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# Fusion of Multi-Model Biometric Authentication Systems Using Iris and Palmprint

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## ABSTRACT

*This paper presents fusion of two biometric traits, i.e., iris and palmprint, at matching score level architecture using weighted sum of score technique. The features are extracted from the pre-processed images of iris and palmprint. These features of a query image are compared with those of a template database image to obtain matching scores. The individual scores generated after matching are passed to the fusion module. This module consists of three major steps i.e., normalization, generation of similarity score and fusion of weighted scores. The final score is then used to declare the person as genuine or an impostor. The system is tested on template databases collected by the authors for 1250 samples and gives an overall accuracy of 97.04% with FAR of 0.58% and FRR of 4.34%.*

**Keywords**: *Iris, Palmprint, Genuine, Impostor, Sum rule and Fusion*

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## I. INTRODUCTION

Biometrics refers to the use of physiological or biological characteristics to measure the identity of an individual. These features are unique to each individual and remain unaltered during a person's lifetime. These features make biometrics a promising solution to the society. The access to the secured area can be made by the use of ID numbers or password which amounts to knowledge based security. But such information can easily be accessed by intruders and they can breach the doors of security. The problem arises in case of monetary transactions and highly restricted to information zone. Thus to overcome the above mentioned issue biometric traits are used. A biometric system is essentially a pattern recognition system which makes a personal identification by determining the authenticity of a specific physiological or behavioral characteristic possessed by the user. Biometric technologies are thus defined as the automated methods of identifying or authenticating the identity of a living person based on a physiological or behavioral characteristic.

The various biometrics traits available are face, fingerprint, iris, palmprint, hand geometry, ear etc. Among the available biometric traits some of the traits outperform others. The reliability of several biometrics traits is measured with the help of experimental results. The biometric system is basically divided into two modes i.e., unimodal biometric system and multimodal biometric system. In case of unimodal biometric system the individual trait is used for recognition or identification. The system performs better under certain assumptions but fails when the biometric data available is noisy. The system also fails in case of unavailability of biometric template. Thus in such a situation multimodal biometric systems are used where more than one classifier is used to arrive at a final decision. The concept of multimodal biometric system has been proposed by Ross and Jain [1] where apart from fusion strategies various levels of integration are also presented. In [2] fusion of iris and face biometrics has been proposed. The score level fusion in multimodal biometrics system is proposed in [3]. A novel fusion at feature level for face and palmprint has been presented in [4]. The purpose in [4] is to investigate whether the integration of face and palmprint biometrics can achieve higher performance that may not be possible using a single biometric indicator alone. Both Principal Component Analysis (PCA) and Independent Component Analysis (ICA) are considered in this feature vector fusion context. It is found that the performance has improved significantly.

In this paper a novel combination of iris and palmrprint biometrics is presented. The two classifiers perform better individually but fail under certain conditions. The problem can arise at the time of iris image acquisition where the user has to be co-operative while giving the iris image. In case of palmprint recognition poor quality palmprint image may create problem. The enhancement module recovers the ridges and wrinkles present but the loss due to cuts and scars present on the palmprint image may create problem in extraction of minutiae points distance. Thus the two recognizers are combined at matching score level and final decision about the person's identity is made. In the next section a brief overview is presented about the iris and palmprint. In Section 3 the two modalities are combined at matching score level. The experimental results prior to fusion and after fusion are presented in Section 4. Conclusion is given in the last section.

## II. INDIVIDUAL RECOGNIZERS

Iris and Palmprint biometrics perform better as compared to other available traits due to their accuracy, reliability and simplicity. These properties make iris and palmprint recognition particularly promising solution to the society. The process starts with preprocessing of the acquired images which removes the effect of noise. Further, features are extracted for the training and testing images and matched to find the similarity between two feature sets. The matching scores generated from the individual recognizers are passed to the decision module where a person is declared as genuine or an imposter.

### 2.1 Iris Recognition

Iris is unique to each individual and remains constant over the life of a person. The eyeball has a circular black disk in the center known as pupil. The pupil dilates when exposed to light and contracts in dark. Thus the size of pupil varies with respect to light it is exposed to. The iris is the annular ring between the sclera and pupil boundary and contains the flowery pattern unique to each individual. This texture information unique to each individual is extracted from rest of the eye image and is transformed into strip to apply pattern matching algorithm between the database and query images of iris. Automated iris recognition system has been proposed by Flom and Safir [5]. The concept of multi-scale quadrature wavelets is used to extract texture phase structure information of the iris, to generate a 2048 bit iris code and compares the difference between a pair of iris representations by computing their Hamming distance using XOR operator [6]. The zero-crossing representation of 1-D wavelet transform at various resolution levels of a virtual circle on an iris image to characterize the texture of the iris has been calculated in [7]. Wildes et al. [8] obtain the iris texture with a Laplacian pyramid constructed with four different resolution levels and use the normalized correlation to determine whether the input image and the model image are from the same class. The important steps involved in iris recognition are:

1. Pupil Detection
2. Iris Detection
3. Normalization
4. Feature Extraction
5. Matching

Prior to implementation of steps mentioned above iris image has to be acquired which should be rich in texture because all subsequent stages depend upon the image quality. The images are acquired using a 3CCD camera under the controlled lab environment. The acquired image is passed to the localization module to detect iris portion from the rest of the image.

#### 2.1.1 Pupil Detection

Pupil is the darkest portion of the eye and is detected and removed from the rest of the eye image so that only iris pattern can be used for matching. The first step involved in pupil detection is to find the contours of the acquired iris image. Since the pupil region contains the lowest intensity values its edges can be formed easily. After edge detection the next step is to find the center of the pupil. Thus the process starts with dilating the edge detected image and the dilated image with filled pupil circle is used to find the Euclidean distance between the non-zero points. By computing the distance between non-zero points the spectrum showing the largest filled circle can be formed within the set of pixels. Since the pupil is the largest filled circle in the image the overall intensity of the spectrum peaks in at the center. This spectrum image can be used to compute the center of the pupil. The pixel position having the maximum value in the spectrum image corresponds to the pupil center. The radius of the pupil is the distance between the pupil center and nearest non-zero pixel.

#### 2.1.2 Iris Detection

To find the outer iris boundary intensity variation approach is used. In this approach concentric circles of different radii are drawn from the detected center. The circle having maximum change in intensity with respect to previous drawn circle is iris circle. The approach works fine for iris images having sharp variation between iris boundary and sclera. The radius of iris and pupil boundary is used to transform the annular portion to a rectangular block, known as strip.

### 2.1.3 Normalization
The localized iris image is transformed into strip. The mapping is done after transforming the Cartesian coordinates into its polar equivalent using

$$
\left.
\begin{aligned}
& I(x(\rho,\theta), y(\rho,\theta)) \rightarrow I(\rho,\theta) \\
& \textit{with} \\
& x_p(\rho,\theta) = x_{\rho 0}(\theta) + r_p * \cos(\theta) \\
& y_p(\rho,\theta) = y_{\rho 0}(\theta) + r_p * \sin(\theta) \\
& x_i(\rho,\theta) = x_{i0}(\theta) + r_i * \cos(\theta) \\
& y_i(\rho,\theta) = x_{i0}(\theta) + r_i * \sin(\theta)
\end{aligned}
\right\} \quad (1)
$$

where $r_p$ and $r_i$ are respectively the radius of pupil and the iris in equation (1), while ($x_p(\theta)$, $y_p(\theta)$) and ($x_i(\theta)$, $y_i(\theta)$) are the coordinates of the pupillary and limbic boundaries in the direction $\theta$. The value of $\theta$ belongs to [0; $2\pi$], $\rho$ belongs to [0; 1].

The transformed iris image consists of points taken from the pupil boundary to the outer iris boundary. Thus the same set of points is taken for every image. The iris image is normalized so that the size of strip does not vary for different images. The size of same iris image may vary due to expansion and dilation of pupil. Thus the size of iris strip is fixed for every iris image. In this experiment the size of strip is 80×360 pixels.

### 2.1.4 Feature Extraction
Features are the attributes or values extracted to get the unique characteristics from the image. Features from the iris image are extracted using Haar Wavelet decomposition process [9]. In the wavelet decomposition the image is decomposed into four coefficient i.e., horizontal, diagonal, vertical and approximation. The approximation coefficients are further decomposed into four coefficients. The sequences of steps are repeated for five levels and the last level coefficients are combined to form a vector. The combined vector is binarized to allow easy comparisons between the iris codes for template database and query image.

$$IC(i) = \begin{cases} 1 & FV(i) \geq 0 \\ 0 & FV(i) < 0 \end{cases} \quad (2)$$

The binarized feature vectors are passed to the matching module to allow comparisons.

### 2.1.5 Matching
The comparison is done between iris codes (IC) generated for template database and query images using hamming distance approach. In this approach the difference between the bits of two codes are counted and the number is divided by the total number of comparisons.

$$MS_{Iris} = \frac{1}{N} \sum_{i=1}^{N} A_i \oplus B_i \quad (3)$$

where A is the binary vector (iris code) for database image and B is the binary vector for query image while N is the number of elements[14]. This matching score ($MS_{Iris}$) is used as input for the fusion module where the final matching score is generated.

### 2.2 Palmprint Recognition
Palmprint is one of the most widely used biometric modality. The main reason behind the use of palmprint biometric is that it is the most proven technique to identify the individual. The palmprint is basically the combination of ridges and wrinkles on the surface of the ridges. The systematic study on the ridge, furrow, and pore structure in palmprints has been published in [10]. The use of minutiae points feature for single fingerprint classification has been introduced in [10]. A system on palmprint classification is discussed in [10] [11]. The major steps involved in palmprint recognition using minutiae matching approach after image acquisition are:
1. Image Enhancement
2. Minutiae Extraction
3. Matching

### 2.2.1 Image Enhancement
A palmprint image is corrupted due to various kinds of noises such as creases, smudges and holes. It is almost impossible to recover the true ridge/wrinkle structures from the unrecoverable regions; any effort to improve the quality of the palmprint image in these regions may be futile. Therefore, any well known enhancement algorithm may be used to improve the clarity of ridges/wrinkles structures of palmprint images in recoverable

regions and to mask out the unrecoverable regions. The steps involved in image enhancement are given in [12]. The process starts with normalization of input palmprint image so that it has pre-specified mean and variance. The orientation image is estimated from the normalized input palmprint image. Further, frequency image is computed from the normalized input palmprint image and the estimated orientation image. After computation of frequency image the region mask is obtained by classifying each block in the normalized input palmprint image into a recoverable or unrecoverable block. Lastly, a bank of Gabor filters which is tuned to local ridge orientation and ridge frequency is applied to the ridge and valley pixels in the normalized input palmprint image to obtain an enhanced palmprint image.

### 2.2.2 Minutiae Extraction

The enhanced palmprint image is binarized and submitted to the thinning algorithm which reduces the ridge thickness to one pixel wide. The skeleton image is used to extract minutiae points which are the points of ridge endings and bifurcations. The location of minutiae points along with the orientation is extracted and stored to form feature set. For extraction of minutiae points eight connected pixels are used [13]. The Crossing Number (CN) method is used to perform minutiae extraction. This method extracts the ridge endings and bifurcations from the skeleton image by examining the local neighborhood of each ridge pixel using a 3×3 window. The CN for a ridge pixel *P* is given by

$$CN = 0.5 \sum_{i=1}^{8} | P_i - P_{i+1} | \qquad (4)$$

$$P_9 = P_1$$

where *Pi* is the pixel value in the neighborhood of *P*. After the CN for a ridge pixel has been computed, the pixel can then be classified according to its CN value. A ridge pixel with a CN of one corresponds to a ridge ending, and a CN of three corresponds to a bifurcation. For each extracted minutiae point, the following information is recorded:

- *x* and *y* coordinates,
- orientation of the associated ridge segment, and
- type of minutiae (ridge ending or bifurcation)

### 2.2.3 Matching

The template database and query palmprints are used for minutiae extraction and stored as points in the two dimensional plane. A minutia based matching essentially consists of finding alignment between the template and the input minutiae sets that results in the maximum number of minutiae pairings. Let A = $\{m_1 \ldots\ldots m_m\}$ and B = $\{m_1 \ldots\ldots m_n\}$ be the set of minutiae points extracted from database and query images respectively. Where m={x,y,θ}, x and y are the coordinates at particular minutiae point and θ is the orientation. The two sets are paired using

$$sd = \sqrt{(x'_j - x_i)^2 + (y'_j - y_i)^2} \le r_0 \qquad (5)$$

$$dd = \min(| \theta'_j - \theta_i |, 360 - | \theta'_j - \theta_i |) \le \theta_0$$

Minutiae in A and a minutia B are considered to be matched if the spatial distance (sd) between them is smaller than a given tolerance $r_0$ and the direction difference (dd) between them is smaller than an angular tolerance $\theta_0$. The paring generates a similarity score ($MS_{Palmprint}$) which is passed to decision module.

## III. FUSION

No individual trait can provide 100% accuracy. Further, the results generated from the individual traits are good but the problem arises when the user is not able to give his iris image due to problem in exposure to light. As eye is the most sensitive organ of human body, the problem becomes severe when there exist some eye diseases. Thus in such a situation an individual cannot be recognized using the iris patterns and the biometric system comes to a standstill. Similarly, the problem faced by palmprint recognition system is the presence of scars and cuts. The scars add noises to the palmprint image which cannot be enhanced fully using enhancement module. Thus, the system takes noisy palmprint as input which is not able to extract the minutiae points correctly and in turn, leads to false recognition of an individual. Thus to overcome the problems faced by individual traits of iris and palmprint, a novel combination is proposed for the recognition system. The integrated system also provide anti spoofing measures by making it difficult for an intruder to spoof multiple biometric traits simultaneously. Scores generated from individual traits are combined at matching score level using weighted sum of score technique. Let $MS_{Iris}$ and $MS_{Finger}$ be the matching scores obtained from iris and palmprint modalities respectively. The steps involved are:

### 3.1 Score Normalization

This step brings both matching scores between 0 and 1 [14]. The normalization of both the scores are done by

$$N_{Iris} = \frac{MS_{Iris} - \min_{Iris}}{\max_{Iris} - \min_{Iris}}$$
$$N_{Palmprint} = \frac{MS_{Palmprnt} - \min_{palmprint}}{\max_{Palmprint} - \min_{Palmprint}} \quad (6)$$

where $\min_{Iris}$ and $\max_{Iris}$ are the minimum and maximum scores for iris recognition and $\min_{Palmprint}$ and $\max_{palmprint}$ are the corresponding values obtained from palmprint trait.

### 3.2 Generation of Similarity Scores

Note that the normalized score of iris which is obtained through Haar Wavelet gives the information of dissimilarity between the feature vectors of two given images while the normalized score from palmprint gives a similarity measure. So to fuse both the score, there is a need to make both the scores as either similarity or dissimilarity measure. In this paper, the normalized score of iris is converted to similarity measure by

$$N'_{Iris} = 1 - N_{Iris} \quad (7)$$

### 3.3 Fusion

The two normalized similarity scores $N'_{Iris}$ and $N_{palmprint}$ are fused linearly using sum rule as

$$MS = \alpha * N'_{Iris} + \beta * N_{Palmprint} \quad (8)$$

where α and β are two weight values that can be determined using some function. In this paper a combination of linear and exponential function is used. The value of weight is assigned linearly if the value of matching score is less than the threshold; otherwise exponential weight age is given to the score. The value of MS is used as the matching score. So if MS is found to be more than the given threshold value the candidate is accepted otherwise it is rejected.

## IV. EXPERIMENTAL RESULTS

The results are tested on iris and palmprint images collected by the authors. The database consists of three iris images (250×3) and two palmprint images (250×2) per person with total of 250 persons. The iris images are acquired using CCD camera with uniform light source. However, palmprint images are acquired using an optical palmprint scanner. For the purpose allowing comparisons two levels of experiments are performed. At first level iris and palmprint algorithms are tested individually. At this level the individual results are computed and an accuracy curve is plotted as shown in Figure 1. At this level the individual accuracy for iris and palmprint is found to be 94.36% and 92.06% respectively as shown in Table 1. However in order to increase the accuracy of the biometric system as a whole the individual results are combined at matching score level. At second level of experiment the matching scores from the individual traits are combined and final accuracy graph is plotted as shown in Figure 2. Table 1 shows the accuracy and error rates obtained from the individual and combined system. The overall performance of the system has increased showing an accuracy of 97.04% with FAR of 0.58% and FRR of 4.34% respectively. Receiver Operating Characteristic (ROC) curve is plotted for Genuine Acceptance Rate (GAR) against False Acceptance Rate (FAR) for individual recognizers and combined system as shown in Figure 3. From the plot it is clear that integrated system is giving highest GAR at lowest FAR. The Histograms for genuine and imposter data are shown in Figure 4 below. The distribution of genuine and imposter data shows that at threshold of 0.5 the system would give minimum FAR and FRR rates with maximum accuracy of 97.04%.

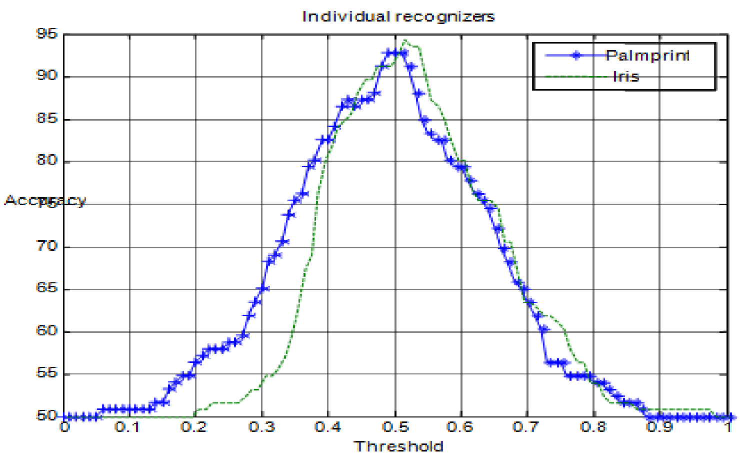



**Figure 1.** Accuracy plots of individual recognizers

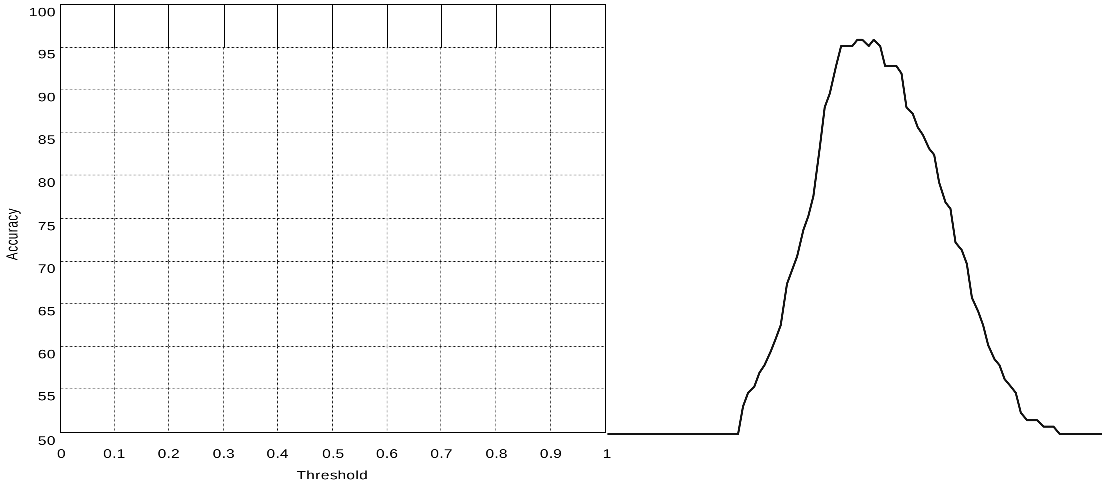



**Figure 2.** Accuracy graph for combined classifier

**Table 1.** Figures showing individual and combined accuracy

| Trait | Algorithm | Accuracy | FAR | FRR |
|---|---|---|---|---|
| Iris | Haar Wavelet | 94.36 | 4.85 | 6.43 |
| Palmprint | Gabor Matching | 92.06 | 3.17 | 12.69 |
| **Fusion** | **Haar Minutiae** | **97.04** | **0.58** | **4.34** |

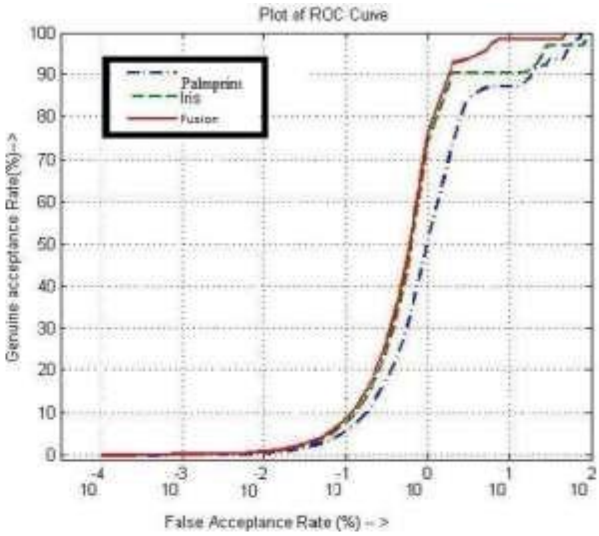
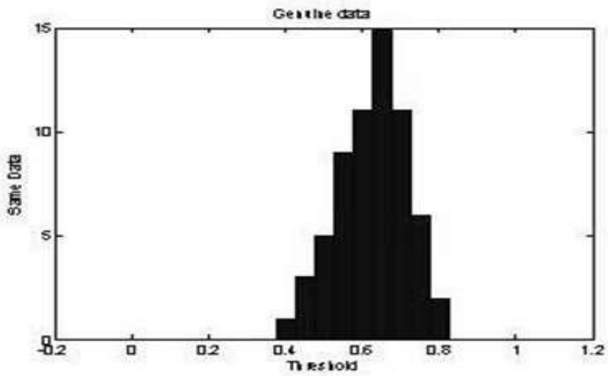
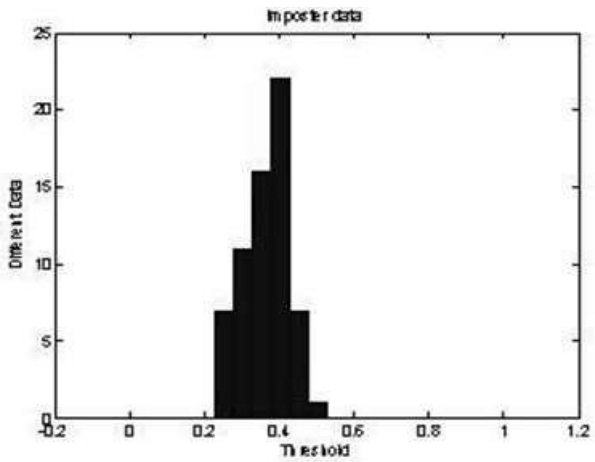



**Figure 3.** ROC Curve for Palmprint, Iris and Fusion



(a)




**(b)**

**Figure 4.** Histogram for (a) genuine and (b) imposter scores

## V. CONCLUSIONS

The paper proposes a biometric personal authentication system using a novel combination of iris and palmprint. For system deployment the combination is found to be useful as one needs a close up system and other needs contact. One modality is used to overcome the limitations posed by the other. The experimental results show that the accuracy of system would increase on combining the traits. The system is giving an overall accuracy of 97.04% with FAR and FRR of 0.58% and 4.34%.

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