

# Robust Iris Recognition Based on Statistical Properties of Walsh Hadamard Transform Domain

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## Abstract

In this paper, a new approach of iris image feature extraction technique based on the statistical properties of Walsh Hadamard Transform (WHT) domain is proposed. A Canny Edge Detection followed by Hough Transform is used to detect the iris boundaries in the digital image of an eye. The segmented and normalized iris region is divided into 8x8 non-overlapping blocks and WHT is applied to each block. Unique iris features are obtained by computing mean value of energy (MVE) and mean value of standard deviations (MSD) of WHT coefficients. The energy-compaction characteristics of WHT are used to capture iris texture variations. Fast Walsh Hadamard Transform Algorithm is used to reduce the computational time. The features extracted by the WHT domain are used to generate unique encoded binary image and corresponding unique binary bit stream/code is constructed. In order to reduce the size of the database, this binary bit stream instead of binary image is stored in database for matching purpose. Further to increase the security of the system, the bit stream obtained is first encrypted using the user key obtained from user password and then the encrypted bit pattern template is stored. Experimental results on Bath University Iris Database reveal that the proposed iris matching scheme provides results comparable to those of recent methods and is also computationally effective.

**Keywords:** *Iris recognition, Walsh Hadamard Transform, biometrics, human identification, image preprocessing.*

## 1. Introduction

Automatic reliable personnel identification systems using biometrics have received a great importance in the past few years. Biometric refers to a science of analyzing human physiological or behavioral characteristics for security purposes. The Biometric characteristics cannot be faked, forged, guessed and stolen easily. One need not remember his/her biometric traits [1].

Iris is the round contractile membrane of the eye suspended between cornea and lens which is perforated by the pupil. Iris begins to form during gestation and by the eighth month of the pregnancy it gets completely formed. The iris of the human eye is so unique that no two irises are alike, even among identical twins or even between the left and right eye of the same person, in the entire human

population. Also changing iris pattern of any person without surgery with high risk is impossible. Thus it is considered as one of the most reliable biometric in case of biometrics-based identification/recognition systems [2, 6].

A typical iris recognition system involves four main modules. The first module, image acquisition deals with capturing sequence of iris images from the subject using cameras and sensors. The second module, preprocessing involves various steps such as iris liveness detection, pupil and iris boundary detection, eyelid detection and removal and normalization. Several methods like Hough transformation, integro-differential operator, gradient based edge detection are used to localize the portions of iris and the pupil from the eye image. It is essential to map the extracted iris region to a normalized form. The iris localization methods are based on spring force, morphological operators, gradient, probability and moments. The third module, feature extraction identifies the most prominent features for classification. The features are encoded to a format suitable for recognition. The fourth module, recognition achieves result by comparison of features with stored patterns [6, 11].

A major approach for iris recognition today is to generate feature vectors corresponding to individual iris images and to perform iris matching based on different metrics [15]. One of the difficult problems in feature based iris recognition is that, the speed of matching is significantly influenced by time required for feature extraction process, size of the template database stored, format of the template database etc. Thus fast, robust and secured implementation techniques are needed.

The rest of this paper is organized as follows. Section 2 provides overview of related works. Section 3 provides the outline of the proposed algorithm for Iris Recognition system. Experimental results are compared with the results of previous works in Section 4; followed by the conclusions in Section 5.

## 2. Related Works

Daugman's system is the first known algorithm for iris recognition [1]. It consists following major stages:

1. Pre-processing stage: To detect the edges of the pupil and iris and to locate the position of the iris within the image with an integro-differential operator.
2. Feature extraction stage: To extract iris image pattern using bi-dimensional Wavelets
3. Feature matching stage: To perform the feature matching process with the XOR function applied to the iris code generated and iris template codes stored in the database.

Wildes [2] proposed the algorithm which first convert image into a binary edge map and then detect circle using Hough transform. Laplacian filter at multiple scales is used to extract features. Finally, the matching between two iris images is done using normalized correlation. S'anchez-Reillo [4] used the left and right portion of the iris in order to avoid the missing data due to eye lashes along with Gabor filters for feature extraction. Liu Yang [5] encrypted the iris code using one way coupled map lattice in order to protect of stored template data. Zhonghua Lin and Bibo Lu [7] used the imaginary coefficients of Morlet Wavelet Transform at different scales to generate the binary code of the iris image. Jing Huang et al., [8] proposed iris recognition based on non separable wavelet. After decomposing iris image into wavelet sub band coefficients using sixteen non-separable wavelet filters, Generalized Gaussian Density (GGD) modeling of each non separable orthogonal wavelet coefficient was carried for feature extraction. The Kullback Leiblar distance between GGDs was computed for matching. Mohammed Abdullah [9] presented an algorithm using wavelet transform for iris recognition where the feature vector is stored in the form of binary code.

All above mentioned techniques are computationally intensive and the size of the template database formed by the extracted feature vectors is large.

### 3. Proposed Scheme

The proposed scheme consists of following processing stages as shown in Figure 1 and the detailed procedure in case of iris identification process is as follows,

#### 3.1 IRIS Recognition

The stages involved in most iris recognition systems consist of following basic modules as shown in Figure 1.

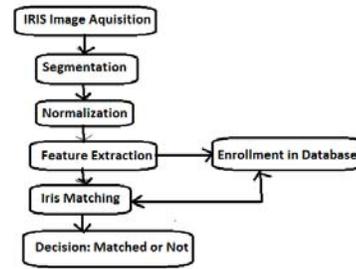


Fig.1. Typical iris recognition schemes

#### 3.2 Segmentation

The segmentation module locates the position of the iris within the image by isolating it from the sclera, pupil, eyelids, and eyelashes.

##### 3.2.1. Canny Edge Detection and Localization

Canny edge detection is used to create an edge map [6, 9]. The Canny method finds edges by looking for local maxima of the gradient of the iris image. The Canny edge detects strong and weak edges, and includes the weak edges in the output only if they are connected to strong edges. This method is therefore less likely than the others to be fooled by noise, and more likely to detect true weak edges. Here the boundary of an iris is located using parameters like centre coordinates  $x$  and  $y$ , the radius  $r$ , which are related according to the following equation,

$$x^2 + y^2 = r^2 \quad (1)$$

In performing the preceding edge detection step, the derivatives of the horizontal direction is to detect the eyelids, and the vertical direction is to detect the outer circular boundary of the iris. The radius of the iris image is determined and provided to the Hough transform. For better accuracy, the Hough transform is carried out initially for iris/sclera boundary and then for iris/pupil boundary.

##### 3.2.2. Hough Transform

The Hough transform is a feature extraction technique used in image analysis, computer vision, and digital image processing [2]. It finds imperfect instances of objects within a certain class of shapes by a voting procedure. This voting procedure is carried out in a parameter space, from which object candidates are obtained as local maxima in a so-called accumulator space that is explicitly constructed by the algorithm for computing the Hough transform.

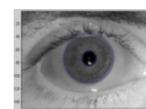


Fig.2. Detection of circular boundaries of pupil and iris.

Canny edge detection is used to build the edges in horizontal direction and then the Parabolic Hough transform is applied on it to detect the eyelids, approximating the upper and lower eyelids with parabolic arcs. If the maximum Hough space is below the threshold then it indicates the non occlusion of eyelids. For isolating eyelashes it is very easy by utilizing thresholding. This is because they are darker while comparing with further elements in eye [2].

### 3.3 Normalization

Once the segmentation module has estimated the iris's boundary, the normalization/iris unwrapping module transforms the iris texture from Cartesian to polar coordinates.

The normal Cartesian to polar transformation is recommended which maps the entire pixels in the iris area into a pair of polar coordinates  $(r, \theta)$ , where  $r$  and  $\theta$  represents the intervals of  $[0 \ 1]$  and  $[0 \ 2\pi]$  as shown in figure 3.

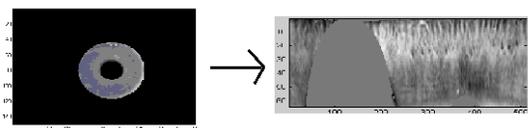


Fig.3. Normalized Iris

Normalization has advantages like, It accounts for variations in pupil size due to changes in external illumination that might influence iris size, It ensures that the irises of different individuals are mapped onto a common image domain in spite of the variations in pupil size across subjects etc.

#### 3.3.1. Histogram Equalization

Histogram equalization is done on each iris template to generate an image whose intensity also covers the entire range of intensity levels. The normalized iris image has very low contrast and it could have a non-uniform brightness in different parts of the image due to the light applied at the acquisition time. This makes the iris texture seem to be with less contrast than it really is. The contrast enhancement of the image is accomplished by means of histogram equalization in order to use the full spectrum of gray levels, hence the textures are highlighted (see figure 4). Further, filtering operation can be applied to remove noisy components.

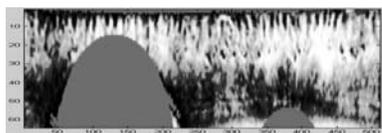


Fig.4. Enhancement of the iris normalized image.

### 3.4 Feature extraction

**Step 1:** In feature extraction stage, the above processed iris region is first resized and segmented into non-overlapping  $8 \times 8$  non-overlapping blocks as shown in figure 5.

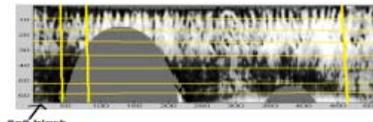


Fig.5. Normalized iris image resized in convenient form

If  $X$  denotes the rectangular iris template having size  $N \times M$ , then

$$X = (x(1), x(2), \dots, x(N_b)) \quad (2)$$

where,  $x(i)$  is  $i^{\text{th}}$  block and  $N_b = (N \times M / 64)$  is total number of blocks.

**Step 2:** Convert each block into 1D vector and apply Walsh Hadamard Transform (WHT) to each of the blocks as,

$$WX_k = \frac{1}{N} (H_M X_k) \quad (3)$$

and the corresponding inverse transform as,

$$X_k = (H_M WX_k) \quad (4)$$

Where the square and symmetric Hadamard transform matrix  $H_m$  of order  $m$  is recursively defined as,

$$H_m = \begin{pmatrix} H_{m/2} & H_{m/2} \\ H_{m/2} & -H_{m/2} \end{pmatrix} \quad (5)$$

for  $m > 1$  and  $m = 2^k$  with  $H_1 = [1]$ .

Since  $H_m$  contains only the  $+1$  or  $-1$  entry, the transformation requires only real additions and subtractions. Further, using matrix factorization or matrix partitioning on the Hadamard matrix of order  $m = 2^n$ , Fast Walsh Hadamard Transform (FWHT) can be implemented. For an  $N$ -sequence, the number of operations is reduced from  $(N^2)$  to  $(N \log_2 N)$  additions and subtractions and thus, increasing the speed of processing [12-14].

**Step 3:** The energy compaction characteristics of WHT captures texture variations in its coefficients. The statistical parameters can be used to capture both local and global variations of iris texture in order to create feature vector template further. Calculate the energy of each block vector as,

$$E_k = \frac{1}{N_k} \sum_{i=1}^{N_k-1} \|WX_i\|^2 \quad (6)$$

Where,  $E_k$  is energy of  $k^{\text{th}}$  block and  $N_k = 64$  is total number of WHT coefficients in each vector.

**Step 4:** Calculate the standard deviation of each block vector as,

$$S_k = \text{std}(X_k) \quad (7)$$

Where,  $S_k$  is standard deviation of  $k^{\text{th}}$  block.

**Step 5:** Capture the global variations/features of iris using mean value of energy (MVE) and mean value of standard deviation (MSD) of whole iris template image which are given as,

$$MVE = \frac{1}{N_b} \sum_{l=1}^{N_b} E_l \quad (8)$$

$$MSD = \frac{1}{N_b} \sum_{l=1}^{N_b} S_l \quad (9)$$

Where,  $N_b=(N \times M/64)$  is total number of blocks.

**Step 6:** Form binary image template using both local and global iris texture variations using the following criteria.

For a  $k^{\text{th}}$  block, if both  $E_k$  is greater than MVE and  $S_k$  is greater than MSD then set all pixels of corresponding  $8 \times 8$  block of binary template as 255 i.e. all white pixels.

Else set all pixels of corresponding  $8 \times 8$  block binary template as 0 i.e. all black pixels as shown in figure 6.



Fig.6. Binary image template formed using MVE and MSD in WHT domain.

**Step 7:** Form final binary bit stream/unique code B corresponding to above binary iris image template using following rule,

If all pixels of  $8 \times 8$  block is marked as 0 then corresponding bit will set as 0 else corresponding bit will set as 1.

$$B = (b(1), b(2), \dots, b(N_b)) \quad (10)$$

This bit pattern will be stored in database for recognition purpose. So the size of overall database is reduced as only binary bitstream of  $N_b$  bits is stored instead of  $N \times M$  sized binary image template. This also increases the computational speed of searching the code during matching process.

**Step 8:** Further to increase the security of the system, the above binary bit stream B is first encrypted using the user key (K) obtained from user password and then the encrypted bit pattern template is stored.

### 3.4.1 Iris Template Matching Process

The matching algorithm consists of all the image processing steps that are carried out at the time of enrolling the encoded iris template in database. User also needs to input the same password to form user key (K). Once the bit encrypted bit pattern B' corresponding to binary image formed is extracted, it is tried to match with all stored encrypted bit patterns B using simple boolean XOR operation. The dissimilarity measure between any two iris bit patterns is computed using Hamming Distance (HD) which is given as,

$$HD = \frac{1}{N_i} \sum_{l=1}^{N_i} X_l (XOR) Y_l \quad (11)$$

Where,  $N_i$ =total number of bits in each bit pattern,  $X_i$ =bit pattern corresponding to the iris image to be matched and  $Y_i$ =bit pattern stored in the template database. As HD is a fractional measure of dissimilarity with 0 representing a perfect match, a low normalized HD implies strong similarity of iris codes.

## 4. Experimental results

### 4.1 Experimental setup

In order to test the performance of the proposed method, a set of eye images obtained from the *Bath University Repository* [10] were used. Figure 7 shows an example of the eye images contained in this database. The data set consists of all grayscale images. Matlab R2009b is used on Intel Core 2 Duo (2.1 GHz) machine with 2GB RAM for the simulation purpose. The time needed for iris recognition was approximately 2-3 seconds. The searching period depends on the database size. There were total 80 numbers of irises stored in the database for this experiment. Figure 8 shows the outputs obtained at each processing stages along with the final binary image template.

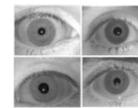


Fig.7. Examples images of the Bath University database

A unique bit stream is constructed from it as shown in figure 9, which is further encrypted using user key K and final encrypted bit stream is stored in the database. This drastically reduces size of total database along with providing higher security against compromise of template database.

|                 |                          |                 |                        |           |                 |
|-----------------|--------------------------|-----------------|------------------------|-----------|-----------------|
|                 |                          |                 |                        |           |                 |
| Original Images | Pupil and Iris Detection | Normalized Iris | Histogram Equalization | Filtering | Binary Template |

Fig.8. Results obtained at different stages.

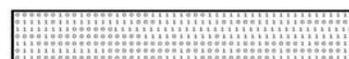


Fig.9. Sample Unique Binary Bit Pattern created representing Iris Features

## 4.2 Performance Evaluation

Following metrics are used to evaluate the performance of the system.

1) False Acceptance Rate (FAR): FAR is the measure of the likelihood that the biometric security system will incorrectly accept an access attempt by an unauthorized user [11]. A system's FAR typically is stated as the ratio of the number of false acceptances divided by the total number of identification attempts.

2) False Rejection Rate (FRR): A statistic used to measure biometric performance when operating in the verification task and defined as the percentage of times the system produces a false reject. A false reject occurs when an individual is not matched to his/her own existing biometric template.

3) Equal Error Rate (EER): EER is the rates at which both accept and reject errors are equal. In general, the lower the equal error rate value, the higher the accuracy of the biometric system. The EER is sometimes referred to as the "Crossover Error Rate".

The above performance parameters are evaluated by splitting total database of 100 persons into 80 and 20 persons. The database is created with 6 images per person i.e., total number of images in the database are 480. FRR is calculated by comparing seventh image of every individual with 480 images in the database of 80 persons. FAR is calculated by considering 20 individuals as imposters and are compared with 480 images in the database. Table 1 shows the resulted FRR and FAR for the proposed and existing technique.

Table1. FAR and FRR Comparison

| User  | Proposed Scheme |       |
|-------|-----------------|-------|
|       | FAR %           | FRR % |
| 1-10  | 0.01            | 0.02  |
| 10-20 | 0.05            | 0.03  |
| 20-30 | 0.02            | 0.05  |
| 30-40 | 0.08            | 0.10  |
| 40-50 | 0.02            | 0.01  |
| 50-60 | 0.04            | 0.05  |
| 60-70 | 0.11            | 0.05  |
| 70-80 | 0.03            | 0.01  |

From the result, it can be observed that the proposed technique results in lesser FRR and FAR. The value of EER obtained is 0.106. From all the results obtained, it can be said that the proposed technique results in better accuracy in recognition/verification process.

## 5. Conclusions

In this correspondence, we propose a novel robust iris recognition scheme having less computational complexity along with higher accuracy. Automatic segmentation is achieved through the use of the canny edge detector and

ough transform for localising the iris and pupil regions. The present work has empirically demonstrated the good performance of statistical properties like Mean Value of Energies and Mean Value of Standard deviations in WHT domain as a robust iris object Descriptor. The energy-compaction characteristics of WHT are used to capture iris texture variations. In order to reduce the size of the database, binary bit stream instead of binary image is stored in the database for matching purpose. Fast Walsh Hadamard Transform Algorithm along with reduced feature vector size provides faster recognition rate. Further to increase the security of the system, the bit stream obtained is first encrypted using the user key obtained from user password and then the encrypted bit pattern template is stored. Experimental results show that the proposed algorithm provides lesser FRR and FAR values during matching along with less computational complexity and better security. The future work will be carried out for real applications utilization such as generation of compact iris codes for mobile phones and PDAs.

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