Ridge Energy Based Human Verification Using Iris and Palm Print

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***Abstract*—**Multimodal biometric systems are being adopted as the most effective solution for security breaches these days as they are more reliable and accurate than unimodal systems. These are the pattern recognition systems which are used for identification/verification of the person using their physical or behavioral traits. Background removal for extracting palm print image from an unconstrained background is done using FCM (fuzzy c-mean) technique. Texture feature extraction of both iris and palm print is done using Ridge Energy Detection (RED) algorithm. Score level fusion is used for combining the two modalities and Hamming Distance is applied for generating matching scores for both the traits. The combination of iris and palm print is a very powerful biometric trait due to the individual strengths and uniqueness of both the traits. The proposed work resulted in a Genuine Acceptance Rate (GAR) of 100% at a very low False Acceptance Rate (FAR) of 0.007 only. The Equal Error Rate (EER) value calculated is found to be 0.005. The values are obtained by testing the algorithm on three datasets i.e. Iris Image Dataset provided by IIT Delhi and two for palm print i.e. Palmprint database provided by COEP, touchless palmprint dataset provided by IIT Delhi.

Keywords*—Multimodal Biometrics; security; Iris; Palm print; Background extraction; FCM; Ridge Energy Detection.*

I. INTRODUCTION

Biometric systems are analytical systems that identify or verify an individual by analyzing his/her behavioral or physical characteristics. With the advancement in technology, it is getting difficult for traditional security methods like I-cards, badges, passwords, etc. to provide a sufficient level of security and protect vital information from imposters. Even unimodal biometric systems sometimes fail to serve the matter. As unimodal biometric systems depend upon one biometric trait only, they suffer from issues such as noisy or incorrect sensor data, dearth of individuality, high error rates, non-universality, spoofing attacks, lack of invariant representation etc. [1, 2]. Considering any field today, from forensics to e-banking, issuing driving license to even entering to any office or country, security has become the most important aspect. As the threat of imposter breaching in the system increases, the methods of providing security must also get updated. So people shifted from unimodal systems to multimodal systems as it uses two or more biometric modalities to complete their desired function. Multimodal systems have over-ruled many of the complications that unimodal systems suffered from.

The biometric modalities on which the functioning of a biometric system mainly depends, can be listed among following two groups i.e. behavioral and physical. The inherent, very stable and time invariant type of traits of an individual are his physical traits, for example palm print, foot print, iris, hand geometry, retina, finger print, height, hand vein, face, ears, etc. Whereas, the one depending upon the habits or behavior of the person, are his behavioral traits for example voice, signature, keystroke, walking speed, arm or leg movement, gait etc. [3]. These biometric traits when used in combination for multimodal biometric systems, can be fused at three different fusion levels [2, 4], those are:

1. Fusion at feature extraction level: First possible level where biometric modalities can be fused is feature extraction level. As the raw data collected from sensors is the richest source of features/information and if fusion is done at this level, it gives the best results for the verification and identification process. But, this level of fusion is also the most difficult one as different sensors produce data in different form, they may or may not be compatible with each other. Similarly, features extracted from different modalities can be in various forms, their compatibility must also be checked before their fusion.

2. Fusion at matching score level: Next level where fusion can be done is matching score level, where the scores generated by the matching classifiers for various feature vectors are fused instead of the feature vectors themselves. This method of fusion is the most used one till date as it is rich in information and easy to fuse also. Matching scores of different feature vectors are generated using classifiers independently using their corresponding template stored in the database and then these scores values are fused to obtain a new matching score that can be further utilized by decision module for accepting or rejecting the individual's identity.

3. Fusion at decision level: Last possible level of fusing modalities is at decision level of the system. Decision for different modalities is taken independently depending on their matching scores. Then these decisions are fused to take the final decision for the acception or rejection using schemes like majority voting etc. This level of fusion is the easiest one to imply but does not work well with real time constraints. All the above mentioned levels of fusion are demonstrated in Figure 1 as well.

Depending on the need of the application, the biometric systems work in two different modes. These two modes are identification mode and verification mode [6, 7]. Identification mode is when the system compares the given biometric sample against all the templates which are already stored in the system's database, to find out the unknown identity of the given trait. This mode of operation is very complex and time taking, but it is very helpful in negative recognition [5] in crucial areas like forensics, criminal cases, etc. On the other hand, in verification mode, the authentication system is used to confirm identity of the already known individual by comparing the given biometric trait against the template stored in the database along with that identity. This mode of operation takes less time as less number of comparisons are to be made. Applications like laptop or phone security system, attendance system, entry security in offices, E-banking etc. are the examples of verification mode. The biometric system presented in this paper will work and get checked for results in future for verification mode.

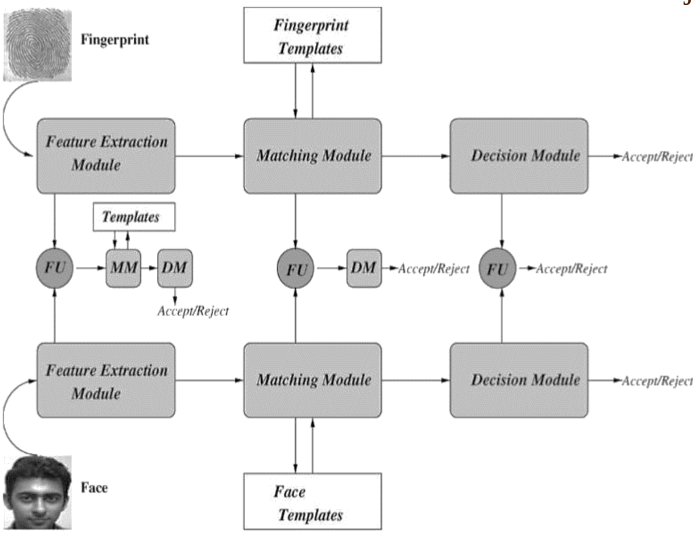


Figure1: Depicting various levels of fusion possible
(FU: Fusion Module, MM: Matching Module, DM: Decision Module) [4]

II. LITERATURE REVIEW

The round shaped flower like portion of the human eye is called iris, which is surrounded by the pupil and sclera on both sides. Iris has been among the most accurate biometric modalities being used since last decade. Many researchers like J. Daugman, Leonard Flom, AranSafir and many more have worked and are still working great in developing new methods for iris recognition. J. Daugman et al. [8] developed the most successful algorithm for iris recognition till date with an accuracy of 99.9% and very low FAR/FRR i.e. 0.01/0.09. But this algorithm got commercial and hence very expensive, also it was very time consuming. Iris was first used as biometric trait successfully in 1987 by Leonard Flom and AranSafir [9]. After that, many techniques like encoding iris code using 2-D Gabor filters [8], circular Hough transform [10], ridge energy detection (RED) method [11, 12] and many more were developed for iris recognition. Among these various algorithms, RED algorithm gained popularity after J. Daugman's presented algorithm. A major problem with iris recognition using all the above discussed methods was its failure in an unconstrained environment. But in 2009, Tan, Tieniu, et al. [13] proposed a solution to this problem with a clustering based algorithm for iris localization and integrodifferential constellation pupil extraction. After that, many other methods were presented to solve the same problem like 1-D and 2-D wavelet based techniques [14], K-mean clustering and circular Hough transform along with the canny edge detector based algorithm [15], Fuzzy-c mean clustering based algorithm [16] etc. Among these, Fuzzy-c mean based algorithm performed better as it considered membership functions for dividing the clusters.

On the other hand, palm print is rather new in biometric field, but has many advantages over many other biometric traits. It can provide more information/features as compared to fingerprint. Sensors and hardware required for palm print are cheaper than iris or retina like traits [17, 18]. Palm print has so many features hidden in it which are grouped under five names i.e. texture, line, geometric, point and statistical features. Combination of these features give a very high accuracy rate in security systems. Some of the techniques developed to use these features include work done by A. Jain et al. [19] in 2001 who used prominent principle lines with feature points in palm region. 2-D Gabor filters were used for feature extraction in [20]. Sobel operator [21, 22], Hidden Markov Model (HMM) classifier [23] etc. were used for line features extraction. Techniques including Principle Component Analysis (PCA) and Independent Component Analysis (ICA) [24], Discrete Cosine Transform (DCT) [25], Fourier transform [26], Scale invariant feature transform for contactless images [27], Contourlet transform [28] and many more were used for extracting texture features of palm print. The results of the above mentioned methods showed that texture features of palm print gave more accurate results among all five types of features.

Table 1: Comparison between various fusion recognition methods.

Author	Dataset size (persons)	Fusion level	Fusion method	Parameters	Values
Xiangqian et al. [29]	120	Score level fusion	Sum, product, maximum, minimum strategies	MTR EER	0.012% 0.006%
Hariprasath et al. [30]	30 (iris) 20 (palm print)	Feature level fusion	Wavelet Packet transform, Concatenation	Accuracy	93.00%
R. Gayathri et al. [31]	125	Feature level fusion	Wavelet based technique	Accuracy FRR	99.2% 1.6%
Kihal et al. [32]	200	Feature fusion, Score fusion, Decision fusion	Concatenation, Sum rule method, Error fusion	GAR FAR[1] FAR[2]	100% 2.10^{-3}% 4.10^{-4}%
Thepade et al. [33]	10	Score level fusion	Mean square error method	GAR	50.20 (Walsh) 51.80 (Kekre) 50.20 (Haar)
Apurva et al. [34]	7	Decision level fusion		RR	100% (iris) 100% (palmprint)

[1]FAR value for fusion of iris and CASIA palmprint database [32],[2]FAR value for fusion of iris and PolyU palmprint database [32]

Iris and palm print both are very effective and reliable biometric traits but both have some limitations as well. Combining these two traits together can rule out their limitations and can develop a highly accurate and reliable security system. Some of the work done on the fusion of these two modalities include the algorithm developed by Xiangqianet al. [29] in 2007 which resulted in 0.012% MTR and 0.006% EER. The author used fusion at score level based on sum and product techniques. Another method using feature level fusion based on wavelet packet transform technique developed by Hariprasath et al. [30] in 2012 gave 93% accuracy rate. In the same year, R. Gayathri et al. [31] also used feature level fusion using wavelet based technique for extracting texture features generating an accuracy rate of 99.2% and FAR of 1.6%. Thereafter, Kihal et al. [32] proved that quality of the image being used highly effects the results of the biometric system in 2014. They proved their point by working on three different datasets, performing all three levels of fusion on texture features of iris and palm print. SD Thepade et al. in 2015, worked in transform domain[33] using Haar, Walsh and Kekre transform for extracting texture features and then performed score level fusion proving that kekre transform works better with a GAR of 51.80 (approx.). Apurva et al. [34], on the other hand, worked in spatial domain using RED algorithm for iris and Harris corner detection algorithm for palm print focusing on geometric features of palm. They used decision level fusion for finalizing the results of their biometric system. Table 1 presents a comparative study of these algorithms discussed above.

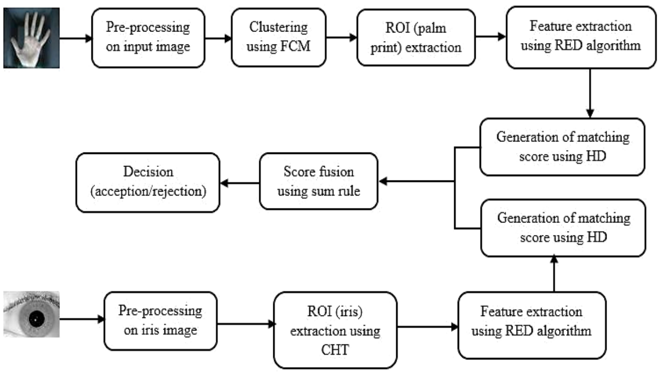


Figure2: Illustrating the sequence of steps in the proposed method

III. PROPOSED WORK

A novel approach is presented in this paper for recognizing human's iris using its ridge energy features. On the other hand for palm print segmentation, a new approach is proposed for background extraction using Fuzzy c-mean (FCM) algorithm. This will help in extracting human's hand image from any kind of unconstrained background making the system more suitable for real time security applications. Figure 2 represents the flow diagram of major steps included in the proposed method. As it is a multimodal system, it works on two modalities which are iris and palm print. Both the traits are very unique and rich in feature information. But both are quite different kind of modalities and their feature sets are also very different so it will be very difficult and complex to fuse them at feature extraction level. Hence, score level fusion is used for combining the scores of iris and palm print to generate final results.

A. Iris feature extraction

1. Iris feature extraction comprises of various pre-processing steps like localization, normalization (polar to rectangular conversion) and then enhancement. These steps are very important for extracting out an iris portion correctly from an eye image. Iris segmentation is one of the stepson which the recognition result of the system will depend upon. So iris segmentation must be done accurately and carefully for better results. After pre-processing, feature extraction is done, in our system, using RED algorithm by generating horizontal and vertical templates and their respective masks. Finally, scores are generated using Hamming Distance (HD).

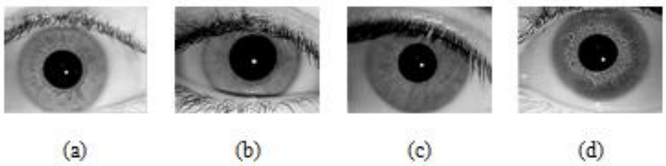


Figure 3: Some samples of images in IITD iris dataset.

2. First step in pre-processing is to detect the edges in the given image using Canny Edge Detection algorithm [35]. Canny is used for this purpose as it is the most efficient edge detection technique till date and its results are shown in figure 4 (a). Then, the inner boundary of iris which is also called pupil boundary and outer iris boundary are detected using Circular Hough Transform (CHT) [36] which is shown in figure 4 (b) and (c), respectively. CHT is a very efficient technique for detecting circles along with their centre and radii in an image. The edges detected by Canny are used to perform CHT more efficiently. With this, the process of localization of iris region is completed. Localized iris image is shown in figure 4 (d).

3. After detecting the localized iris region, ROI (iris) is extracted as shown in figure 5 (a). This ROI is then normalized to perform RED algorithm on it. As the extracted ROI is in circular form, feature extraction can't be performed on it effectively. It has to be first converted into rectangular form and then any further operation can be performed. This conversion from polar to rectangular form is called normalization of iris region which is illustrated in figure 5 (b).Daugman's rubber sheet model [8] is used in our system for normalization purpose. Generally normalized iris is generated using a radial resolution of 90 pixels along with an angular resolution of 480 pixels to get 90*480 iris templates. So that we use only the inner portion of iris, which is around pupil, leaving the outer portion, which is away from pupil, unused. This is done to avoid the interference of noise in the recognition results. This noise can be generated due to the presence of eye lids or eye lashes. After its conversion, normalized image is equalized using adaptive histogram equalization to enhance the ridges in iris region shown in figure 5 (c).

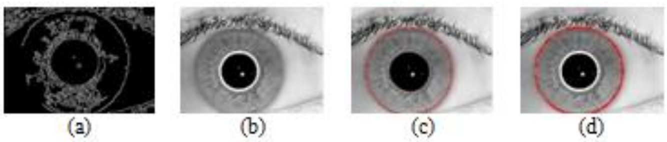
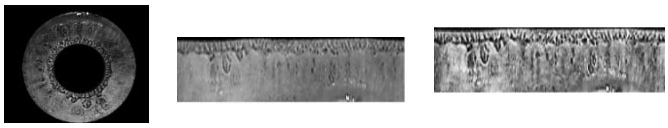


Figure 4: Outcomes of (a) edge detection (b) Pupil boundary detection (c) Outer Iris boundary detection (d) Localized iris region

4. On this enhanced normalized image of iris, RED algorithm is applied and features are extracted using horizontal and vertical filtering [11]. This is done using two 9*9 masks, one for generating horizontal template and one for vertical template. Then final iris code is generated by comparing these two templates. The template which contains more features/information is stored in iris code. This is done by masking the template with 0 or 1 bit, 1 if vertical template is strong and 0 if horizontal template is strong. Both the templates and iris code are illustrated in figure 6. The extracted features/information are then compared against the already retained template in the dataset using HD method. These matching scores are then stored for further reference.

$$HD = \frac{\sum((Template\ A \otimes Template\ B) \cap mask\ A \cap mask\ B)}{\sum(mask\ A \cap mask\ B)} \quad (1)$$

HD is the average similarity score generated using Hamming Distance as illustrated in equation (1). Template A is the already stored in the database and Template B is the one captured from image. Heremask A and mask B are the respective validity masks of the templates. The symbol ⊗ stands for the XOR operation whereas the symbol ∩ refers to the binary AND operation. Validity masks are generated along with the generation of final template by comparing each location with a defined threshold value. These are helpful in reducing the calculation of hamming distance for those locations which don't contribute effectively in the matching process. At some locations in the image, energy is so low that it gets difficult to recognize whether there is a ridge or not. These locations, if used for calculation, can reduce the accuracy of the system and increase the computational time. So, these locations are discarded with the help of validity mask. In our algorithm, four different threshold values i.e. 50, -50, 100 and -100 are tested for generating mask. Among these, the mask with -100 threshold value performed the best.



(a) (b) (c)

Figure 5: (a) Extracted ROI (b) normalized image (c) enhanced image

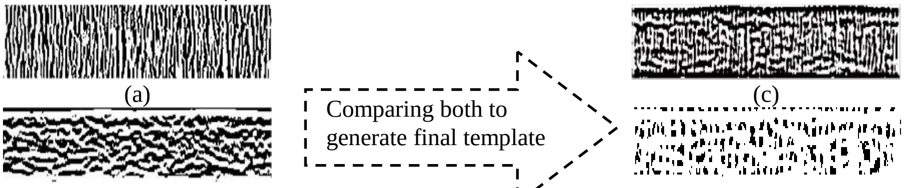


Figure 6: RED template generation (a) vertical template (b) horizontal template (c) final iris template (d) validity mask.

B. Palm print feature extraction

(a) (b) (c) (d)

Figure 7: Examples of hand images and their respective red channel images (a) and (b) from COEP Palmprint database, (c) and (d) from IIT Delhi palmprint database.

1. Extract the red channel out for the hand image as red channel contains most of the important information of the image out of the three channels i.e. red, green and blue. So, it can be used individually for the extraction of background. This is done to reduce the overheads during background extraction process and make it faster. This is one of the pre-processing steps of the method. Red channel images of few sample images from both the datasets being used are shown in second row of figure 7.

Input image Segmented hand region Extracted palm region

Figure8: Results showing segmented hand area and extracted ROI (palm print)

2. FCM algorithm is then applied on the extracted red channel of the hand image for dividing the image into two clusters, one for the background and one for the human hand. This technique is chosen for clustering because it uses fuzzy logic to cluster out the pixels. The image will be divided into two clusters based on the intensity values of the pixels and then on the basis of the membership function of belongingness to each cluster, it is decided that which part of the image belongs to which cluster. The output of FCM technique is further refined using few morphological operations like dilation, closing, filling, etc. Final output of FCM and morphological operations is shown in figure 8.

3. ROI (palm print) is extracted out from clustered hand image using a sequence of morphological operations i.e. opening, filling, erosion, dilation and closing. Extracted palm print images are shown in figure 8 with their respective sample images. Palm print region is full of different type of features that are geometrical, statistical, line, point and textural. In this method, main focus is kept on textural features i.e. ridge energy map and line features. Texture features are observed to give more accurate results among all the five types of features and line features are also found to be very unique such as principle lines.

4. For feature extraction RED algorithm is being used. RED algorithm is applied on iris till now for extracting features from it. We thought of applying it on palm print considering the fact that RED algorithm works on lines and ridges energy when applied on iris and in palm print also it can work well for principle lines and ridges extraction. The bit codes generated using the RED algorithm for various samples are shown in figure 9. Extracted features are then compared against the already stored template in the dataset along with their validity masks and matching score is generated using Hamming Distance method. Both the template and mask are generated in the same way as for iris above. These scores are then stored for further use.

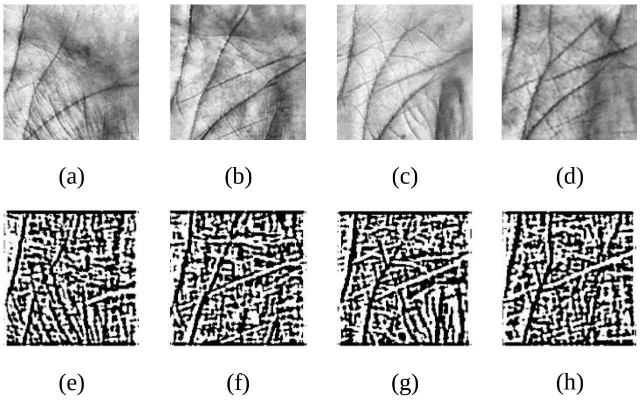


Figure9: (a)-(d) sample palm images from database, (e)-(h) their respective palm code templates.

C. *Fusion*

The matching scores generated for both the modalities are then fused using weighted sum rule method and then integrated matching scores are generated.

$$F = (w_1*I)+(w_2*P) \quad (2)$$

Here, F is the final score obtained by multiplying the scores of iris (I) and palm print (P) with their respective weights and then combining them. Depending on this matching score, final decision is made for the verification process. If the results match successfully that means the person is verified to be the authentic person, otherwise he is not the authentic person and trying to be someone else or trying to hide his original identity. For fusion many other strategies are also available like product rule, minimum or maximum strategy, etc. We can also assign weights to these scores while taking average if we want to give more value to one trait than another.

IV. DATASETS

Two different datasets of palm print were used for experimenting the background extraction technique i.e. COEP Palmprint database and Touchless palmprint database version 1.0 provided publically by IIT Delhi. This was done to make sure that any kind of unconstrained background can be extracted using this technique. COEP Palmprint database is publically available dataset maintained by College of Engineering, Pune, consisting of palm print samples of 167 different people with 8 different instances of the same person. IIT Delhi touchless palmprint database is composed of images from right and left hand of more than 230 subjects having 5 hand image instances for each of the hand. For palm print feature extraction and matching process, IIT Delhi palm print database was used. For feature extraction of iris and its matching process, IITD Iris database was used. The mentioned dataset consists of 2,240 images acquired from 224 different users having 10 different instances of each user.

V. EXPERIMENTAL RESULTS

For evaluating the proposed method, 100 different users were chosen from the above said datasets with 5 different instances of iris and 5 instances of palm print. This scenario gave us 1,000 genuine scores for iris and 1,000 genuine scores for palm print, along with 99,000 imposter scores for iris and 99,000 imposter scores for palm print. There were 10 iris scores generated for a single user along with 10 palm scores. Then the generalization of these scores generated a total of 10,000 various scores including 100 genuine user scores and 9,900 imposter scores. This generalization can be done in various ways, from which, two ways are adopted in our work. One way is to take average of all 10 scores and get one general score, and second method is to take the maximum score from all the 10 scores. Then these generalized scores are used for score level fusion. At the time of fusion, weighted sum rule method is used in our algorithm. The weights assigned to both the modalities can be same or it can be different for different modalities. In our algorithm, both cases are considered and their outcomes are tabulated in table 2 to 5. The results in table 2 and 4 are obtained by using equal weights for both iris and palm print whereas, results in table 3 and 5 are obtained by using w_1=0.3 and w_2=0.7 where, w_1 and w_2 are the weights of iris and palm print respectively.

Table 2:Performance parameters with equal weights and average score generalization.

Threshold	FAR	FRR	GAR
0.39	0.001	0.27	0.73
0.4	0.027	0.12	0.88
0.41	0.24	0.04	0.96
0.415	0.44	0.01	0.99
0.416	0.48	0	1

Table 3: Performance parameters with unequal weights and average score generalization.

Threshold	FAR	FRR	GAR
0.39	0	0.52	0.48
0.4	0.0003	0.32	0.68
0.41	0.01	0.17	0.83
0.42	0.21	0.04	0.96
0.426	0.52	0	1

Table 4: Performance parameters with equal weights and max-max score generalization.

Threshold	FAR	FRR	GAR
0.41	0.0023	0.04	0.96
0.413	0.0038	0.02	0.98
0.416	0.012	0	1
0.42	0.032	0	1

Table 5: Performance parameters with unequal weights and max-max score generalization.

Threshold	FAR	FRR	GAR
0.415	0	0.08	0.92
0.419	0.0003	0.07	0.93
0.42	0.0004	0.04	0.96
0.424	0.0028	0.02	0.98
0.426	**0.0072**	**0**	**1**

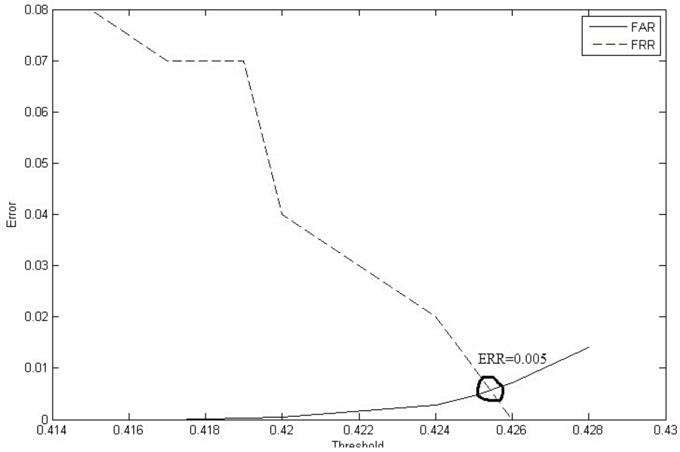


Figure 10: Graph showing error rates along with ERR value for the proposed method.

The results in above tables clearly shows that this scheme with maximum score generalization scheme and w_1=0.3 and w_2=0.7 gave most promising results with a GAR of 100% for a FAR of 0.0072 only. The above combination outperformed all other schemes tested on the proposed work.As the graph in figure 10 shows that our proposed method gave an EER of 0.005% which is significantly close to zero. The ROC curve for the proposed work is also given in figure 11.

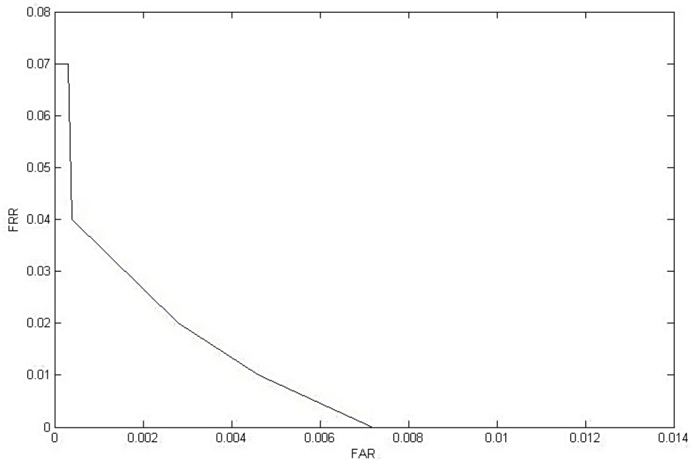


Figure 11: ROC curve for the proposed method.

CONCLUSION

In today's era, biometric systems are gaining very much importance for providing sufficient security to the vital information these days. Multimodal biometric system is the current trend in security systems. Iris and palm print, the two traits considered in this paper are very efficient, unique and reliable biometric modalities. This paper provides a short review of both the modalities and their fusion, also a novel approach is presented for using palm print and iris together for verifying the identity of any individual. In this approach, FCM is used for extracting hand image from unconstrained background, morphological operations for extracting the ROI (palm print) and RED algorithm for feature extraction. CHT and Daugman's rubber sheet modal are used for localization and normalization of iris. RED algorithm is used for feature extraction followed by HD for score generation. Score level fusion is used for fusing both the modalities and taking the final decision about the identity of the individual. FCM technique used in this approach uses fuzzy logic to cluster out the pixels and it gives very good results. Also, RED algorithm that has never been used before for palm print texture feature extraction, is implemented successfully in the work carried out with very encouraging results. This technique is experimented for results on three databases i.e. Palmprint database provided by COEP, touchless palmprint database version 1.0 provided by IIT Delhi and Iris Image Database version 1.0 provided by IITD. The technique gave a GAR of 100% for a FAR of 0.0072 only.Our proposed method gave an EER of 0.005% which is significantly close to zero.The results are found to be encouraging and more work can be done on this technique for further improvements.

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