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Biometric Authentication System based on Iris Patterns

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Abstract

In the present age of digital impersonation, biometric techniques are being used increasingly to prevaricate against identity thefts. Iris recognition is a proven, accurate means to identify people. Iris is regarded as the most reliable biometric feature in terms of its uniqueness and robustness. The objective of this work is to present a biometric authentication system for high security physical access control based on iris pattern. The proposed iris recognition with improvement in segmentation and matching stages using Hamming distance provides match for iris pattern if hamming distance is below 0.15. The CASIA IRIS image database of **C**hinese **A**cademy of **S**ciences **I**nstitute of **A**utomation is used and the system is implemented in MATLAB. The proposed approach found to report higher verification accuracy of 99.2%.

Keywords
Iris Recognition, Segmentation, Hamming Distance, CASIA, Gabor Filters

1. Introduction

Traditional methods for personal identification are based on what a person possesses (a physical key, ID card, etc.) or what a person knows (a secret password, etc.). These methods have some problems. Keys may be lost, ID cards may be forged, and passwords may be forgotten. In recent years, biometric personal identification is receiving growing interests from both academia and industry.

Biometrics, described as the science of recognizing an individual, based on physiological or behavioral traits and it is accepted as a legitimate method for determining an individual's identity, Biometric solutions analyze human characteristics for security, authentication and identification purposes [1]. Among the various physical biometric traits used for personal authentication Iris patterns have attracted a lot of attention in biometric technology because they have stable and distinctive features for personal identification.

Facial recognition faces many problems since face itself is a 3D object that varies depending on the angle, pose, illumination and age. In this, even best current algorithms have error rates of 43% to 50% [2].

Though many security forces have launched fingerprint identification for border crossing, airport security, approximately two percent of population does not have a legible fingerprint biometrics system.

Iris has become an interesting biometric modality with low false acceptances especially when there is a need to search a large database due to high pattern variability among different persons. Iris begins to form in the third month of gestation and the structures creating its patterns become unchangeable in two or three years. Furthermore, the iris pattern does not correlate with genetic determination since its forming depends on the initial environment of the embryo. This yields to the fact that even the left and the right irises for the same person are not identical. Thus iris has been taken as a biometric feature in this work.

2. Literature Review

The French ophthalmologist Alphonse Bertillon seems to be the first to propose the use of iris pattern (color) as a basis for personal identification [3]. In 1981, after reading many scientific reports describing the iris great variation, Flom and San Francisco ophthalmologist Aran Safir also suggested using the iris as the basis for a biometric.

In 1987, they began collaborating with computer scientist John Daugman of Cambridge University in England to develop iris identification software who published his first promising results in 1992 [4]. Flom and Safir were conferred patent [5] for their algorithm in 1987.

Daugman collaborating with Flom and Safir developed and introduced the application and usage of iris as a biometric characteristic for individual identification. Daugman has used 2D Gabor filters and phase coding to obtain 2048 binary feature code and tested his algorithm on many images successfully [6]. Daugman used multi-scale Gabor wavelets to demodulate the texture phase information. This algorithm segment iris image using Integro - differential operator and filter the iris image with a family of Gabor filters that generate 2048-bit complex valued iris code [7,8,9]. The difference between the two iris code is computed by measuring their Hamming distance. This algorithm is most widely implemented in the available systems in the world.

Boles and Boashash [10] generated one-dimensional (1-D) signals by calculating the zero-crossings of wavelet transform at various resolution levels over concentric circles on the iris. Comparison of the 1-D signals with model features using dissimilarity functions does the matching. Wildes [11] represented the iris texture with a Laplacian pyramid constructed with four different resolution levels and used the normalized correlation to determine whether the input image and the model image are from the same class.

Lim [12] method is based on key local variations. The local sharp variation points denoting the appearance or vanishing of an important image structure are utilized to represent the characteristics of the iris. This algorithm uses one-dimensional intensity levels to characterize the most important information and position sequence of local sharp variation points are recorded using wavelets. The matching has been performed by Exclusive OR operation to compute the similarity between a pair of position sequences.

Some of the problems present in the existing approaches are outlined below :

1) Eyelids and eyelashes bring about some noise edges and occlude the effective regions of the iris. This may lead to the inaccurate localization of the iris, resulting in the false non-matching.
2) The corneal and specular reflections will occur on the pupil and iris region. When the reflection occurs in the pupil from iris/ pupil border, the detection of the inner boundary of the iris fails.
3) The orientation of the head with the camera may result in the orientation of the iris image to some extent.

The above mentioned problems have been resolved by implementing an effective iris based authentication system based on Daugman's algorithm through improvement in iris segmentation.

3. Iris - A Biometric Feature

Iris recognition is considered to be the most reliable and is an emerging biometric solution for authentication in highly secured environments. Iris is the colored part of the eye behind the eyelids and in front of the lens. It is the only internal organ of the body that is externally visible.

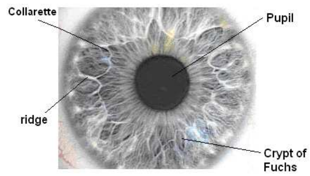

Fig. 1 Image of Human Iris

Fig. 1 shows the front view of human eye. The iris is protected by the eye's cornea and its function is to control the light intensity levels. The pupil is the aperture for the light entrance and it is controlled by the iris. The iris is embedded with tiny muscles that dilate and constrict the pupil size [14].

The iris is considered to be a reliable biometric for human identification for several reasons :

- It is an internal organ that is well protected against damage and wear by a highly transparent and sensitive membrane (the cornea). This distinguishes it from fingerprints, which can be difficult to recognize after years of certain types of manual labor.
- The iris is mostly flat, and its geometric configuration is only controlled by two complementary muscles (the sphincter pupillae and dilator pupillae) that control the diameter of the pupil. This makes the iris shape far more predictable than, for instance, that of the face.
- The iris like fingerprints has a fine texture that is determined randomly during embryonic gestation. Even genetically identical individuals have completely independent iris textures, whereas DNA (genetic "fingerprinting") is not unique for the about 0.2% of the human population.

3.1. Iris Images - CASIA Database

In order to make the iris recognition system to work efficiently a high quality image of the iris has to be captured. The acquired image of the iris must have sufficient resolution and sharpness to support recognition. The images used in the proposed work are from CASIA database captured using infrared cameras with high contrast and low reflections for good quality images. A sample image is shown in Fig. 2.

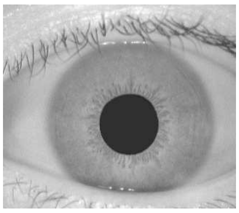

Fig. 2 Eye image from CASIA database

The CASIA database contains 756 grayscale eye images with 108 unique eyes or classes and 7 different images of each unique human eye. Images from each class are taken from two sessions with one interval between sessions. The images are captured especially for iris recognition research using specialized digital optics developed by National Laboratory of Pattern Recognition, China. The eye images are mainly from persons of Asian decent, whose eyes are characterized by irises that are densely pigmented with dark eyelashes.

Noise and artifacts exists in iris images, and they have a negative impact on the system performance. Such artifacts include the eyelash occlusion, the eyelid occlusion and the specular reflections.

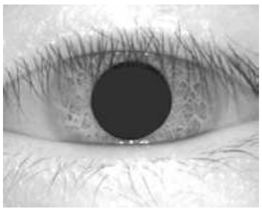

Fig. 3 Occluded Eye Image

Fig. 4 Iris image with specular reflections

Fig. 3 shows an iris image contaminated with both eyelash occlusion and eyelid occlusion. Therefore these should be detected and eliminated from the subsequent recognition process. Fig. 4 shows an example of iris image with specular reflections. Specular reflections are mirror like reflections, such as the light reflected on a tranquil water surface. Similarly in the iris image acquisition procedure, the specular reflections occur in such a way that the light source gets reflected and captured by the camera. The strong reflection intensity in the image results in high pixel values deviate absolutely from the original iris patterns. This constitutes a major source of distortion and therefore should be eliminated, in order to make the iris recognition more accurate.

3.2. Iris Recognition System

An effective iris based authentication system is implemented based on Daugman's algorithm through improvement in iris segmentation. The steps of the algorithm are diagrammatically represented in Fig. 5 and are as follows :

Step 1: Image acquisition is the first phase but the proposed approach uses images from CASIA database.

Step 2: Iris localization takes place to detect the edge of the iris as well as that of the pupil, thus extracting the iris region.

Step 3: Normalization is done to remove the dimensional inconsistencies between eye images due to stretching of iris caused by pupil dilation from varying levels of illumination.

Step 4: The normalized iris region is unwrapped into a rectangular region.

Step 5: Finally the most discriminating feature in the iris pattern is extracted to construct the iris code using Gabor filters. The iris code is compared with the templates to generate a matching score.

The iris and pupil of the eye image are segmented using canny edge detectors and circular Hough transform.

The iris region is first unwrapped into a rectangular region. Hence, the localized iris region is then normalized into a rectangular block to account for imaging inconsistencies.

A. Pupil Edge Detection

Pupil is a dark black circular region in an eye image. Hence pupil detection [15] is equivalent to detecting the black circular region. The steps involved in detecting pupil is as follows :

1) The eye image in Fig. 6 is converted to a binary image using a threshold value of 40, that is, if the pixel value is less than or equal to 40 it is converted into 255 (white) and if the pixel value is greater than 40 it is converted in to 0 (black) as in Eq. (1)

   $g(x) = 1$ for $f(x) > 40$; $g(x) = 0$ for $f(x) \leq 40$ (1)

   where f(x) is original and g(x) is the image after thresholding.
2) The resulting image will contain the pupil and some other noises (pixels whose value is less than 40 for e.g., eyelash).
3) To remove these noises morphological erosion and dilation is applied over the image.
4) The hit and miss operator is applied to segment only the circle region in the image (Fig. 7).
5) A bounding box is drawn in Fig. 8 by searching for the first black pixel from top, bottom and from sides of image.
6) The length or breadth of the box gives diameter of pupil. The centre of bounding box gives the centre of the pupil.

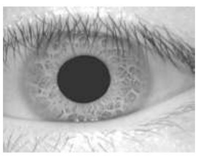

Fig. 6 Input Eye image

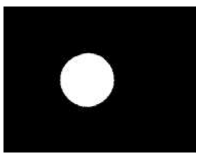

Fig. 7 Segmenting Pupil

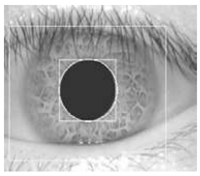

Fig. 8 Bounding box around pupil

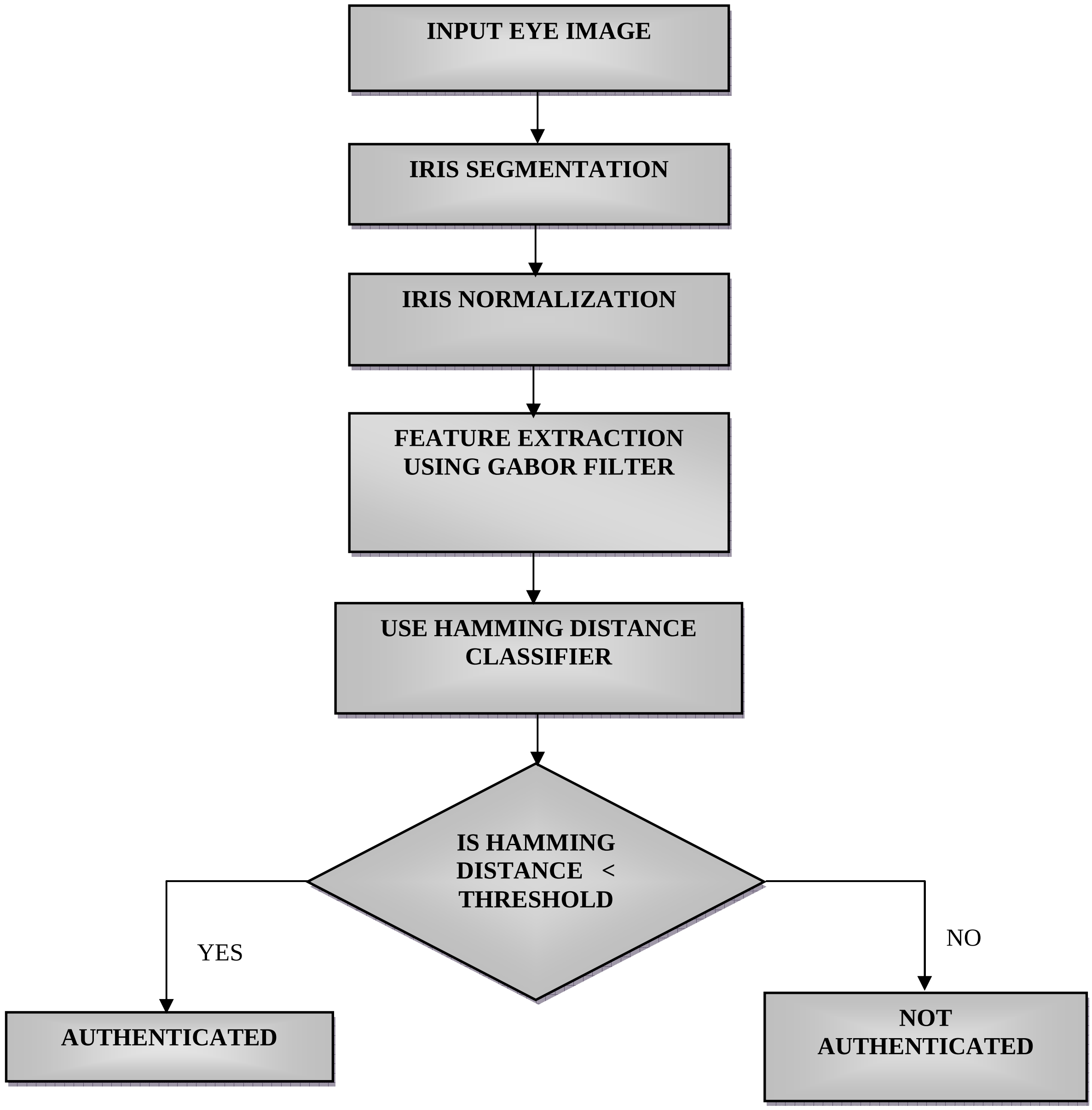

Fig. 5 Flowchart for Proposed Hamming Distance Algorithm

The noise is also eliminated in this procedure and the pupil is detected as shown in Fig. 8. The proposed method has proven very efficient and reliable when tested with CASIA iris database. From all 70 iris images considered, the proposed algorithm correctly determined the center and radius of 66 exemplars (99.6%) with a very low failure rate.

B. Iris Detection

After detecting the pupil edge, the iris/ sclera border is detected. The iris/sclera is low in contrast and may be partly occluded by eyelids and eyelashes. The contrast of the iris region is increased by first applying Gaussian smoothing and then Histogram equalization. The boundary of the enhanced iris image is found by using canny edge detector.

The Canny operator is optimum even for noisy images as the method bridge the gap between strong and weak edges of the image by connecting the weak edges in the output only if they are connected to strong images. Hence the edges are more likely to be the actual ones. Therefore compared to other detection method, this Canny operator is less fooled by spurious noise.

The iris/sclera region is low in contrast and may be partly occluded by eyelids and eyelashes. The steps for iris detection are:

1) A bounding box of height equal to that of the pupil and width equal to up to eight times (as the size of the iris varies from 10% to 80% to that of the pupil) is drawn as in Fig. 9. Only regions within this bounding box are used to detect iris/sclera boundary.

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2) The contrast of the iris region is increased, by first applying Gaussian smoothing and then by histogram equalization.
3) Canny edge detector is applied to find the edges of the enhanced image and probabilistic circular Hough transform is applied to the edge detected image to find the centre and radius of the iris using the Eq. (2).

$$(x_i-x_c)^2 + (y_i-y_c)^2 = r^2 \quad (2)$$

where (x_c, y_c) is the center of iris , (x_i, y_i) is the iris co- ordinate pixel and r is the radius of the iris.

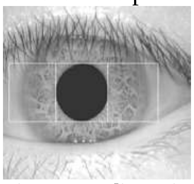


Fig. 9 Bounding Iris

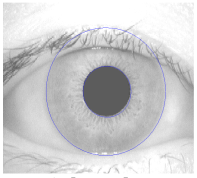


Fig. 10 Iris boundary - Hough Transform

4) The CASIA database images have radius (r) in the range of 100 to 120. Hence, the radius parameter in the Hough transform is set between 95 and 125.
5) The pupil and iris are not concentric. The centre of the iris lies within the pupil area and hence the probability that the centre of the iris lying in this area is high. Therefore the centre parameters (x_c,y_c) are taken to be the pupil area. This reduces the number of edge pixels to be computed.
6) The centre and radius of the iris is found by applying Hough transform (Fig. 10).

C. Iris Normalization

Once the iris region is localized, the next stage is to normalize this part in order to enable generation of the iris code and their comparisons. The variations in eye image due to optical size of the iris, position of pupil and the iris orientation change from person to person. The Cartesian to polar transform of the iris region is based on the Daugman's Rubber sheet model, which is used to unwrap the iris region.

The steps are as follows :

1) The centre of the pupil is considered as the reference point. The iris ring is mapped to a rectangular block in the anti-clockwise direction.
2) Radial resolution is the number of data points in the radial direction. Angular resolution is the number of radial lines generated around iris region.
3) Radial direction is taken to be 64 data points and horizontal direction is 360 data points.
4) Using Eq. (3) the doughnut iris region is transformed to a 2D array with horizontal dimensions of angular resolution and vertical dimension of radial resolution.

$$I(x(r, \theta), y(r, \theta)) \rightarrow I(r, \theta) \quad (3)$$

5) Normalization produces the image of unwrapped iris region of size 360×64 is shown in Fig. 11.

Fig. 11 Normalized into Polar Coordinates

6) The unwrapped image has very low contrast and has noises. To obtain a good feature extraction the texture must be clear and the contrast must be high. Median filter is applied to remove the noises and Histogram equalization is used to increase the contrast of the normalized image.
7) Fig. 12 shows the enhanced normalized image after histogram equalization. It shows rich texture suitable for feature extraction.

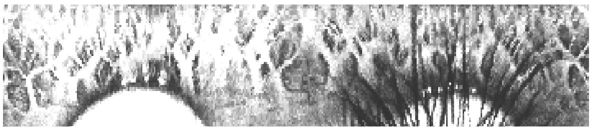


Fig. 12 Enhanced Normalized Image

3.3. Feature Extraction

In order to provide accurate recognition of individuals, the most discriminating information present in an iris pattern must be extracted. Only the significant features of the iris must be encoded for comparison between templates. Most iris recognition system makes use of band pass decomposition of the iris image to create a biometric template. Wavelet is powerful in extracting features of textures and the template generated using this also needs a corresponding matching metric, which gives a measure of similarity between two iris templates. The proposed method is carried out using Gabor filters, which generates 2048 bits of information from 256 feature vectors, giving better accuracy, takes less computation time and processing is simple. The normalized iris image is divided into multiple regions. Each local region is transformed in to a complex number with 2-D Gabor filters. The real and imaginary part of the complex number is encoded in to 1 or 0 depending on the sign. The steps for feature extraction and matching is as follows,

1) The normalized iris image is divided into 8 parts of 45 degrees interval each.
2) Each part is further sub divided into 8 regions to form sixty-four small channels.

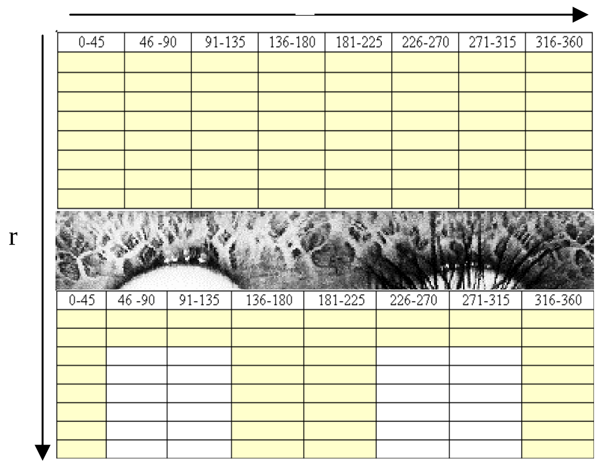


Fig. 13 Multi channel Feature Extraction

3) From Fig. 13 it is apparent that the eyelids and eyelashes can occlude the irises in the regions between 45 and 135 degrees, 270 and 315 degrees. Hence only the top two channels in these regions are considered for the feature extraction. Therefore the iris is divided in to forty channels, which are mostly not occluded, by eyelashes or eyelids.
4) A bank of thirty Gabor filters is generated using the 2D Gabor wavelet Eq. (10)

$$G(x, y; \theta, \omega) = \exp\{-1/2\,[x'^2 / \delta x'^2 + y'^2 / \delta y'^2]\} \exp(i\omega(x + y)) \quad (4)$$

$$x' = x\cos\theta + y\sin\theta \quad (5)$$

$$y' = y\cos\theta - x\sin\theta \quad (6)$$

5) The frequency parameter is often chosen to be power of 2. In this work, the central frequencies used are 2, 4, 8, 16, and 32. For each frequency the filtering is performed at orientation 0, 30, 60, 90, 120 and 150 degrees. So, there are thirty filters with different frequencies and directions.

3.4. Hamming Distance Matching Classifier

The template that is generated in the feature encoding process need a corresponding matching metric, that gives a measure of similarity between two iris templates. This metric should give one range of values when comparing templates generated from the same eye, known as intra-class comparisons. Another range of values when comparing templates created from different irises is known as inter-class comparisons. Among the different matching classifiers, Hamming distance (HD) approach is a matching metric employed by Daugman for comparing two bit patterns and it represents the number of bits that are different in the two patterns and hence can be decided whether the two patterns are generated from the same iris or from different ones.

$$HD = \frac{1}{N}\sum_{i=1}^{N} X_j (XOR) Y_j \quad (7)$$

where X_j and Y_j are the two bit patterns that is computed and N=2048. Basically when the bit in pattern X_j is different than that of pattern Y_j, the Exclusive-OR gives a result of 1 and these ones are accumulated till all the bits in the two patterns are compared. Finally the result is divided by N, the total number of bits constituting the iris code. Ideally, the HD between two iris codes generated for the same iris pattern should be zero. When the HD is large i.e. closer to 1, the difference in two patterns are more different and the two patterns are to be identical when this distance is closer to 0. Hence by choosing properly the threshold value for matching decision, one can better iris recognition results with very low error probability.

In the normalization or unwrapping part, Daugman's rubber sheet model does not take into account the rotational inconsistencies. So in order to overcome this problem the HD of two templates is calculated with one template being shifted left and right bit -wise trials and the corresponding HD values are calculated from successive shifts. This bit-wise shifting in the horizontal direction corresponds to rotation of the original iris region by an angle that can be known from the angular resolution used. The calculated lowest HD value is 0 used since this corresponds to the best match between the two templates. This shifting process is illustrated in Fig. 14.

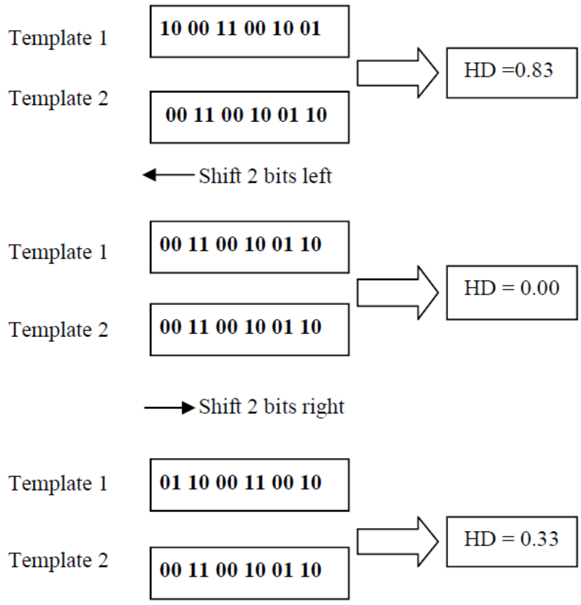


Fig. 14 An illustration of the shifting process

In cases where a person might move his neck while his eye is being photographed, that causes a shift in the angle axis. To prevent that, shift the matrix cyclic for about 20 columns and try to find the HD not only for the current matrix but also for all the shiftings. The minimal result is the desired one. Closer this distance is to zero, the more probable the two patterns are identical. Thereby properly choosing the threshold, one can get better iris recognition system with very low error probability.

The threshold value of 0.15 has been chosen for matching iris patterns in this work and if the HD is below 0.15, the two iris patterns are given a match and is a genuine attempt. If HD is greater than 0.15 the two iris patterns are given a mismatch and is an imposter attempt. HD is chosen as a matching metric. It is found from the experiments that the HD between two irises belonging to the same eye is less than 0.15.

4. Performance Measurements

Biometric systems show variations in measuring human characteristics or behavior. A measure of variation is embedded into these systems, in technical language this translates intolerance of false rejection error and false acceptance error. The proportion of false rejections is known as Type I error and the proportion of false acceptance as Type II error. Type I and Type II errors can be translated in false acceptance and false rejection curves which are related to system's sensitivity threshold setting. Since the tolerance level is adjustable, there is a tradeoff between the two errors. The multi algorithm system proposed is evaluated using the two performance measures. They are Accuracy and Receiver Operating Characteristics Curve (ROC).

1. Accuracy is a measure that decides the degree of security in a biometric system. Thresholds of a biometric trait can be adjusted to a wide range of accept/ reject ratios depending upon the security required and it decides the accuracy of the biometric system.

2. Receiver Operating Characteristics Curve (ROC) is a graph showing the variation of false rejection rate with false acceptance rate. False rejection rate (FRR) and False Acceptance Rate (FAR) gives a performance measure of the system. FRR is the present error of a system that rejects genuine users as imposters while FAR is the present error of a system that accepts imposters as genuine users.

(i) False Rejection Rate (FRR): It is obtained from testing the system by matching the extracted features of the same person. In other words, the test image data of a claimer must be extracted and matched with the template of the same person. The system decides whether it will accept or reject the claimer by comparing the distance to a predefined threshold. The FRR is computed by Eq. (8) as follows :

$$FRR = \frac{\sum_{i=1}^{N} f(x_i)}{N}, f(x_i) = \left\{ \frac{1,\ D_x(F_i, Y_{ci}) > T}{o,\ \text{otherwise}} \right\} \quad (8)$$

where

F_i is the feature vector of the test image of i^{th} user

F_{ci} is the feature vector template of the claimed identity, in this case, the same person as the claimer

T is a predefined threshold, $f(x_i)$is the function that equals one when the distance is higher than the threshold.

D_x (F_i,Yc_i) is the distance measured from matching the feature vector with the template Yc_i.

N is the total number of test claimer's images.

Sometimes, the FRR is changed to GAR (Genuine Acceptance Rate) and is calculated as GAR= 1- FRR

(ii) False Acceptance Rate (FAR): It is obtained by testing the system by matching the extracted features of a claimer with the templates of other registered persons'. Distance (D_x) from the matching process is measured and compared with the predefined threshold. In order to make the FAR and FRR comparable, the predefined thresholds used for the processes of finding FRR and FAR must be set equally.

The FAR is calculated by Eq. (9) as follows

$$FAR = \frac{\sum_{i=1}^{N} f(x_i)}{N}, f(x_i) = \left\{ \frac{1,\ D_x(F_i, Y_{cj}) < T; i \neq j}{0,\ \quad \text{otherwise}} \right\} (9)$$

For a verification system the optimal performance of the system is where the FRR equals the FAR. For the identification mode, a claimer is matched with all the registered identities. If all matching are higher than a predefined threshold, it means that the claimer or the test user, which is actually one of the registered users, is classified as an imposter by the system.

To estimate the performance of a biometric system all three metrics must be evaluated, as reliance one or two metrics without the third can be highly misleading. If manufacturers provide only the FAR, it is possible that the system with the lower FAR has got an unacceptable high FRR, Changing settings, such as the matching threshold can influence each of the three metrics. Increasing the threshold will make the system less accessible to imposters, but also the probability that legitimate users will be rejected increases. Such an adjustable threshold makes it hard to compare different systems, because there is no reasonable way to decide if a system with a higher FAR and a lower FRR performs better than a system with lower FAR and a higher FRR value. The Equal Error Rate (EER) of a system can be used to give a threshold independent performance measure.

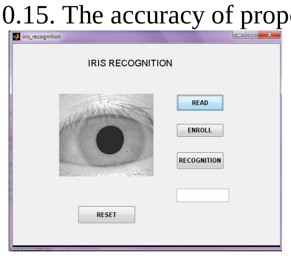
5. EXPERIMENTAL RESULTS

Human Iris Pattern Recognition System implemented with improvement in Segmentation algorithm is found to give better results. The algorithm is tested for 75 eye images of 25 individuals with 3 samples per person.

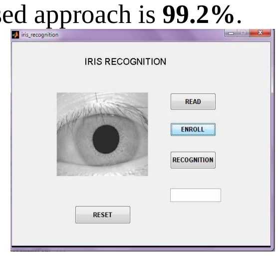
The first segmentation method localized 24 images out of 30. This is due to poor intensity separability between sclera, iris and pupil. The proposed method successfully localized 28 images out of 30. The two exemplars are due to iris images having high degree of overlapping eyelashes and eyelids. The success rate is evaluated using Eq. (10)

$$\text{Sucess rate} = \frac{\text{No. of Localized IRIS Images}}{\text{Total No. of IRIS Images in Database}} \times 100 \quad (10)$$

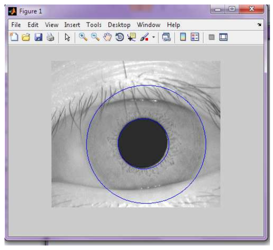
The eye images from CASIA database has been used to verify the performance of the technology. It is found from the experiments that the Hamming distance between two irises belonging to the same eye is less than 0.15. The accuracy of proposed approach is **99.2%**.



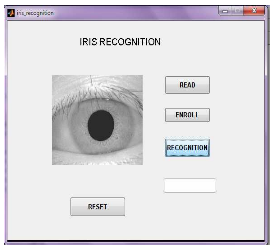
a) Reading of an Image



b) Enrolling of the Image



c) Iris and Pupil Detection



d) Recognition of the Image

Fig. 15 Recognition using HD algorithm

The hamming distance is 0.12, subject is Authenticated.

Performance of an iris recognition system could also be evaluated with the variability among iris feature templates, within subject variability and between subject variability. The False Acceptance Rate (FAR) and False Rejection Rate (FRR) are directly proportional and the accuracy of a system is high when its ROC curve is close to the axes.

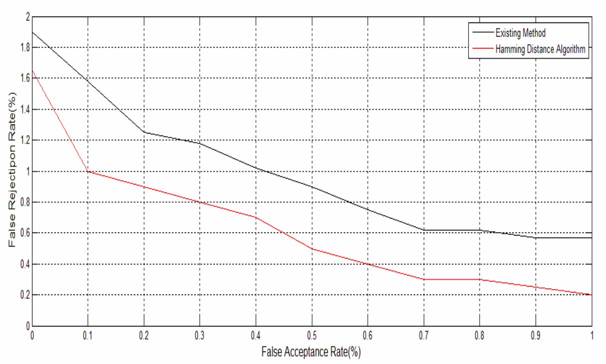


Fig. 16 ROC Curve for Iris Recognition

Fig. 16 is ROC graph that shows the relationship between the FAR and FRR between the existing system and the proposed algorithm. The Hamming distance ROC curve for the existing method represented by the black curve and proposed Hamming distance algorithm represented by the red curve is shown in ROC graph. Since the ROC curve for proposed approach is very close to the axes, the Receiver Operating Characteristics curve confirms that the proposed system out performs the existing system.

Table 1 indicates the enhanced performance of the proposed work detailing the FRR values obtained at different FAR values for both the existing and the proposed system.

Table 1: Performance Analysis

	Existing method [16]	Proposed Hamming Distance Algorithm
FAR	**FRR**	**FRR**
0	1.9	1.65
0.1	1.58	1
0.2	1.25	0.9
0.3	1.18	0.8
0.4	1.02	0.7
0.5	0.9	0.5
0.6	0.75	0.4
0.7	0.62	0.3
0.8	0.62	0.3
0.9	0.57	0.25
1	0.57	0.2

6. Conclusion

An efficient iris recognition system using Gabor filters has been implemented with improvement in segmentation algorithm and it is found to be more accurate in recognition. Experimental results prove that this system improves the matching performance. It is found from the experiments that HD between two irises of the same eye is less than 0.15.

This algorithm presented an iris recognition system with improvement in segmentation stage at an improved accuracy of **99.2%** when compared with the existing iris recognition [16] reported at **98.6%.**

6.1 Future Scope

The efficiency of the proposed approach can be improved and extended by proposing a multi-algorithmic biometric system by fusion of two algorithms at the classifier stage for iris authentication. The present work can also be extended by testing more samples of iris images and using different algorithms in neural network. Since the images in the CASIA database are mainly eyes of Chinese people the testing could be done for ethnic group.

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