Personal Authentication Using Palmprint with Phase Congruency Feature Extraction Method

Jyoti Malik[1], Ratna Dahiya[1], G. Sainarayanan[2]

[1]Electrical engineering Department, National Institute of Technology, Kurukshetra
[2] Maples ESM Technologies, Chennai, India
jyoti_reck@yahoo.com, ratna_dahiya@yahoo.co.in, sai.jgk@gmail.com

Abstract

Palmprint recognition is a biometric method to automatically identify a person's identity. In this paper, phase congruency method is proposed to extract features from a palm-print image for authentication. The phase congruency is one of the promising methods to analyse the image as it is invariant to image contrast and therefore can extract reliable features under varying illumination conditions. In this paper, the phase congruency features in 6 different orientations are arranged in such a manner to get the best combination of orientations for authentication. The hand image is pre-processed to get the desired Region of Interest (ROI) / palmprint. The palmprint features are extracted by phase congruency method and are stored in feature vector. The 20 different types of feature vectors are prepared using different combination of orientations. Hamming distance similarity measurement with Sliding window is used to compare the similarity/dissimilarity between two feature vectors. Experiments were developed on a database of 600 images from 100 individuals, with five image samples per individual for training and one image sample per individual for testing. The accuracy of 97.3% can be achieved using FV11.

Keywords: *Palmprint, Palmprint Authentication, Phase Congruency, Hamming distance.*

1. Introduction

Personal identification using biometric methods is gaining attention in today's automated world. Biometric authentication can be done using physiological or behavioral characteristics of the individual. The physiological characteristics signifies using human body parts for authentication like fingerprint, iris, ear, palmprint, face etc. The behavioral characteristics include action done using body parts like voice, signature and gait etc. for authentication. 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. [1]. The need of the time is to design biometric security systems that use the physiological and/or behavioural attributes of an individual. These attributes are unique for every individual and cannot be forgotten, mimicked, stolen or lost. These attributes have the ability to replace the conventional token- and knowledge-based security schemes.

The existing biometric verification systems employ various biometric traits such as fingerprint, face, iris, hand geometry, retina, voice, signature, palmprint etc. [2 - 6]. Palmprint-based recognition is considered both user friendly as well as fairly accurate biometric system.

Palmprint has several features like geometry features, line features, point features, texture features etc. In this paper, line features are analysed for palmprint recognition [7-14] because palm lines for every individual are unique. Line feature includes principal lines, wrinkles and ridges. Here, a more promising phase congruency method is proposed. Phase congruency method is less sensitive to image distortions and poor illumination conditions [20-22].

The following section of the paper is organised as follows: Section 2 describes the basic of palmprint authentication system. In section 3 phase congruency as a feature extraction method is discussed. Section 4 presents the hamming distance similarity measurement method and MMTR method. The experimental results are presented in Section 5, while section 6 concludes the paper.

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, a database of Palmprint-PhaseCongruency Features, Reference threshold value, minimum and maximum threshold values of each person are stored in the database.

In Authentication system, the authenticity of a person is verified with the help of Reference threshold value and Minimum and maximum values stored in Pre-authentication system database.

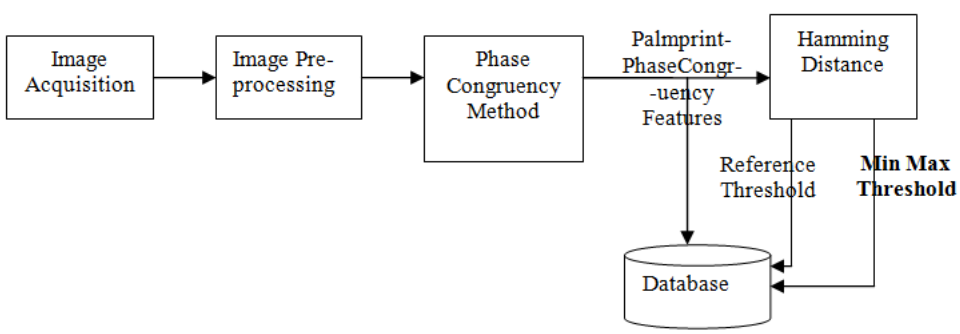


Figure 1: Palmprint Pre-Authentication system

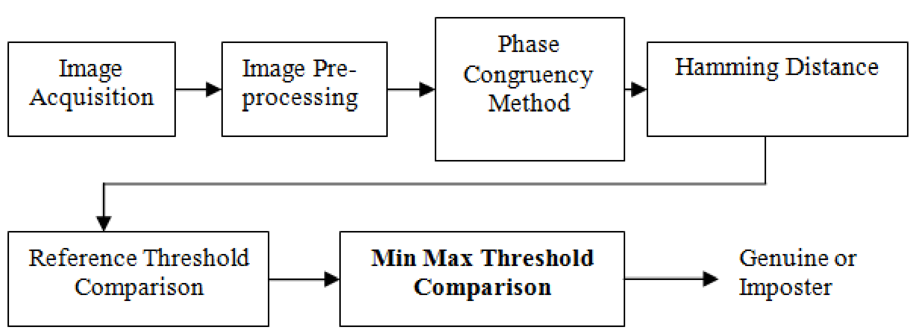


Figure 2: Palmprint Authentication System

3. Phase Congruency Method

The phase congruency model finds out the points in the palmprint where log-Gabor filter response over various scales (s) and orientations (o) is maximal in phase. The 2D phase congruency $PC_{2D}(x)$ is defined as:

$$PC_{2D}(x) = \frac{\sum_s \sum_o W_o(x) \left\lfloor A_{so}(x)\left(Cos\left(\phi_{s0}(x) - \overline{\phi_o(x)}\right) - \left|Sin\left(\phi_{so}(x) - \overline{\phi_o(x)}\right)\right|\right) - T_o \right\rfloor}{\sum_s \sum_o A_{so}(x) + \varepsilon} \tag{1}$$

where x is the pixel location in the spatial domain. $W_o(x)$ is weighing function of phase congruency by frequency spread at orientation o. $A_{so}(x)$ denotes the amplitude of the grey scale palmprint image. $\phi_{so}(x)$ denotes the phase response of palmprint image at scale s and orientation o of log- Gabor filter. $\phi_o(x)$ represents the mean phase angle at orientation o. ε is small constant which prevents division by zero. $\lfloor \ \rfloor$ symbol denotes that the enclosed quantity is equal to itself when its value is positive and zero otherwise. T_0 is the estimated noise energy at orientation o.

3.1. Phase Congruency Line Feature Extraction

In this paper, line feature extraction by phase congruency edge detector is proposed. Line features includes principal lines, wrinkles and ridges. There exist several line detection and gradient-based feature extraction methods like Sobel operators, Canny [16], line directional detectors that are based on the points of high intensity gradients and therefore got affected by the image contrast and brightness. The proposed phase congruency edge detector is invariant to changes in image brightness and contrast. The extraction of Phase Congruency (PC) features from the palmprint image is shown in Fig. 3.

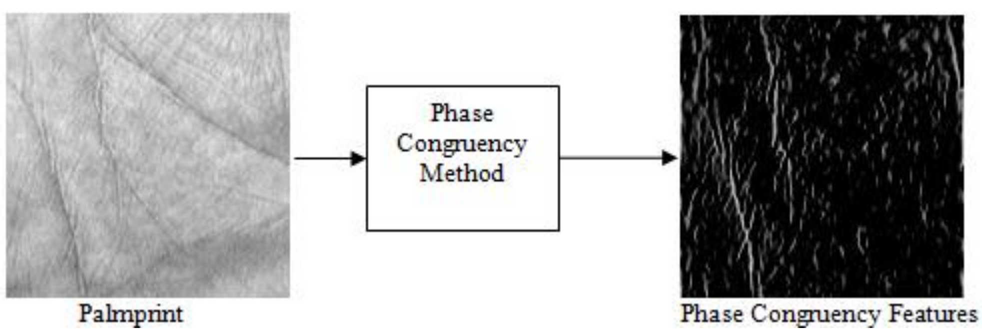
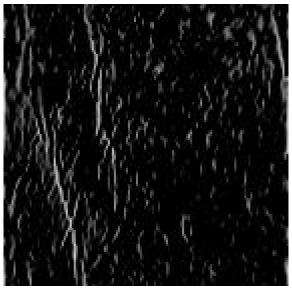
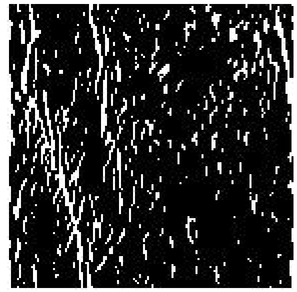


Figure 3: Feature Extraction by Phase Congruency method on Palmprint Image.

The number of phase congruency features images depends on the number of orientations considered. Here, the number of orientation considered is six. The Phase Congruency Features (PC) extracted and the binarized phase congruency features images are shown in Fig. 4.

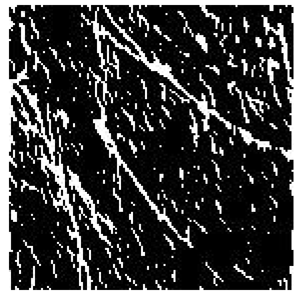


PCF1

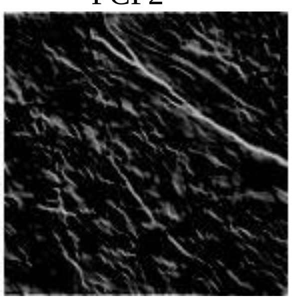


Binarized PCF1

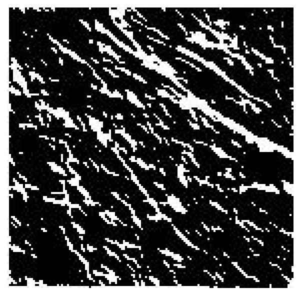
PCF2



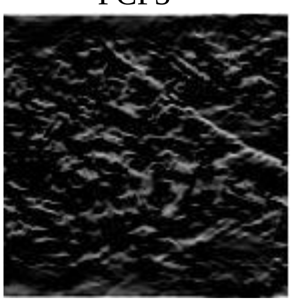
Binarized PCF2



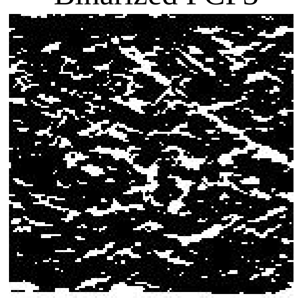
PCF3



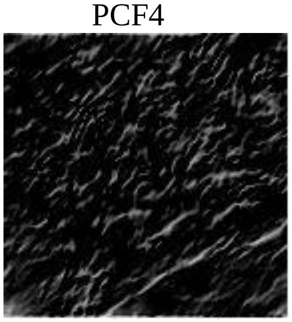
Binarized PCF3



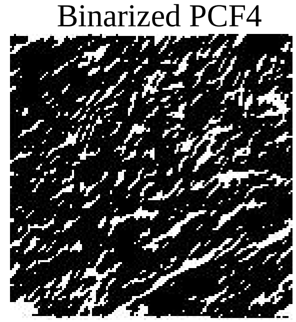
PCF4



Binarized PCF4



PCF5



Binarized PCF5

PCF6

Binarized PCF6

Figure 4: Phase Congruency Features and Binarized Phase congruency features.

The line information (Phase Congruency features) extracted is binarized by the following equation (2):

$$PC\ (i,j)=\begin{cases}1, PC\ (i,j)>0\\ 0, PC(i,j)\le 0\end{cases} \tag{2}$$

where, $PC\ (i,j)$= phase congruency features at i , j. i and j are the rows and columns of the phase congruency features.

3.2. Feature Representation

Once a palm-print image is transformed by phase congruency model, the edge information extracted is stored in the feature vector *FV*. In this paper, 6 different orientations are investigated individually and in combination. *FV1* TO *FV6* represent the feature vectors with single orientations

$$FV1 = PC(0)$$
$$FV2 = PC(1)$$
$$FV3 = PC(2)$$
$$FV4 = PC(3)$$
$$FV5 = PC(4)$$
$$FV6 = PC(5)$$

The combination of two, four and six orientation phase congruency features are investigated using AND operation. *FV7* to *FV13* represent the AND-ed feature vector.

$$FV7 = PC(0)\,\&\,PC(3)$$
$$FV8 = PC(1)\,\&\,PC(5)$$
$$FV9 = PC(2)\,\&\,PC(4)$$
$$FV10 = PC(0)\,\&\,PC(3)\,\&\,PC(1)\,\&\,PC(5)$$
$$FV11 = PC(0)\,\&\,PC(3)\,\&\,PC(2)\,\&\,PC(4)$$
$$FV12 = PC(1)\,\&\,PC(5)\,\&\,PC(2)\,\&\,PC(4)$$
$$FV13 = PC(0)\,\&\,PC(1)\,\&\,PC(2)\,\&\,PC(3)\,\&\,PC(4)\,\&\,PC(5)$$

The combination of two, four and six orientation phase congruency features are investigated using SUM operation. *FV14* to *FV20* represent the SUM-ed feature vector.

$$FV14 = PC(0) + PC(3)$$
$$FV15 = PC(1) + PC(5)$$
$$FV16 = PC(2) + PC(4)$$
$$FV17 = PC(0) + PC(3) + PC(1) + PC(5)$$
$$FV18 = PC(0) + PC(3) + PC(2) + PC(4)$$
$$FV19 = PC(1) + PC(5) + PC(2) + PC(4)$$
$$FV20 = PC(0) + PC(1) + PC(2) + PC(3) + PC(4) + PC(5)$$

4. Feature Matching by Hamming Distance Similarity Measurement

In a palm-print recognition system operating in verification mode the feature vector is extracted from the given input palm-print image by the phase congruency method. The feature vector is compared (or matched) with the template associated with the claimed identity. The template is constructed during the enrolment stage. Here, Hamming Distance similarity measurement is used to produce the matching score.

4.1. Hamming Distance Similarity Measurement

The hamming distance similarity measurement for phase congruency edge operator binary feature vectors can be defined as:

$$HD = \sum_{i}^{64}\sum_{j}^{64}\left(FV(i,j) \oplus FV_{DB}(i,j)\right) \tag{3}$$

where, *HD* denotes the Hamming distance, *i* and *j* is the row and column of the Phase Congruency feature vector, $\oplus$ is the exclusive OR operation, FV_{DB} denotes the feature vector in database.

4.2. Sliding Window Method

The Phase Congruency feature vectors are matched by Hamming distance similarity measurement using Sliding window approach. Sometimes during ROI extraction, it happens that the ROI of the same hand may be displaced by some rows or columns. To overcome this problem, Sliding Window method is used. In sliding window method the ROI is reduced by the window size and the window ((64–WS)×(64–WS)) slides over the rows and columns and minimum of the value is considered. The palmprint area of (64–WS) × (64–WS) pixels out of 64×64 pixels is considered for Hamming distance matching. The palmprint area of Phase Congruency feature vector is matched with the Phase Congruency feature vector in the database.

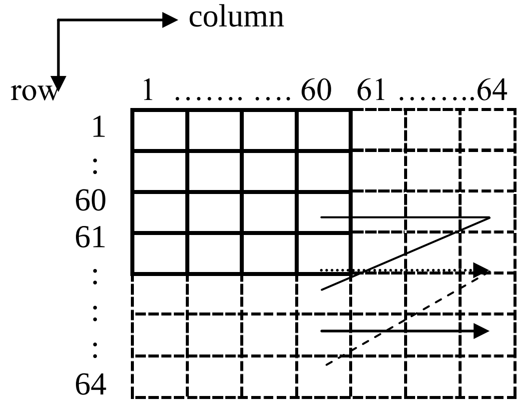


Figure 5: Sliding Window Approach with window size 4 and palmprint size 64×64

The Hamming distance value with window size *WS* is defined as:

$$HD_{WS} = \sum_{i}^{64-WS} \sum_{j}^{64-WS} \left(FV\,(i,j) \oplus FV_{DB}(i,j) \right) \tag{4}$$

where, HD_{WS} denotes the Hamming distance with window size *WS*, *i* and *j* is the row and column of the Phase Congruency feature vector, $\oplus$ is the exclusive OR operation, *FV* denotes the feature vector of the person to be matched, FV_{DB} denotes the feature vector in database. For window size *WS*, there will be $WS \times WS$ Hamming distance values. For example, if window size is 4, there will be 4×4 = 16 Hamming distance values. The minimum value out of 16 values of Hamming distances is chosen as Hamming distance.

$$HD = \min\left(HD_1, HD_2, HD_3, ...HD_{16} \right) \tag{5}$$

Hamming Distance value approaching "1" signifies both feature vectors belongs to same palm image. A 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, feature vectors are considered to be from same hands otherwise different hands.

4.3. Accuracy Improvement using Min Max Threshold Range (MMTR) Approach

In this paper, Min Max Threshold Range (MMTR) method is proposed that helps in increasing overall system accuracy by matching a person with multiple threshold values [28]. First, the person is authenticated using Reference threshold. Secondly, the person is authenticated using range of Minimum and Maximum thresholds stored for a person. There are chances of false acceptance if personal authentication is done using reference threshold only. So, by providing second level of authentication 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. By using second level of authentication, FAR is reduced considerably. This concludes that MMTR is an effective technique to increase the accuracy of the palmprint authentication system by reducing the False Acceptance Rate (FAR).

In MMTR method, multiple hand image samples are required to find out reference threshold and min max threshold range of each hand. The hand image samples are divided into two groups G1 and G2.

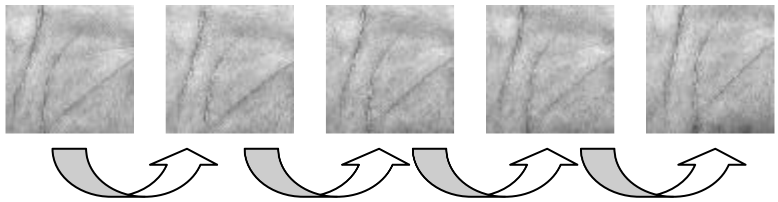


Figure 6: Matching of Palmprints with each other

G_1 group

$$P_1 = \lfloor I_1, I_2, ...I_{(M-1)} \rfloor,\ P_2 = \lfloor I_1, I_2, ...I_{(M-1)} \rfloor, ...\ P_N = \lfloor I_1, I_2, ...I_{(M-1)} \rfloor \tag{6}$$

G_2 group

$$P_1 = [I_M],\quad P_2 = [I_M], ...\ P_N = [I_M]$$

(7)

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.

j \ i	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 measurement method. The matching values are stored in threshold array.

$$TA_1 = \lfloor HD_{12}, HD_{13}, ..HD_{1M-1}, HD_{21}, HD_{23}, ...HD_{2M-1}, ...HD_{(M-1)1}, HD_{(M-1)2}, ..HD_{(M-1)(M-2)} \rfloor \tag{8}$$

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

$$T_A = TA_1 + TA_2 + ... + TA_N \tag{9}$$

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 equation (10).

$$\left.\begin{aligned} T_{AiMIN} &= \min(T_{Ai}) \\ T_{AiMAX} &= \max(T_{Ai}) \end{aligned}\right\}_{i=1,...N} \tag{10}$$

The accuracy of the system is identified by matching group G_2 samples with group G_1 samples using threshold values stored in threshold array. Finally, a threshold value is chosen where FAR and FRR is minimum, this value is called Reference threshold.

In real time authentication system, 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. 7.

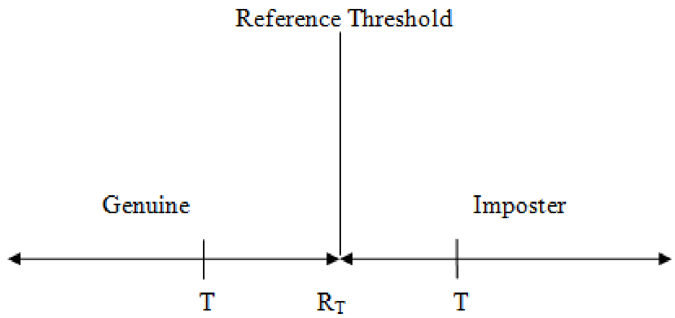


Figure 7: Criteria of Authentication

It is possible that some wrong hand can be accepted as genuine if matching score fulfils the reference threshold criteria. Here, a second level of verification by min-max threshold range (MMTR) at hand level 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 figure 8. 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.

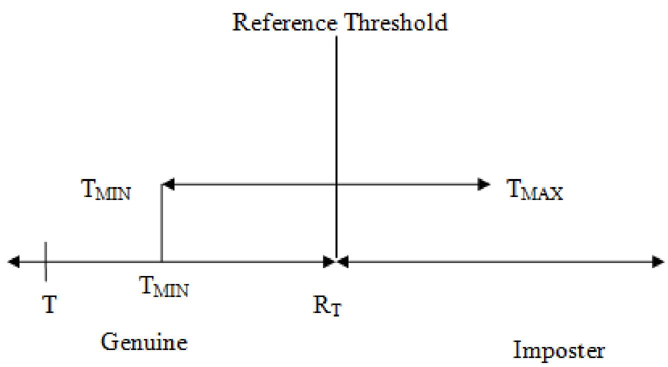


Figure 8: Criteria of Authentication with MMTR Method

MMTR method can be summarized as that hamming distance measurement method is used to match the feature vectors and the matching values are stored in threshold array as shown in equation (16) and (17). The min and max threshold values are identified from threshold array in equation (18) and stored in database. It is observed that different hands have different min and max range of threshold. So, the second level of verification within min and max range of threshold can reduce the chances of false acceptance.

5. Experimental Setup

A database of 600 palm images from 100 palms with 6 samples for each palm is taken from PolyU palmprint database [29].

5.1. Palmprint Authentication System

The palmprint database is divided into two groups, first group (G_1) consists of 100 persons with each person having 5 palm sample images to train the system, and second group (G_2) contains 100 persons with each person having one palm image different from the first group images to test the system. The hand image size is 284×384 pixels. The palmprint image used is 64×64 pixels.
G_1 group

$$P_1 = [I_1, I_2, I_3, I_4, I_5], \quad P_2 = [I_1, I_2, I_3, I_4, I_5], \ldots\ldots\ldots\ldots\ldots\ldots..$$
$$P_{100} = [I_1, I_2, I_3, I_4, I_5]$$

In G_1 group each hand P_i contains 5 sample image $I_{1\text{-}5.}$
G_2 group

$$P_1 = [I_6], \quad P_2 = [I_6], \ldots\ldots\ldots\ldots\ldots\ldots P_{100} = [I_6]$$

In G_2 group each hand P_i contains only sample image I_6.

Image is pre-processed to get the region of interest. Pre-processing includes image enhancement, image binarization, boundary extraction, cropping of palmprint/ROI. The ROI size is 64×64 pixels. Sample of ROI is shown in Fig. 9.

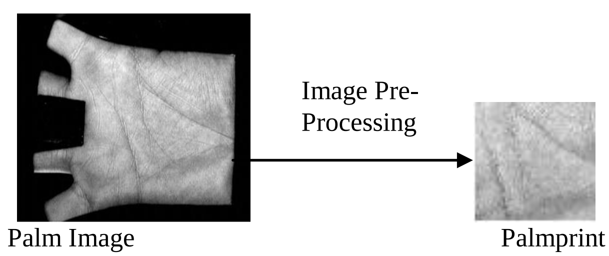


Figure 9: Sample of ROI.

Line features are extracted using Phase Congruency method**.** Hamming distance similarity measurement method is used for feature matching.

5.2 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. The matching values are stored in threshold array. Similarly, for all 100 hand image samples, 2000 matching values are stored in Threshold array *(T_A).*

$$T_A = TA_1 + TA_2 + \ldots\ldots + TA_{100}$$

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

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

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_V threshold values.

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

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

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

Similarly, $\Delta T_V = T_{AMIN} + T_V \Delta$

These T_V 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. Accuracy corresponding to each feature vector is tabulated in table 2.

Table 2: Feature Vector and Accuracy Values

Feature Vector	Accuracy	Feature Vector	Accuracy
FV1	96.6	**FV11**	**97.3**
FV2	90.5	FV12	92.2
FV3	90.3	FV13	94.4
FV4	92.9	FV14	93.4
FV5	91.4	FV15	92.4
FV6	91.5	FV16	95.4
FV7	96.3	FV17	94.6
FV8	96	FV18	95
FV9	91.3	FV19	94.5
FV10	97	FV20	91.4

Threshold values, respective FAR and FRR values and accuracy for the Phase congruency line feature method are tabulated in Table 3.

Table 3: Threshold Values, FAR, FRR, Accuracy Values Corresponding To Fv11

Reference Threshold	FAR	FRR	Accuracy
9.64E-01	1.80E-02	9.91E-03	9.86E+01
9.65E-01	2.52E-02	9.82E-03	9.82E+01
9.66E-01	3.03E-02	9.73E-03	9.76E+01
9.67E-01	4.23E-02	9.54E-03	9.74E+01
9.68E-01	**4.19E-02**	**9.46E-03**	**9.73E+01**
9.69E-01	4.30E-02	9.37E-03	9.72E+01

Table 4 also shows the overall accuracy improvement after applying MMTR.

Table 4: Threshold Values, FAR, FRR, Accuracy Values After MMTR

Reference Threshold	FAR	FRR	Accuracy	FAR with MMTR	FRR with MMTR	Accuracy with MMTR
9.68E-01	4.19E-02	9.46E-03	9.73E+01	1.07E-02	1.75E-03	9.94E+01

The accuracy of the authentication system is 97.3% where the FAR and FRR values are minimum. By applying MMTR method, the accuracy can be improved to 99.4%. FAR values with respect to FRR values are plotted in Fig. 10.

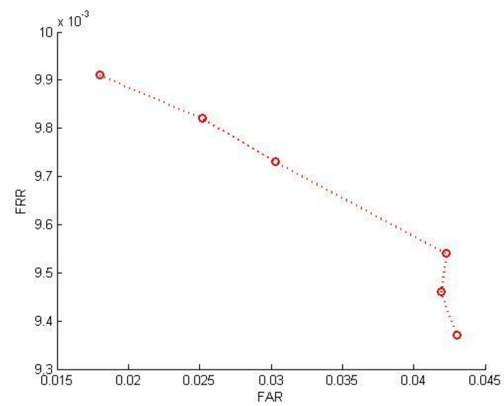


Figure 10: FAR Vs FRR

Accuracy values with respect to threshold values are plotted in Fig. 11.

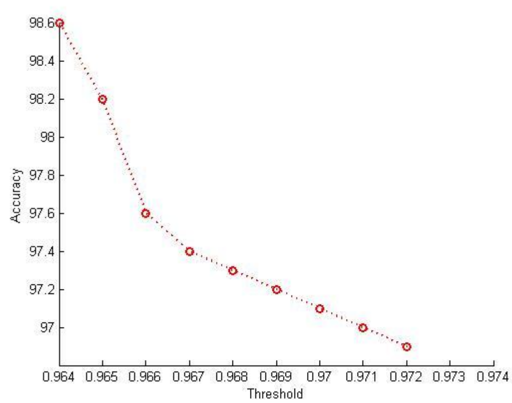


Figure 11: Accuracy Vs Threshold

5.3. Methods Comparison

In this paper, we have compared the accuracy performance of Edward et. al [20, 21] with the proposed approach. We have also tested the performance with Directional operator [22] and DLEF [23] with our proposed approach. Table 5 shows the comparison of feature extraction methods with our proposed approach of phase congruency method with MMTR.

Table 5: Comparison of Feature Extraction methods with proposed approach

Method	Accuracy
David Zhang et. al [18]	98.5
Edward et. al [20]	97.35
Edward et. al [21]	94.84
Directional operator [22]	97.81
DLEF [23]	97.50
Proposed Approach Accuracy	99.4

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

6. Conclusion

In this paper, line features are extracted using phase congruency edge detector. 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). In this paper, a promising approach of phase congruency for the extraction of discriminative palm-print features is proposed. The phase congruency feature vector is compared with other feature vector in the database using Hamming distance similarity measurement and sliding window method. Experimental results clearly show that phase congruency methodology has the ability to discriminate similar palmprints.

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Authors

Jyoti Malik received her B.Tech in 2002 from R.E.C, Kurukshetra University, Haryana, and M.Tech in 2004 from NIT, Kurukshetra, Deemed University, Haryana. Presently, she is pursuing her Ph.D. in the area of biometric authentication from NIT, Kurukshetra. Her research interests are Image processing, Pattern recognition and Signal processing.

Ratna Dahiya received her B.Tech from GBU, Pant Nagar and M.Tech and Ph.D. degree in Electrical Engineering from R.E.C, Kurukshetra, Kurukshetra University, Haryana, India. Currently, she is working as Asstt.Prof. in Electrical Engineering Department with the NIT, Kurukshetra (Deemed University), Haryana, India. Her research interests include Image processing, Pattern recognition, SMES, Induction Machines, Power quality, Motor drives and Renewable energy.

G. Sainarayanan is currently working in Maples ESM Technologies, Chennai, Tamilnadu. He received his B.E., M.E., and Ph.D. degrees, respectively, from Annamali University, India, Bharathiar University, India, and University Malaysia Sabah, Malaysia, in 1998, 2000, and 2002. His research interests are in the areas of Vision rehabilitation, Medical imaging and intelligent control.