In this paper, we have proposed a palmprint based biometric authentication method with improvement in time and accuracy, so as to make it a real time palmprint authentication system. Several edge detection methods, wavelet transform, phase congruency etc. are available to extract line feature from the palmprint. In this paper, Multi-scale Sobel Code operators of different orientations (0°, 45°, 90°, and 135°) are applied to the palmprint to extract Sobel-Palmprint features in different directions. The Sobel-Palmprint features extracted are stored in Sobel-Palmprint feature vector and matched using sliding window with Hamming Distance similarity measurement method. The sliding window method is accurate but time taking process. In this paper, we have improved the sliding window method so that the matching time reduces. It is observed that there is 39.36% improvement in matching time. In addition, a Min Max Threshold Range (MMTR) method is proposed that helps in increasing overall system accuracy by reducing the False Acceptance Rate (FAR). Experimental results indicate that the MMTR method improves the False Acceptance Rate drastically and improvement in sliding window method reduces the comparison time. The accuracy improvement and matching time improvement leads to proposed real time authentication system.

Keywords:
Hamming Distance, Palmprint Identification, Sobel Code

1. INTRODUCTION

Nowadays personal authentication is done by token based and knowledge based approaches [1, 2]. Authentication based on a token and password etc. can be stolen or forgotten. Person's friends or relatives can easily access token and can guess the password. It is necessary to add some features that can almost eliminate the limitation of token-based and knowledge based methods. Biometric identification of a person by his/her physiological or behavioral characteristics, like face, finger, palmprint, gait, signature, voice etc. has become increasingly popular in modern personal identification and verification systems [3][4]. Here, palmprint biometric is one of the most desirable biometric that can independently authenticate a person by palmprint features. Palmprint is unique among people and relatively low resolution images (less than 100 dpi) are sufficient to extract its unique features [5-11].

Palmprint features include geometry features, line features, minutiae points, delta point features. Several methods are available in the literature to extract palmprint features. The extraction of palm lines using stack filter [12], derivative of Gaussian [13], Fourier transform [14], wavelet transform [15], phase congruency [16] have been used earlier. In this paper, the palmprint line feature that includes principal lines, wrinkles and ridges is extracted using Sobel Code operators [17-19]. Sobel Code operators in four respective directions are applied on palmprint lines and Sobel-Palmprint features are extracted. Features are stored in Sobel-Palmprint feature vector that are matched by Hamming Distance similarity measurement.

The rest of the paper is organized as follows: Section 2 defines the palmprint authentication system. Section 3 explains about feature extraction by Sobel Code operators. Section 4 discusses the feature matching by hamming distance and sliding window method. Section 5 explains Comparison time improvement using Sliding window method 1 (SWM1) and Sliding window method 2 (SWM2). Section 6 discusses about the Min Max Threshold Range (MMTR) method. Section 7 explains the experimental results. Section 8 includes the conclusion.

2. PALMPRINT AUTHENTICATION SYSTEM

In this paper, the palmprint authentication system is divided in following two subsystems:

(a) Pre- Authentication System

(b) Authentication System

In Pre-authentication system, we train the system for authentication by identifying Sobel-Palmprint features, Reference threshold and Min Max threshold values. These values are stored in database. These values will be required in Authentication system.

In Authentication system or testing stage the authenticity of a person is identified with the help of Reference threshold and Min Max threshold values stored in Pre-authentication system database.

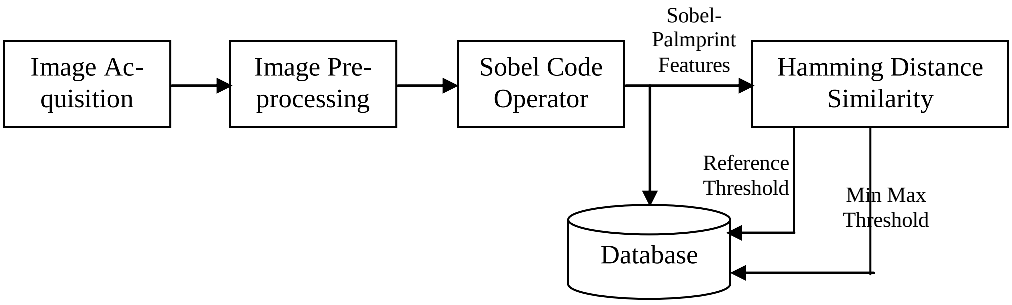


Fig.1. Palmprint Pre-Authentication system

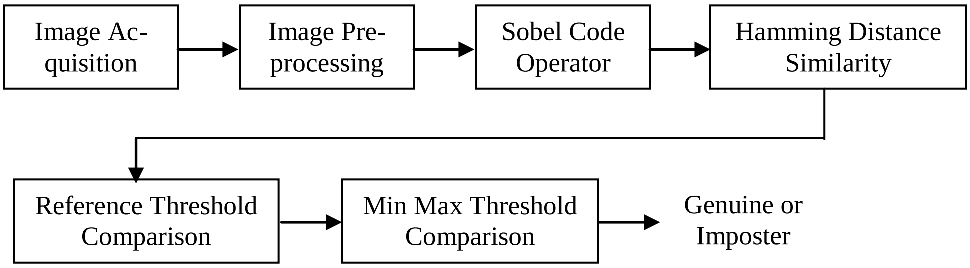


Fig.2. Palmprint Authentication System

3. FEATURE EXTRACTION BY SOBEL CODE OPERATORS

Sobel Code operators are used to detect edges in specific direction. It can operate in four different directions 0°, 45°, 90°, 135° and when convolved with the palmprint image gives Sobel-Palmprint features. The sample of 3×3 Sobel Code Operator convolution with the palmprint image is shown in Fig.3.

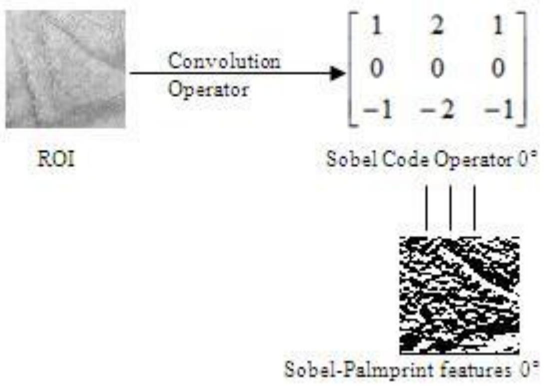


Fig.3. Feature extraction by Sobel Code operators

The Sobel Code Operator matrices and Sobel-Palmprint features for 3×3, 5×5 and 7×7 are mentioned in the Fig.4, Fig.5 and Fig.6.

3.1 3×3 SOBEL CODE OPERATOR

$$\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \qquad \begin{bmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{bmatrix}$$

Sobel 0° Sobel 45°

$$\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \qquad \begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{bmatrix}$$

Sobel 90° Sobel 135°

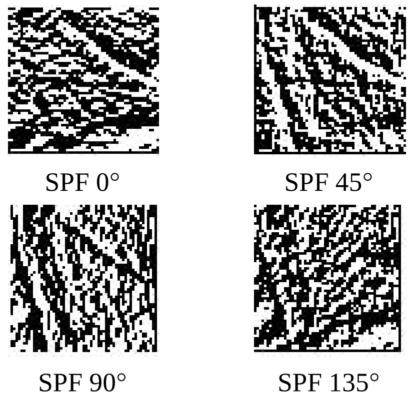


Fig.4. 3×3 Sobel Code Operator and Sobel-Palmprint features

3.2 5×5 SOBEL CODE OPERATOR

$$\begin{bmatrix} 1 & 2 & 3 & 2 & 1 \\ 1 & 2 & 4 & 3 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ -1 & -3 & -4 & -3 & -1 \\ -1 & -2 & -3 & -2 & -1 \end{bmatrix}$$

Sobel 0°

$$\begin{bmatrix} 3 & 2 & 2 & 1 & 0 \\ 2 & 4 & 3 & 0 & -1 \\ 2 & 3 & 0 & -3 & -2 \\ 1 & 0 & -3 & -4 & -2 \\ 0 & -1 & -2 & -2 & -3 \end{bmatrix}$$

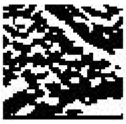
Sobel 45°

$$\begin{bmatrix} 1 & 1 & 0 & -1 & -1 \\ 2 & 3 & 0 & -3 & -2 \\ 3 & 4 & 0 & -4 & -3 \\ 2 & 3 & 0 & -3 & -2 \\ 1 & 1 & 0 & -1 & -1 \end{bmatrix}$$

Sobel 90°

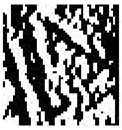
$$\begin{bmatrix} 0 & -1 & -2 & -2 & -3 \\ 1 & 0 & -3 & -4 & -2 \\ 2 & 3 & 0 & -3 & -2 \\ 2 & 4 & 3 & 0 & -1 \\ 3 & 2 & 2 & 1 & 0 \end{bmatrix}$$

Sobel 135°

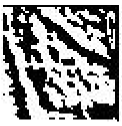


SPF 0°

SPF 45°



SPF 90°



SPF 135°

Fig.5. 5: 5×5 Sobel Code Operator and Sobel-Palmprint features

3.3 7×7 SOBEL CODE OPERATOR

$$\begin{bmatrix} 1 & 2 & 3 & 4 & 3 & 2 & 1 \\ 1 & 3 & 4 & 5 & 4 & 3 & 1 \\ 1 & 4 & 5 & 6 & 5 & 4 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -4 & -5 & -6 & -5 & -4 & -1 \\ -1 & -3 & -4 & -5 & -4 & -3 & -1 \\ -1 & -2 & -3 & -4 & -3 & -2 & -1 \end{bmatrix}$$

Sobel 0°

$$\begin{bmatrix} 4 & 3 & 2 & 1 & 1 & 1 & 0 \\ 3 & 5 & 4 & 3 & 4 & 0 & -1 \\ 2 & 4 & 6 & 5 & 0 & -4 & -1 \\ 1 & 3 & 5 & 0 & -5 & -3 & -1 \\ 1 & 4 & 0 & -5 & -6 & -4 & -2 \\ 1 & 0 & -4 & -3 & -4 & -5 & -3 \\ 0 & -1 & -1 & -1 & -2 & -3 & -4 \end{bmatrix}$$

Sobel 45°

$$\begin{bmatrix} 1 & 1 & 1 & 0 & -1 & -1 & -1 \\ 2 & 3 & 4 & 0 & -4 & -3 & -2 \\ 3 & 4 & 5 & 0 & -5 & -4 & -3 \\ 4 & 5 & 6 & 0 & -6 & -5 & -4 \\ 3 & 4 & 5 & 0 & -5 & -4 & -3 \\ 2 & 3 & 4 & 0 & -4 & -3 & -2 \\ 1 & 1 & 1 & 0 & -1 & -1 & -1 \end{bmatrix}$$

Sobel 90°

$$\begin{bmatrix} 0 & -1 & -1 & -1 & -2 & -3 & -4 \\ 1 & 0 & -4 & -3 & -4 & -5 & -3 \\ 1 & 4 & 0 & -5 & -6 & -4 & -2 \\ 1 & 3 & 5 & 0 & -5 & -3 & -1 \\ 2 & 4 & 6 & 5 & 0 & -4 & -1 \\ 3 & 5 & 4 & 3 & 4 & 0 & -1 \\ 4 & 3 & 2 & 1 & 1 & 1 & 0 \end{bmatrix}$$

Sobel 135°

SPF 0°

SPF 45°

SPF 90°

SPF 135°

Fig.6. 7×7 Sobel Code Operator and Sobel-Palmprint features

The Sobel-Palmprint features in Eqs.(1)-(4) are used to obtain feature vector as in eq (5):

$$SPF0 = \text{Palmprint} * Sobel0^{o} \quad (1)$$

$$SPF1 = \text{Palmprint} * Sobel45^{o} \quad (2)$$

$$SPF2 = \text{Palmprint} * Sobel90^{o} \quad (3)$$

$$SPF3 = \text{Palmprint} * Sobel135^{o} \quad (4)$$

$$FV_i = [SPF0_i, SPF1_i, SPF2_i, SPF3_i] \quad (5)$$

where *SPF* denotes Sobel-Palmprint features, Palmprint*$Sobel0^{o}$ signifies convolution of palmprint with Sobel operator of orientation 0°, *FV* is feature vector and i can be 3×3, 5×5 and 7×7 Sobel Code operator.

4. FEATURE MATCHING BY HAMMING DISTANCE AND SLIDING WINDOW METHOD

In this paper, the degree of similarity between Sobel-Palmprint feature vectors are matched by Hamming distance similarity measurement method that works on binary feature vectors. The line information (Sobel-Palmprint features) extracted is binarized by the following Eq.(6):

$$SPF_k(i,j) = \begin{cases} 1, SPF_k(i,j) > 0 \\ 0, SPF_k(i,j) \le 0 \end{cases}, \quad (6)$$

where, $SPF_k(i, j)$ = Sobel-Palmprint features corresponding to different orientations, 0^o, 45^o, 90^o, 135^o, k = 0….3, i and j are the rows and columns of the Sobel-Palmprint features.

Hamming Distance calculates the similarity/dissimilarity between two binary feature vectors using XOR operation that can be defined as:

$$HD_{0^\circ} = \sum_i^{60}\sum_j^{60}\left(FV(i,j) \oplus FV_{DB}(i,j)\right) \quad (7)$$

$$HD_{45^\circ} = \sum_i^{60}\sum_j^{60}\left(FV(i,j) \oplus FV_{DB}(i,j)\right) \quad (8)$$

$$HD_{90^\circ} = \sum_i^{60}\sum_j^{60}\left(FV(i,j) \oplus FV_{DB}(i,j)\right) \quad (9)$$

$$HD_{135^\circ} = \sum_i^{60}\sum_j^{60}\left(FV(i,j) \oplus FV_{DB}(i,j)\right) \quad (10)$$

where HD_θ denotes the hamming distance at an orientation θ, θ = 0^o, 45^o, 90^o, 135^o, i and j is the row and column of the Sobel-Palmprint feature vector, ⊕ is the exclusive OR operation, FV denotes the feature vector of the person to be matched, FV_{DB} denotes the feature vector in database.

In this paper, feature vectors are matched by Hamming distance similarity measurement using Sliding window approach. The problem of ROI displacement by some rows or columns can be overcome by Sliding Window method. In sliding window method the ROI of 60×60 pixels is reduced by the window size and the window ((60–WS)×(60–WS)) slides over the rows and columns and minimum of the value is considered. The palmprint area of Sobel-Palmprint feature vector is matched with the Sobel-Palmprint feature vector in the database. Fig.7 shows the sliding window method using palmprint image.

The hamming distance value at $0°$ with window size WS is defined as:

$$HD_{WS\,0^\circ} = \sum_i^{60-WS}\sum_j^{60-WS}\left(FV(i,j) \oplus FV_{DB}(i,j)\right), \quad (11)$$

where $HD_{WS\theta}$ denotes the hamming distance with window size WS and at an orientation θ, θ = 0^o, 45^o, 90^o, 135^o, i and j is the row and column of the Sobel-Palmprint feature vector, ⊕ is the exclusive OR operation, WS denotes the window size, FV denotes the feature vector of the person to be matched, FV_{DB} denotes the feature vector in database.

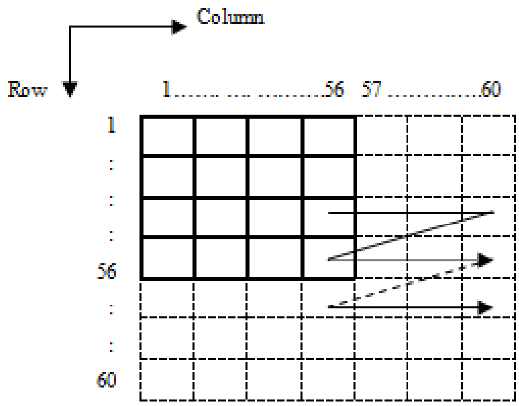
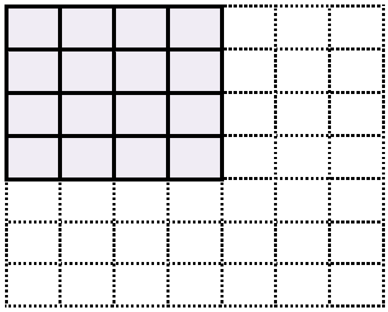


Fig.7. Sliding Window Approach with window size 4 and palmprint size 60×60

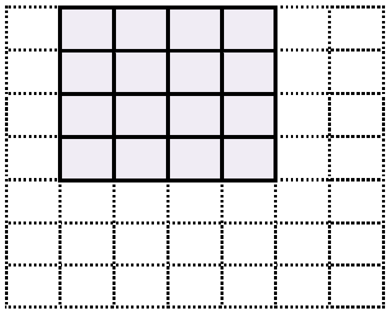
For window size WS, there will be $WS \times WS$ hamming distance values. For window size 4, 4×4 = 16, the minimum value out of 16 values of hamming distances is chosen as final hamming distance,

$$HD_{0^\circ} = \min\left(HD_{1\_0^\circ}, HD_{2\_0^\circ}, HD_{3\_0^\circ}, \ldots\ldots HD_{16\_0^\circ}\right) \quad (12)$$

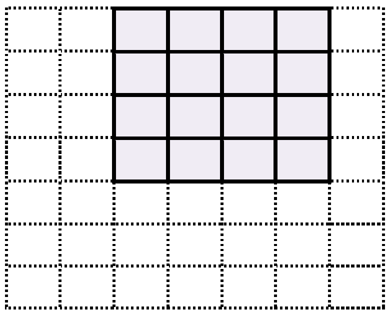
The various steps in sliding window method can be shown by the following images.



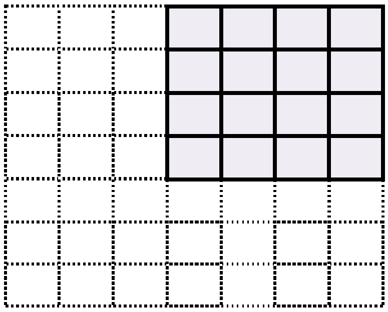
(a) Step 1



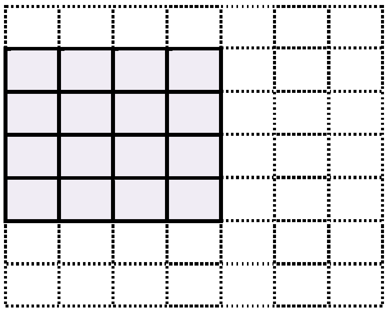
(b) Step 2



(c) Step 3

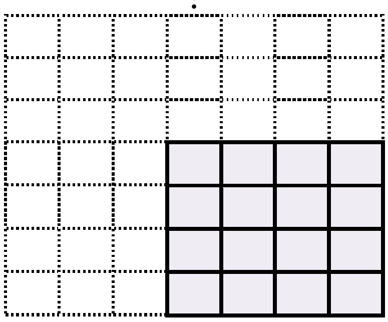


(d) Step 4



(e) Step 5

:



(f) Step 6

Fig.8. Various steps in Sliding window method

Similarly, hamming distance values at various angles HD_{45°, HD_{90° and HD_{135° are calculated. The average of all the four Hamming distances is calculated as shown in Eq.(13)

$$AHD = \frac{\left(HD_{0^\circ} + HD_{45^\circ} + HD_{90^\circ} + HD_{135^\circ}\right)}{4}, \tag{13}$$

where, HD_{0° denotes the hamming distance value at orientation 0°, AHD denotes the average value of hamming distance. The average value will help in finding the reference threshold value.

Hamming distance value near to "1" is identified that is known as reference threshold. If matching score (or Hamming distance) of two feature vectors is less than reference threshold value, person is considered as genuine otherwise imposter. In this paper, a unique and effective technique of Min Max Threshold Range (MMTR) is proposed that can extremely decrease FAR and can result in stable authentication system. The proposed approach can improve overall system accuracy. The accuracy of the biometric authentication can be defined by following Eq.(14)

$$Accuracy(\%) = \left(100 - \left(FAR(\%) + FRR(\%)\right)/2\right), \tag{14}$$

where, FAR is False Acceptance Rate, FRR is False Rejection Rate.

5. COMPARISON TIME IMPROVEMENT

The sliding window method is an accurate method but very time consuming. According to Eq.(11), if WS = 4 and time taken for each EX-OR operation is T_1 as shown in Eq.(15), then total time taken for hamming distance calculation is $56\times56\times T_1$ shown in Eq.(16)

$$\left(FV\ (i,j) \oplus FV_{DB}(i,j)\right) = T_1 \text{ time}, \tag{15}$$

$$HD_{WS\,0^\circ} = 56\times56\times T_1 = 3136T_1. \tag{16}$$

If WS = 4, then according to Eq.(11) 4×4 = 16 values of hamming distance are calculated. In Eq.(12) minimum hamming distance value using sliding window method is calculated. Time taken for one orientation will be $56\times56\times16\times T_1 = 50176T_1$. Total time for 4 orientations will be

$$T_{SWM} = 4\times16\times56\times56\times T_1 = 200704T_1. \tag{17}$$

Time T_{SWM} specifies time taken to compare feature vectors of two palmprints. In real time authentication system, palmprint matching will take place with hundreds or thousands of palmprints in the database. If we consider 100 palmprints the total matching time will be $200704T_1\times100 = 20070400T_1$. It is observed that the number of operations is large in number in sliding window method. It can be improved by improving sliding window method.

5.1 SLIDING WINDOW METHOD 1 (SWM1)

In this method, a small segment of the actual palmprint area is considered. The palmprint area can be any of the palmprint segment mentioned in the Fig.9. The palmprint segment size is less as compared to the palmprint, so the number of EX-OR operations are less.

According to Eq.(11), if WS = 4 and time taken for each EX-OR operation is T_1 as shown in Eq.(15), then total time taken for hamming distance calculation is $(15\text{-}4)\times(60\text{-}4)\times T_1$ shown in Eq.(18)

$$HD_{WS\,0^\circ} = 11\times56\times T_1 = 616T_1. \tag{18}$$

In Eq.(12) minimum hamming distance value using sliding window method is calculated. In SWM1 method, hamming distance value for each orientation is found out using sliding window method as shown in Eq.(12). The Eq.(12) signifies minimum hamming distance in sliding window as the closest matching between two palmprints.

Time taken for one orientation will be $16\times11\times56\times T_1 = 9856T_1$.

$$\min\_\ index\_HD_{0^\circ} = index\left(\min\left(HD_{0^\circ}\right)\right) \tag{19}$$

Time taken to compare two palmprints at minimum index value is $56\times56T_1$. Time taken for one orientation will be $16\times11\times56\times T_1 + 56\times56T_1 = 9856T_1 + 3136T_1 = 12992T_1$. Total time for 4 orientations will be, $T_{SWM1} = 4\times(16\times11\times56\times T_1 + 56\times56T_1) = 51968T_1$. If we consider 100 palmprints the total matching time will be $51968T_1\times100 = 5196800T_1$

The number of EX-OR operations in this method is reduced drastically as compared to sliding window method, that leads to improvement (reduction) in matching time. The improved matching time signifies fast authentication system.

It is observed that with the above mentioned assumption, the number of comparisons done for every orientation is reduced. As we know, less the number of comparisons faster will be the authentication speed.

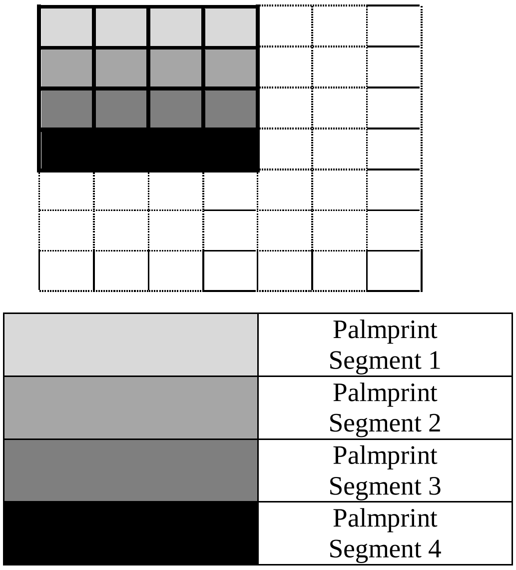
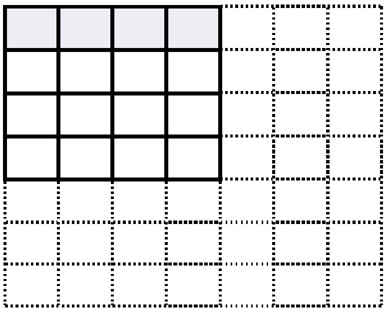
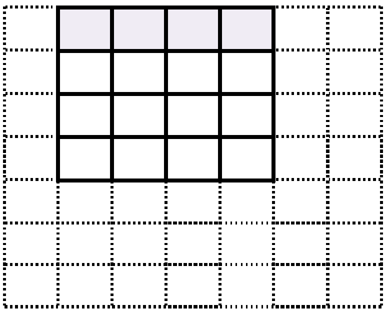


Fig.9. The segmented palmprint

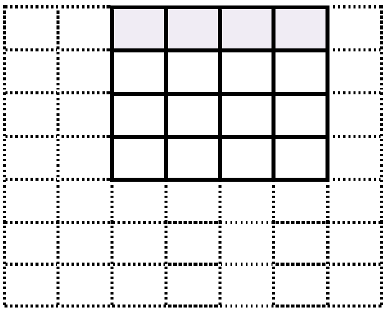
The sliding window method on the chosen palmprint area can be shown diagrammatically as:



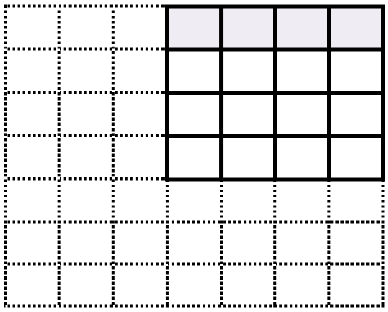
(a) Step 1



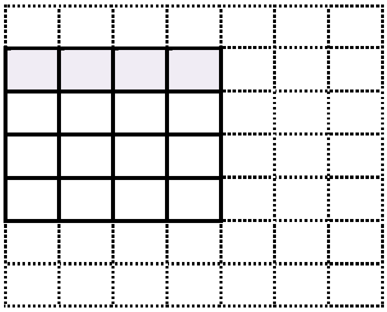
(b) Step 2



(c) Step 3



(d) Step 4



(e) Step 5

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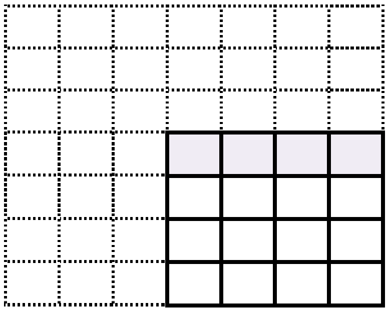

(f) Step 6

Fig.10. Various steps in improved Sliding window method

As we can see from the above diagrams that the area of palmprint segment in sliding window method has reduced considerably and it leads to lesser number of EX-OR operations.

5.2 SLIDING WINDOW METHOD 2 (SWM2)

In this method, the minimum hamming distance value is not calculated for all the orientations using sliding window method. The index of minimum hamming distance value is calculated for one orientation and same index value will be used to calculate hamming distance for other orientations. The total time taken $T_{SWM2}= (16\times11\times56\times T_1+56\times56T_1) + (56\times56T_1) \times3 = 22400T_1$. If we consider 100 palmprints the total matching time will be $22400T_1\times100 = 2240000T_1$.

6. ACCURACY IMPROVEMENT USING MIN MAX THRESHOLD RANGE (MMTR) APPROACH

In this paper, Min Max Threshold Range (MMTR) method is proposed that first authenticate the person using Reference threshold. Secondly, the person is authenticated using range of Minimum and Maximum thresholds defined for a person. There are chances of false acceptance using reference threshold method for personal authentication. So, by using the Minimum and Maximum Thresholds range of false accepted persons at personal level, a person is identified to be false accepted or genuinely accepted. MMTR is an effective technique that can increase the accuracy of the palmprint authentication system by reducing the False Acceptance Rate (FAR).

The hand image samples are divided into two groups G1 and G2 [23].

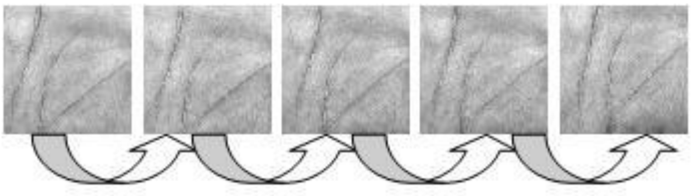

Fig.11. Matching of palmprints with each other

G_1 group

$$P_1 = [I_1, I_2, \ldots\ldots I_{(M-1)}],\ P_2 = [I_1, I_2, \ldots\ldots I_{(M-1)}], \ldots\ldots.. \quad P_N = [I_1, I_2, \ldots\ldots I_{(M-1)}], \tag{20}$$

G_2 group

$$P_1 = [I_M],\ P_2 = [I_M],\ \ldots..\ P_N = [I_M], \tag{21}$$

where P_i denotes i^{th} person in group G_1, G_2, I_j denotes the j^{th} palm image in group G_1, G_2.

Table.1. Matching In Group G_1 Among Person P_1

i / j	**1**	**2**	**3**		**M-1**
1	X	HD_{12}	HD_{13}	………	$HD_{1(M-1)}$
2	HD_{21}	X	HD_{23}	……….	$HD_{2(M-1)}$
:	:	:	:	:	:
:	:	:	:	:	:
M-1	$HD_{(M-1)1}$	$HD_{(M-1)2}$	$HD_{(M-1)3}$		X

In group G1, each hand feature vector in P_1 is matched with all other (m-1) hands feature vector by Hamming distance similarity measurement method and the matching values are stored in threshold array

$$TA_1 = \begin{bmatrix} HD_{12}, HD_{13},..HD_{1M-1}, HD_{21}, HD_{22},.HD_{2M-1}, \\ ....HD_{(M-1)1}, HD_{(M-1)2}..HD_{(M-1)(M-2)} \end{bmatrix}. \tag{22}$$

Similarly, all N hand image samples matching results are stored in Threshold array (T_A)

$$T_A = TA_1 + TA_2 + ... + TA_N. \tag{23}$$

The minimum and maximum of matching values are found out from the threshold array (TA_1, TA_2,……..TA_N) for each individual as shown in Eq.(24)

$$\left.\begin{aligned} T_{AiMIN} &= \min(T_{Ai}) \\ T_{AiMAX} &= \max(T_{Ai}) \end{aligned}\right\}_{i=1,....N}. \tag{24}$$

The accuracy of the system is found out by matching group G_2 samples with group G_1 samples using threshold values stored in threshold array. Finally, reference threshold is chosen where FAR and FRR is minimum.

In real time authentication system, the matching score is calculated by comparing a person's hand with the samples present in the database. If matching score (Hamming Distance value T) is less than reference threshold (R_T), the person is considered to be genuine otherwise imposter as shown in Fig.12.

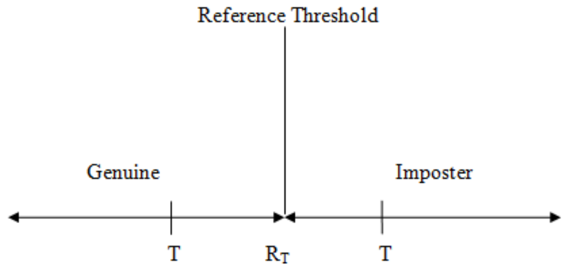

Fig.12. Criteria of authentication

There is a possibility of some wrong hand getting accepted as genuine because matching score fulfils the criteria of reference threshold as shown in Fig.12. Here, a second level of authentication by min-max threshold range (MMTR) is proposed. For successful authentication matching score must be less than reference threshold and within the min-max threshold range of the person as shown in Fig.13. If the matching score of a person to be matched is in the T_{MIN} to R_T range, then the person will be considered as genuine otherwise imposter.

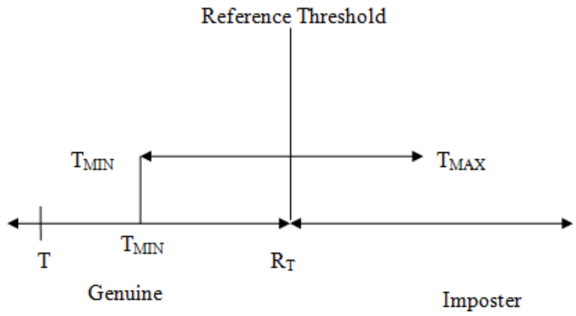

Fig.13. Criteria of authentication with MMTR method

In MMTR, the second level of verification within min and max range of threshold can reduce the chances of false acceptance. The accuracy of the system increases as the value of FAR reduces as in Eq.(14).

7. EXPERIMENTAL RESULTS AND ANALYSIS

A database of 600 palm images from 100 palms with 6 samples for each palm is taken from PolyU palmprint database [24].

7.1 PALMPRINT AUTHENTICATION SYSTEM

The palmprint database is divided into two groups, first group (G_1) consists of 100 persons with 5 palm sample images to train the system, and second group (G_2) contains 100 persons having one palm image different from the first group images to test the system.

Image is pre-processed to get the region of interest. The ROI size is 60×60 pixels. Sample of ROI is shown in Fig.14.

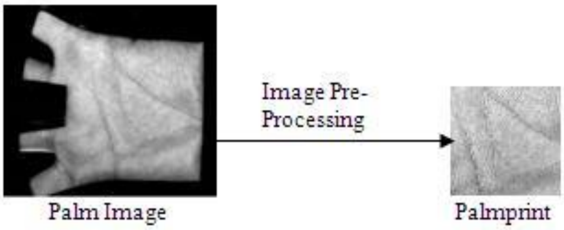

Fig.14. Sample of ROI

Line Feature extraction is done by 3×3, 5×5 and 7×7 Sobel Code method. The Sobel-Palmprint feature vector contains the Sobel-Palmprint features in 0°, 45°, 90° and 135° directions for each hand. Sobel-Palmprint feature vector for all hand images samples is stored in database. The feature vector matrix is given by FV_i = [*SPF*0, *SPF*1, *SPF*2, *SPF*3], where i can be 3×3, 5×5 and 7×7 Sobel Code operator.

Hamming distance similarity measurement method is used for feature matching.

7.2 MIN MAX THRESHOLD RANGE (MMTR) APPROACH

In group G1, each hand feature vector in P_1 is matched with all other 4 hands feature vector by Hamming distance measurement method and matching values are stored in threshold array. Similarly, for all 100 hand image samples, matching values are stored in Threshold array (T_A)

$$T_A = TA_1 + TA_2 + \dots\dots + TA_{100}.$$

The minimum and maximum of matching values are found out from the threshold arrays $(TA_1, TA_2, \dots\dots TA_N)$ for 100 individuals and are stored in the database

$$\left.\begin{aligned} T_{AiMIN} &= \min(T_{Ai}) \\ T_{AiMAX} &= \max(T_{Ai}) \end{aligned}\right\}_{i=1,\dots.100}.$$

The maximum and minimum values are found out from threshold array (T_A) to calculate the reference threshold,

$$T_{AMIN} = \min(T_A),$$
$$T_{AMAX} = \max(T_A).$$

The minimum and maximum values of threshold array are divided into T_H threshold values,

$$\Delta = (T_{AMAX} - T_{AMIN}) / T_H$$

$$\Delta 1 = T_{AMIN} + \Delta$$

$$\Delta 2 = T_{AMIN} + 2\Delta$$

Similarly, $\Delta T_H = T_{AMIN} + T_H \Delta.$

These T_H threshold values are tested with group G_2 and group G_1 images. The value of reference threshold is chosen where FAR and FRR are minimum.

Threshold values, respective FAR and FRR values and accuracy for the Sobel Code operator are tabulated in Table.2.

Table.2. Threshold Values, FAR, FRR, Accuracy Values

Reference Threshold	FAR	FRR	Accuracy
0.877	0.0547	0.000725	97.2
0.879	**0.0264**	**0.00016**	**98.7**
0.892	0.00998	0.0118	98.9
0.894	0.00997	0.0147	98.8
0.895	0.00997	0.0145	98.8
0.897	0.00998	0.0132	98.8
0.899	0.00998	0.0130	98.9
0.901	0.00998	0.0128	98.9
0.903	0.00998	0.0127	98.9
0.905	0.00998	0.0119	98.9

Table.3 also shows the overall accuracy improvement after applying MMTR.

The accuracy of the authentication system is 98.7% where the FAR and FRR values are minimum. By applying MMTR method, the accuracy can be improved to 99.5%. FAR values with respect to FRR values are plotted in Fig.15.

Table.3. Threshold Values, FAR, FRR, Accuracy Values After MMTR

Reference Threshold	FAR	FRR	Accuracy	FAR with MMTR	FRR with MMTR	Accuracy with MMTR
0.879	0.0264	0.00016	98.7	0.00814	0.000121	**99.5**

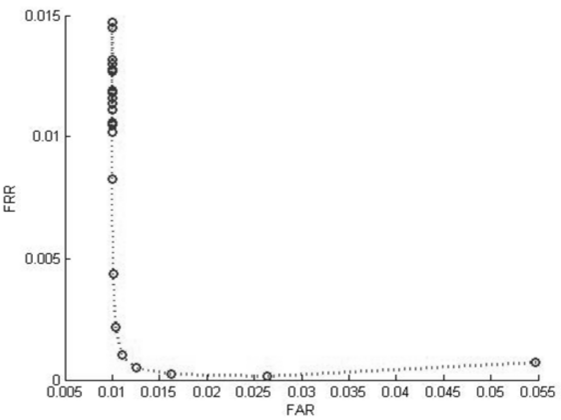

Fig.15. FAR Vs FRR

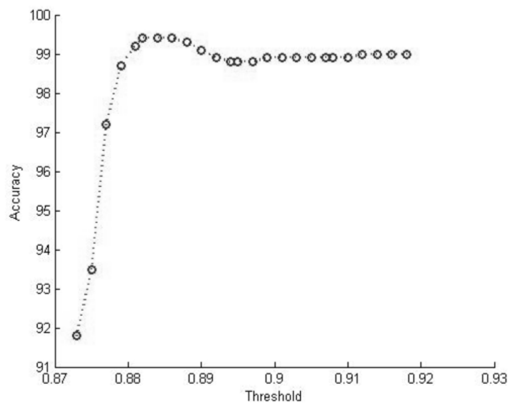

Fig.16. Accuracy Vs Threshold

Accuracy values with respect to threshold values are plotted in Fig.16.

7.3 METHODS COMPARISON

In this paper, we have compared the accuracy performance of Edward et. al [18, 19] with the proposed approach. We have also tested the performance with Directional operator [20] and DLEF [21] with our proposed approach. Table 4 shows the comparison of feature extraction methods [18, 19] with our proposed approach of Sobel code method with MMTR.

We have found that our proposed approach has performed better than other methods. This shows that by using Sobel code method with MMTR accuracy of the system improves because MMTR offers two level of authentication.

Table.4. Comparison of Feature Extraction Methods with Proposed Approach

Method	Accuracy
David Zhang et. al [15]	98.5
Edward et. al [18]	97.35
Edward et. al [19]	94.84
Directional operator [20]	97.81
Method	Accuracy
DLEF [21]	97.50
Proposed Approach Accuracy	**99.5**

7.4 SPEED PERFORMANCE

Table.5 shows the reduction in comparison time by sliding window method 1 and sliding window method 2 (SWM1 & SWM2). The time between the original palmprint processing till the matching result is counted. It can be observed that the as the palmprint size is reduced, the comparison time reduces and speed to verify the person is improved. Fig.17 and Fig.18 shows that with SWM2 the EX-OR time and comparison time improves significantly. The number of operations, EX-OR operation time with respect to window size (used in sliding window approach) is tabulated in Table.6. The number of operations, comparison time with respect to window size is tabulated in Table.7. The comparison time of 5×5 Sobel code operator with respect to window size (used in sliding window approach) for (60×60) and (128×128) palmprint size is tabulated in Table.8. Table.5, 6, 7 and 8 are mentioned in the next page of the paper.

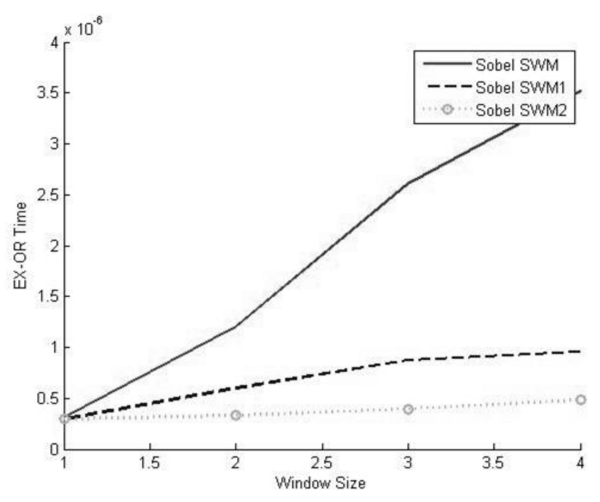

Fig.17. Comparison time Vs Window size

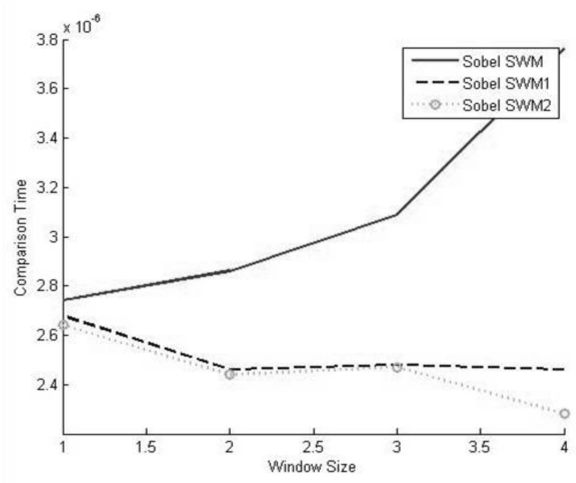

Fig.18. Comparison time Vs Window size

The DB preparation time for (3×3, 5×5 and 7×7) Sobel Code operators is shown by bar graph.

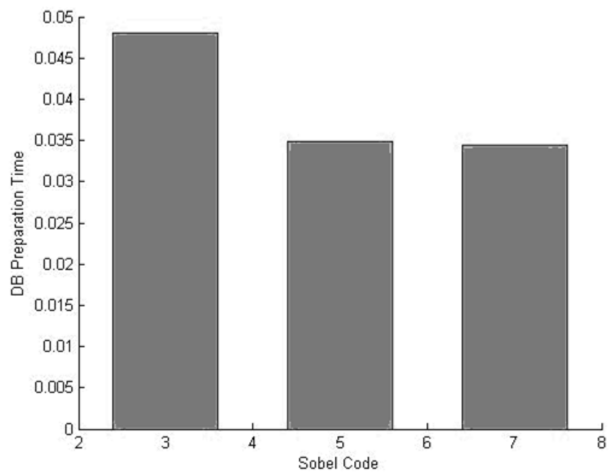

Fig.19. Sobel code method Vs DB Preparation Time

Table.5. Sliding Window Method Improvement

Method used	**Number of operations**
1. Hamming distance calculation with sliding window method with window size *WS*. $HD_{WS\,0^\circ} = \sum_{i}^{60-WS} \sum_{j}^{60-WS} \left(FV\,(i,j) \oplus FV_{DB}(i,j)\right)$	$\underbrace{56 \times 56} \times 16 \times 4 = 2{,}00{,}704$ Operations The (56×56) implies the number of comparisons of the palmprint with the palmprint in the database. 56×56×16 applies to sliding window method comparisons for window size 4, so (4×4 = 16) comparisons. The total number of comparisons takes place for four orientations (0°, 45°, 90°, and 135°) is 2, 00, 704.
2. SWM1: Hamming distance calculation with sliding window method (15×60) with window size 4. $HD_{0^\circ} = \sum_{i}^{15-WS} \sum_{j}^{60-WS} \left(FV\,(i,j) \oplus FV_{DB}(i,j)\right)$ The palmprint segment size is 15×60.	$(\underbrace{11 \times 56} \times 16 + \underbrace{56 \times 56}) \times 4 = 51{,}968$ Operations The (11×56) implies the number of comparisons of the palmprint segment with the palmprint segment in the database. 11×56×16 applies to sliding window method comparisons for window size 4, so (4×4 = 16) comparisons. 56×56 signifies the comparison of palmprint at the minimum index value. The sum of (11×56×16) and (56×56) give the number of comparison for each orientation. The total number of comparisons takes place for four orientations (0°, 45°, 90°, and 135°) is 51,968 Operations.
Assumption: If time taken to do each EX-OR operation is T_1.	Theoretical time improvement $\frac{\left(200704T_1 - 51968T_1\right)}{200704T_1} \times 100 = 74.11\%$
3. SWM2: Hamming distance calculation with sliding window method (15×60) with window size *WS*. $HD_{0^\circ} = \sum_{i}^{15-WS} \sum_{j}^{60-WS} \left(FV\,(i,j) \oplus FV_{DB}(i,j)\right)$	$(\underbrace{11 \times 56} \times 16 + \underbrace{56 \times 56}) + (\underbrace{56 \times 56}) \times 3 = 22{,}400$ Operations The assumption here is that the minimum hamming distance values for other orientations will also be at the same index as it is for angle 0°orientation 11×56×16 signifies the comparison of palmprint and finding the minimum index value. The sum of (11×56×16) and (56×56) give the number of operations for 0°orientation. The number of comparisons for (45°, 90°, and 135°) is at the minimum index value as assumed for this method. So, additional (56×56) ×3 comparisons will be added. The total number of comparisons is 22, 400.
Assumption: If time taken to do each EX-OR operation is T_1.	Theoretical time improvement $\frac{\left(200704T_1 - 22400T_1\right)}{200704T_1} \times 100 = 88.84\%$

Table.6. Percentage Reduction In EX-OR Operation Time

Sliding Window Size	**Number of Operations**			**EX-OR operation Time**			**Percentage reduction in EX-OR time**		
	SWM	SWM1	SWM2	SWM	SWM1	SWM2	SWM	SWM1	SWM2
1	13924	13924	13924	3.13E-07	2.93E-07	2.93E-07	NA	6.39	6.39
2	53824	25520	16472	1.20E-06	5.97E-07	3.30E-07	NA	50.25	72.5
3	116964	37620	19152	2.61E-06	8.76E-07	3.96E-07	NA	66.44	84.83
4	200704	51968	22400	3.52E-06	9.57E-07	4.85E-07	NA	72.79	89.27

Table.7. Percentage Reduction in Comparison Time

Sliding Window Size	**Number of Operations**			**Comparison Time**			**Percentage reduction in comparison time**		
	SWM	SWM1	SWM2	SWM	SWM1	SWM2	SWM	SWM1	SWM2
1	13924	13924	13924	2.74E-06	2.68E-06	2.64E-06	NA	2.19	3.65
2	53824	25520	16472	2.86E-06	2.46E-06	2.44E-06	NA	13.99	14.69
3	116964	37620	19152	3.09E-06	2.48E-06	2.47E-06	NA	19.74	20.06
4	200704	51968	22400	3.76E-06	2.46E-06	2.28E-06	NA	34.57	39.36

Table.8. Comparison of (60×60) And (128×128) Palmprint Size With 5×5 Sobel Code Operators With Respect To Comparison Time

Sliding Window Size	**Comparison Time (60×60)**			**Comparison Time (128×128)**		
	SWM	**SWM1**	**SWM2**	**SWM**	**SWM1**	**SWM2**
1	2.74E-06	2.68E-06	2.64E-06	3.84E-06	3.72E-06	3.70E-06
2	2.86E-06	2.46E-06	2.44E-06	4.88E-06	5.16E-06	3.72E-06
3	3.09E-06	2.48E-06	2.47E-06	6.60E-06	3.79E-06	3.73E-06
4	3.76E-06	2.46E-06	2.28E-06	8.85E-06	3.77E-06	3.72E-06

8. CONCLUSION

Accuracy and time are the main and important part of real time palmprint authentication. In this paper, three different Sobel Code operators are used for feature extraction. The accuracy is improved using MMTR method and time improvement is done using palmprint segment of (15×60) pixels. PolyU database palm images are used to prepare the database of 600 palm images. Palm images are enhanced and pre-processed to get the region of interest (ROI). Multi-scale (3×3, 5×5 and 7×7) Sobel Code operators are applied to the palmprint image in four different directions. The Sobel feature vector is compared with other feature vector in the database using Hamming distance similarity measurement method. An accuracy of 99.5 percent is obtained using Sobel Code feature vector.

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