An Expert Multi-Modal Person Authentication System Based on Feature Level Fusion of Iris and Retina Recognition

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***Abstract*—This research proposed a multi-modal person authentication system developed by feature level fusion of iris recognition and retina recognition. The reasons for choosing iris and retina as biometric characteristics are they provide the highest level of uniqueness, performance, universality, and circumvention. The 'curse-of-dimensionality' problem introduced in feature level fusion which was the main limitation of the prior works in this field, was minimized to a great extent by applying Principal Component Analysis (PCA) on the augmented feature template. To validate this approach, iris and retina images obtained from 'IITD' and 'DRIVE' datasets respectively are used. The recognition rate for the proposed multi-modal biometric system was 98.37% whereas it is 96.74% and 94.56% for iris recognition and retina recognition respectively.**

***Keywords*—Multimodal biometrics, iris recognition, retina recognition, feature level fusion, curse-of-dimensionality**

I. Introduction

Biometrics is an authentication technique by which an individuals identity is authenticated by the help of physical or behavioral characteristics of a human such as fingerprint, face, iris, retina etc. As the need for highly secure and more reliable biometric systems are increasing, it is necessary to improve unimodal biometric systems and hence, the concept of multi-modal biometric system has come which eliminates the drawbacks of the unimodal system and enhances the strength. The goal of this work is to develop a multimodal person authentication system by fusing iris and retina recognition. So there are three main parts of this work: iris recognition technique, retina recognition technique and fusion of iris and retina. The algorithms developed by John Daugman were used to implement the iris recognition system. For retina recognition system Isotropic Undecimated Wavelet Transform (IUWT), spline fitting, gradient method and Discrete Wavelet Transform (DWT) were used. Hamming distance measurement is used for classification for both iris and retina. Finally, the feature vectors known as templates obtained from these two recognition systems are augmented by feature level fusion and a multi-modal biometric system is formed. The empirical results show the proposed multi-modal authentication system is superior in terms of reliability, security and robustness than its unimodal constituents.

II. Background Study

In general sense, "biometric" refers to "life measurement". It is mainly used to distinguish an individual by the utilization of unique biological or behavioral characteristics. It is a new medium of verifying authenticity. It utilizes biological characteristics like face, retina, fingerprint etc. or behavioral like hand geometry, voice, signature etc. features to recognize an individual [1].

A. Biometric Systems

Biometric systems can be of mainly two types [2]. Such as:

- Unimodal biometric system - perform a person's recognition based on only a single source of biometric information
- Multi-modal biometric system - perform a person's recognition based on multiple sources of biometric information

Unimodal biometric systems have many limitations and problems like: lack of universality, noisy signals, high in-class and low inter-class variability, unacceptable error rates etc. [3]. To overcome these problems and drawbacks of unimodal biometric systems, the multimodal systems are used. Multimodal biometric systems can be accomplished in different ways such as Multi-Sensor Systems, Multi-Method Systems, Multi-Capture or Instance Systems and so on [3].

B. Fusion

The process of combining the information collected from different modalities is known as fusion. Information gathered from different modalities like face, iris, retina, fingerprint and so on are used for the multi-modal biometric authentication system. The fusion can be accomplished mainly in two different ways [4]. Such as:

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- Fusion before matching (Sensor level fusion, Feature level fusion)
- Fusion after matching (Matching score level fusion, Rank level fusion, Decision level fusion)

C. Selected Biometric Characteristics

Among various biometric characteristics, Iris and Retina are used for this research work. The reasons for choosing these two may be summarized as follows: [5], [6]

- A unique structure shaped by 10 months of age
- Remains stable throughout the lifetime
- No actual contact with a scanner
- Recognition carried out through Contact lenses or glasses
- A person's two eyes have an absolutely different pattern
- Twin baby have isolated iris
- Highly secured organ
- High accuracy and high recognition Speed
- Externally invisible; low-intensity infrared light is used to scan the back of the eye
- Random blood vessel pattern of great complexity and uniqueness

III. Iris Recognition System

Iris recognition is a process of extracting, representing and comparing the textural intricacy present on the surface of the iris. Although at present there exists many iris recognition model, the model proposed by Professor John Daugman is used in this research work. The whole system can be accomplished by the following five steps [6]:

1) Iris image acquisition
2) Iris segmentation
3) Iris normalization
4) Feature extraction and encoding
5) Matching

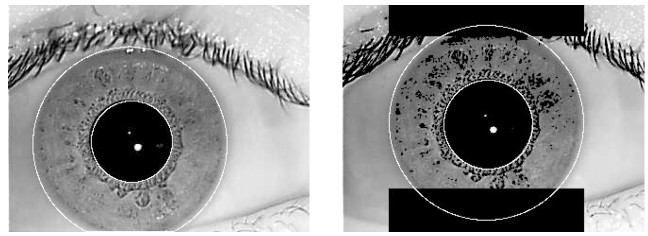
A. Iris image acquisition

Iris image acquisition means iris image capturing by iris scanner. This can be accomplished by any iris camera available in the market. Some of these are enlisted in article 4.3.1. However, in this thesis work, we have used publicly available IIT Delhi Iris Database Version 1.0 [7]. This database contains left and right eye images of 224 individuals each subject having ten various images.

B. Iris Segmentation

After the acquisition of the eye image, the next step is to isolate the iris area from the eye image. Iris region is divided into two circles such as iris/sclera boundary and iris/pupil boundary(interior to iris/sclera boundary). This process is known as segmentation. It can be done by following steps:

- **Specular noise and eyelash detection:** Convolution of separable eyelashes and Gaussian smoothing function are used.
- **Iris and pupil localization:** Candidate edge pixels were approximated by Canny Edge Detection algorithm. Iris & pupil boundaries were found by Circular Hough Transform.
- **Eyelids detection:** Candidate edge pixels were approximated by Canny Edge Detection algorithm. Eyelid & eyelash regions were detected by Linear Hough Transform.



(a) Detection of Iris and Pupil Boundaries

(b) Image after the Removal of Eyelids and Eyelashes

Fig. 1: Iris Segmentation

C. Iris Normalization

After successful segmentation of proper iris region, the next task is to normalize it into a rectangular box to sustain the pattern for successful matching. In a word, normalization means a transformation of the iris region into a fixed dimension. It is done to minimize dimensional inconsistencies. Dimensional inconsistencies may be introduced for several reasons like changing imaging distance, pupil dilation, rotation of the camera and eye and so on. Circular iris region is transformed into a fixed rectangular dimension by **Daugmans Rubber Sheet Model** [5].

(a) Normalized Iris Region

(b) Noise Array

Fig. 2: Image of Iris Region after Normalization

D. Feature Extraction and Encoding

In feature extraction and encoding step, the most significant and discriminating features are extracted. It is done so that the system is able to provide accurate recognition rate. For successful comparisons between iris templates, only the significant features of the iris image must be encoded. Encoding of iris features and creation of templates can be carried out by different algorithms. But in this research,**1D Log-Gabor filters** [8] is used for this purpose.

E. Matching

Feature matching means comparing different templates to verify whether they are the same iris or different irises. It can be done in different methods. In this work, matching is done by **Hamming distance measurement** [9]. In Hamming distance measurement bit-wise comparisons of iris templates are necessary. Noise mask is also considered during Hamming distance calculation. Calculated Hamming distance is compared with the predefined threshold to differentiate between genuine and impostor access. The threshold value was selected by taking several values and calculating FAR (False Accept Rate) and FRR (False Reject Rate).

IV. Retina Recognition System

The retina is an ultra-thin layer made of nerve cells and blood vessels behind the eyeball. The retina recognition means the recognition of the complex blood vessel specimen of the retina. From a person's retina, the unique vessel model is obtained by retinal scanning. By the help of precise lighting, the vessel pattern can be identified easily. Light is absorbed more smoothly in the blood vessels of the retina than the neighboring tissue. At first, the scanner's eyepiece is set in front of a person's eyeball. Then a small energy light is thrown for performing the retinal scan. An ascertained line is marked by the ray of light at the retina surface. Identification process of a retinal scanning system is similar to other biometric technologies. Retina recognition is accomplished in four main steps [10]:

1) Retinal image acquisition
2) Retinal vessel segmentation
3) Unique feature extraction
4) Feature matching

A. Retinal image acquisition

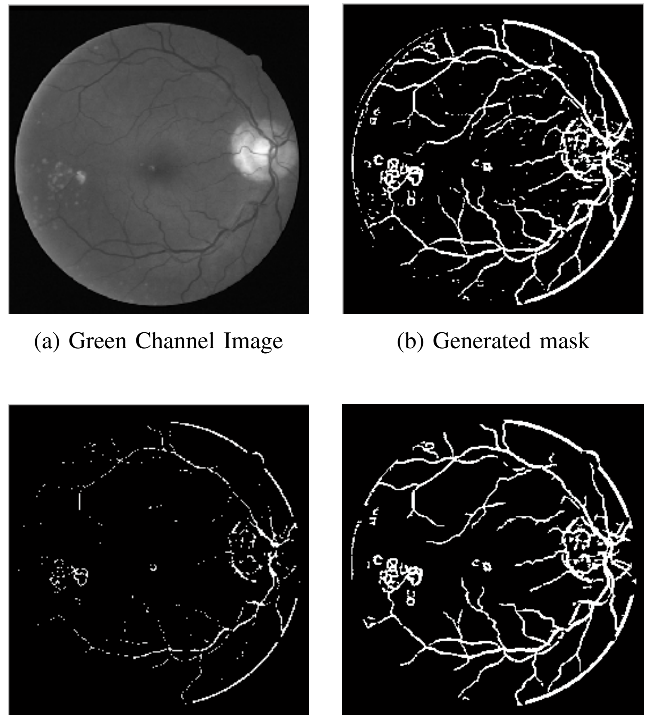
There are different types of retina scanning devices for capturing the digital images of the retina and these devices scan the back of the eye to get the retinal images. But all the retinal images used in this research were collected from DRIVE (Digital Retinal Images for Vessel Extraction) database [11].

B. Retinal vessel segmentation

After the retinal image acquisition, the vascular pattern of retina needs to be identified. In this thesis work retinal vessel segmentation is carried out by Isotropic Undecimated Wavelet Transform (IUWT). This is a process of following steps [10]:

1) At first from the original retinal image, the green channel image was selected
2) A mask was generated by thresholding
3) The Isotropic Undecimated Wavelet Transform (IUWT) was applied on the green channel retinal image
4) Wavelet coefficients were thresholded for the removal of small objects and holes
5) The spline fitting was applied to determine the centerlines of retinal vessels
6) Finally, edges were detected perpendicular to centerlines by zero crossings

The outcomes of this step are shown in the following figures:



(a) Green Channel Image (b) Generated mask

(c) Generated marker (d) Segmented retinal image

Fig. 3: Retinal vessel segmentation

C. Unique Feature Extraction

Once the retinal blood vessel detection using gradient orientation analysis is done, the feature extraction is done by analyzing the segmented retinal image using multi-resolution analysis through the wavelet-based approach [12]. Then two-dimensional wavelet transformation decomposes the image in several directions. By using filters, discrete wavelet transformation (DWT) is implemented, and the wavelet energies in horizontal, vertical, and diagonal direction are calculated. Finally, the feature template is obtained. This feature template is used to represent the global features of the blood vessels.

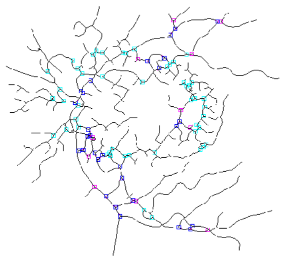
The obtained feature template from this step is then encoded as in the iris recognition system and hence, the template is generated. The outcomes of this step are shown in the following figures:

D. Feature Matching

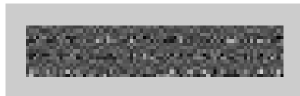
Feature matching means comparing different templates to verify whether they are the same retina or different retina. It can be done in different methods. In this work, matching is done by **Hamming distance measurement**, the same procedure as iris template matching.

V. Feature Level Fusion

Feature templates obtained from different sources are concatenated in feature level fusion. Let feature vectors gathered from different sources are denoted by $X =$



(a) Extracted feature points



(b) Generated feature template

Fig. 4: Unique feature extraction

$\{x_1, x_2, x_3, ..., x_m\}$ and $Y = \{y_1, y_2, y_3, ..., y_m\}$. To form a new feature vector, Z, these two feature sets are combined. It is done because it can represent the individual more accurately. At first the two feature vectors X and Y are augmented and then feature selection is performed on the resultant feature vector and hence the final feature vector Z is generated [13]. This process can be divided into three steps:

1) Feature normalization
2) Feature augmentation
3) Feature selection

A. Feature Normalization

As feature sets can be heterogeneous, normalization is done to map them in a common form before augmentation. The aim of this step is to manipulate the mean and variance of the features values. It ensures that the contribution of every component is comparable to the final match score. It can be carried out by various methods. **Min-Max Normalization** is used for normalization in this work [14].

B. Feature Augmentation

In this step, the normalized feature sets of iris and retina were augmented to form a newly combined feature vector. In this work, the normalized iris and retinal templates were represented as 20×240 matrices. Hence the concatenation of two matrix results in a new feature matrix of size 20×960. The obtained new feature matrix is shown in the following figure:

Fig. 5: Augmented feature template

C. Feature Selection

Feature augmentation may result in **'curse-of-dimensionality'** problem. It indicates that the augmented feature vector may not improve the matching performance of the system. What is more is that some feature values may be 'noisy' compared to the others which is a serious issue. To get rid of the problems which may happen during feature augmentation some techniques need to be applied for appropriated feature selection. It is done to choose a minimal feature set that improves performance. In this research work, the **Principal Component Analysis(PCA)** is applied to this purpose [15]. The resultant new feature vector looks like: $Z = \{z_1, z_2, z_3, ..., z_k\}$. The outcomes of this step are shown in the following figures:

Fig. 6: Augmented feature template

VI. Experimental Result

In order to validate the correctness and reliability of the proposed multimodal biometric authentication system, an experimental analysis is done. IIT Delhi iris database version 1.0 [7] and DRIVE (Digital Retinal Images for Vessel Extraction) database [11] were used to test Iris Recognition System and Retina Recognition System respectively. From these images 47 intra-class comparisons and 137 inter-class comparisons were made to evaluate the performance and recognition rate of three proposed systems.

For 47 intra-class comparisons and 137 inter-class comparisons the number of successfully recognized items for three systems can be shown in the following table:

TABLE I:

No. of successful recognition of unimodal and multi-modal biometric systems for intra-class and inter-class comparisons

	No. of Successful Intra-Class Comparisons	**No. of Successful Inter-Class Comparisons**
Iris Recognition System	46	132
Retina Recognition System	44	130
Multimodal Biometric System	47	134

The False Accept Rate(FAR) and the False Rejection Rate(FRR) of these systems can be shown as follows. Here, the false accept rate (FAR) means the biometric system will incorrectly accept an unauthorized individual. The false rejection rate (FRR) means the biometric system will incorrectly reject an authorized individual.

TABLE II:

FAR and FRR for unimodal and multi-modal biometric systems

	Number of Iris Image Pair	**Successfully Recognized**	**False Acceptance Rate(%)**	**False Rejection Rate(%)**
Iris Recognition	184	178	1.08	2.18
Retina Recognition	184	174	1.63	3.81
Multimodal Biometric System	184	181	0	1.63

And finally, the following table represents the recognition rates of the unimodal systems(i.e, iris and retina recognition system) and the multi-modal biometric system.

TABLE III:

Comparison among iris recognition system, retina recognition system and the multi-modal system in terms of recognition rate

Biometric Method	Recognition Rate(%)
Iris Recognition	96.74
Retina Recognition	94.56
Feature Level Fusion ofIris and Retina	98.37

VII. Conclusion

The developed multi-modal person authentication system is able to provide better accuracy and performance than its constituent unimodal biometric systems. From the result section it is clear that while iris recognition and retina recognition falsely accept some samples, the false accept rate for the multi-modal biometric system is zero and the recognition rate is the highest. In the prior works on this field [16] the main problem associated with feature level fusion i.e. **'curse-of-dimensionality'** problem was minimized by feature selection. The problem occurred because when the two different templates were fused, the dimensionality of the augmented feature template was increased. This reduces the performance of the multi-modal system. This problem is minimized by feature selection by **Principal Component Analysis (PCA)**.

Though the developed system is able to fulfill the requirements of the proposed system it has some constraints like: iris segmentation problem, used algorithms were not enough universal, sensitive to noise which gives an opportunity of future work in this field.

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