Review on Iris Recognition for High Security Access Environment

Ms. Pranali P. Chavhan
PG Student
Department of Electronics & Telecommunication,
S.S.G.M.C.E., Shegaon, India
pranali.chavhan@rediffmail.com

Prof. V. K. Bhangadiya
Assistant Professor
Department of Electronics & Telecommunication,
S.S.G.M.C.E., Shegaon, India
vikasbb@gmail.com

Abstract- Iris recognition,a technique used to identify individuals by the textural pattern of iris of their eye, has gained a great attention over a past decade, due to its high reliability, ease of use, accuracy, nearly zero False Acceptance rate (FAR), and safety in controlling access to high-security areas reducing the possibility of illegal access. This paper explores various Iris Recognition techniques used by different researchers, how it works, how it stacks up against other forms of biometric identification methods such as fingerprint, retinal scanning, face, voice and hand geometry etc. There are five main stages in iris recognition system: image acquisition, Iris segmentation, Normalization, feature extraction and template matching.

Keywords- *Biometrics, Hough Transform, Wavelets, Feature Extraction, Template Matching.*

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I. INTRODUCTION

Security and the identification of individual is necessary for different areas of our lives, reliable personal recognition schemes are required by a wide variety of systems to confirm identity of an individual requesting their services to ensure that the services are accessed only by a authorized user. For example secure access to buildings, computer systems, electronic data security, e-commerce, medical records management, laptops, cellular phones, and ATMs. The three main types of identification are password, a card or token, and biometric. Passwords are weak and easy to crack due to human tendency of writing them down somewhere easily accessible and to make them easy to remember. Although the token or card is recognizable, there is no way of identifying if the person presenting the card is the actual owner. Biometrics provides a safe and secure way of identification and recognition, as they are difficult to steal and replicate.

Biometric recognition means the automatic recognition of individual based on his/her physiological and/or behavioral characteristics. A biometric system works by capturing and storing the biometric information in the form of binary template and then comparing the scanned biometric with the stored template. Some common physical characteristics that may be used for identification are fingerprints, palm prints, hand geometry, Face, voice, retinal patterns and iris patterns. Any human physiological or behavioral characteristic can be used as a biometric if it satisfies the following requirements [1].

- Universality:it means each person should have the characteristic.
- Distinctiveness:it indicates any two persons should be sufficiently different in terms of the characteristic.
- Permanence:it means the characteristic should be sufficiently invariant (with respect to the matching criterion) over a period of time.
- Collectability:it shows that the characteristic can be measured quantitatively.
- Performance:it refers to the achievable recognition accuracy and speed, the resources required to achieve the desired recognition accuracy and speed, as well as the operational and environmental factors that affect the accuracy and speed.
- Acceptability: itindicates the extent to which people are willing to accept the use of a particular biometric identifier in their daily lives.
- Circumvention**:**it reflects how easily the system can be fooled using fraudulent methods.

Fig (1) shows a comparison between the most common biometric identifiers based on above mentioned characteristics. Each value was obtained through averaging and weighting of the classifications proposed in [1], [5], [6], [7]. Iris is best suited for identification as it provides higher uniqueness and circumvention values.

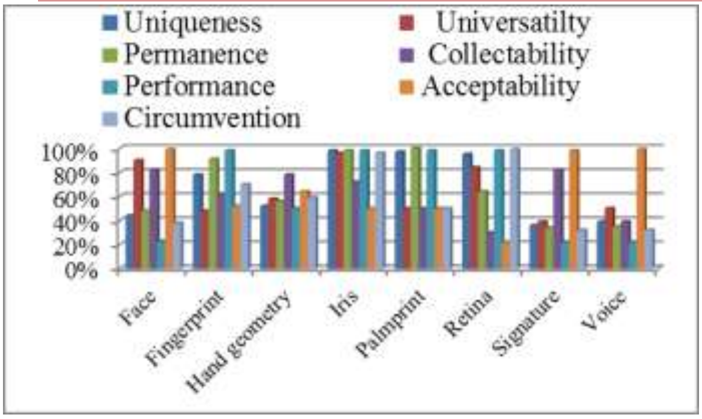

Fig. 1 Comparison different biometric identifiers

In comparison to other recognition techniques, the iris has a great advantage that there is huge variability of the pattern between two persons [2]. Iris is one of the most accurate physiological characteristics because the probability of the existence of two irises that are same has been estimated to be very low, i.e. one in 1072 [3]. It is the only internal organ which can be seen from outside the body. Iris texture patterns are believed to be different for each person, and even for the two eyes of the same person. Iris is colored part of the eye surrounding the pupil and located behind the cornea. Iris development begins during third month of gestation and fully developed at the age of 1 year and then remain stable throughout the life. The average diameter of the iris is 12 mm, and the pupil size can vary from 10% to 80% of the iris diameter [3].

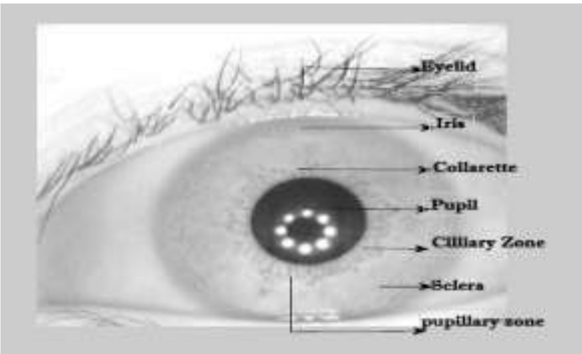

Fig. 2 Front view of human eye

II. LITERATURE SURVEY

Various algorithms had been proposed earlier, but John Dougman implemented first working automated iris recognition system. **John Dougman et al. [2]**proposed a system that uses integro-differential operator for segmentation of iris from eye image. Integro-differential operator searches over the eye image for the circular pupil and the limbic borders of the iris and then a 256 byte code is obtained using multiscale quadrature 2-D Gabor wavelet. Hamming distance is then used for comparison of two iris codes at 4000 per second for matching[8].

Wilde et al.[9]has implemented a two step iris segmentation method: i) a binary edge map based on gradient is constructed from the intensities of the pixels in an iris image, ii) then hough transform is used to detect iris inner and outer borders. Laplacian of Gaussian filter(LOG) is use for encoding Also, the upper and lower boundaries of the eyelid are approximated using parabolic curves and matching is performed using normalized correlation.

Libor Masek et al.[10]proposed a method involves first applying Canny edge detection to generate an edge map then gradients were biased in the vertical direction for the outer iris/sclera boundary, as suggested by Wildes [9]. Vertical and horizontal gradients were weighted equally for the inner iris/pupil boundary. For segmentation modified version of Kovesi's Canny edge detection MATLABfunction [11] was implemented with hough transform. 1-D log Gabor filter is used for feature extraction and hamming distance for matching.

Huang et al. [13] has first coarsely segment the iris using edge detection filters and Hough transform. The noise due to eyelids is then localized by the edge information based on phase congruency.

Lim et al.[14]has made the use of competitive learning Neural Network for matching of two iris codes, 2-D Haar wavelet is used for encoding purpose the segmentation method is same as wildes [9].

Dougman et al.[15] presents the following advances in iris recognition. Active contours for detecting and modeling the iris inner and outer boundaries. Fourier-based methods for solving problems in iris trigonometry and projective geometry, statistical inference methods for detecting and excluding eyelashes and exploration of score normalizations, depending on the amount of iris data that is available in images and the required scale of database search.

Raul Sanchez-Reillo[16] proposed a system for access control using iris recognition. This technique provides a high level of security with nearly zero False Acceptance Rate(FAR) and very small False Rejection Rate (FRR).

Boles et al. [17] employed a new approach for recognizing the iris in which Zero-crossings of the wavelet transform at various resolution levels are calculated over concentric circles on the iris, and the resulting one-dimensional (1-D) signals are compared with model features using different dissimilarity functions.

III. IRIS RECOGNITION SYSTEM

The main work of an iris recognition system is to extract, represent and compare the textural pattern present on the surface of the iris. Iris recognition system is classified into 2 sections Enrollment and Authentication. Enrollment process include capturing, processing and storing the iris information in the database. Recognition or authentication process compares the input features with enrolled features in the systems database with a reference. This system comprises of modules for iris segmentation, normalization, feature extraction (encoding) and feature matching. Fig 3 shows the block diagram of iris recognition system.

1. Image Acquisition

It is the process of capturing the eye image using CCD camera. Acquiring images of Iris is major characteristic for the recognition system. Images with good resolution and sharpness need to maintain with adequate intensity. We use publicly available Iris database from Chinese academic of science (CASIA) with 756 grayscale images of eye with 108 different eyes or classes and seven different images of each eye[18].

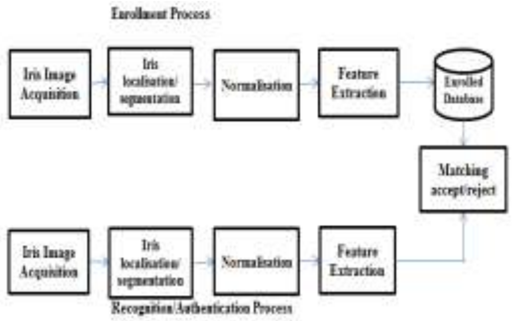

Fig. 3 Iris Recognition System

2. Segmentation

The next step after capturing the image is to separate the iris part (the region which contains information) from the eye image known as segmentation. There are various algorithms proposed by various authers.

2.1 Dougman's Integro-differential operator

Dougman's system make the use of integro-differential for locating inner and outer boundaries of the iris and pupil and also the area occupied by the upper and lower eyelids. The integro-differential operator is givan as,

$$\max_{(r,\, x_0,\, y_0)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint \frac{I(x,y)}{2\pi r}\, ds \right| \quad \textbf{(1)}$$

Where, * represents convolution and G_σ is a smoothing guassian function of scale σ, r is the radius and (x_0 y_0) are centre coordinates of circle, I(x, y) is the image of eye.Itsearches iteratively for the circular path where there is maximum change in pixel values, by varying the radius and centre (x, y) position of the circular contour. The amount of smoothing is progressively reduced to obtain precise localization of iris boundaries. For eyelid detection the path of contour integration is changed from circular to arc. It does not suffer from the thresholding problems as the Hough transform, as it works with raw derivative information. It works only on a local scale, so it can face problems where there is noise, such as from reflections.

2.2 Hough Transform

Wildes et al. [9],Huang et al. [13], Lim et al. [14]has implemented an automatic segmentation algorithm based on the circular Hough transform.It is a standard computer vision algorithm used to determine simple geometric objects in the image. In his method first the image intensity levels are converted into binary edge map, and then from the edge map, votes are cast in Hough space for the parameters of circles (centre coordinates X and Y, and the radius R) passing through each edge point. Any circle can be defined according to the equation

$$X^2+Y^2=R^2 \qquad (2)$$

A maximum point in the Hough space will correspond to the radius and centre coordinates of the circle best defined by the edge points. Approximating the upper and lower eyelids as parabolic arcs, the parabolic Hough transform to detect the eyelids. Hough transform for Iris/Sclera boundary is performed first and then for Iris/pupil boundary because pupil is always contained within the Iris. The problem with hough transform is that for edge detection it requires threshold values to be approximated, and this may result in critical edge points being removed, which results in failure to detect circles/arcs,it is computationally intensive so not suitable for real time applications.

3. Normalization

Once the iris part is localized next step is normalization. Normalization means converting the iris image into fixed dimension image to allow comparisons. The differences in dimensions of eye images are mainly due to the stretching of the iris caused by pupil dilation from varying levels of illumination, different imaging distance, rotation of the camera, head tilt, and rotation of the eye within the eye socket. The normalization process will convert all the images into same constant dimensions.

3.1 Dougman's Rubber sheet model

There are various algorithms available for normalization out of which Dougman's Rubber sheet model is most effective and widely used. This model remaps all point within the iris region to a pair of polar coordinates (r, θ), where θ is the angle [0, 2π] and r is on the interval [0, 1]. The center of the pupil is taken as reference point and a remapping formula is applied to convert the points on the Cartesian scale to the polar scale.

$$I(x(r,\Theta),y(r,\Theta)) \longrightarrow I(r,\Theta) \qquad (3)$$

With $x(r,\Theta) = (1-r)x_p(\Theta) + rx_i(\Theta)$
$y(r,\Theta) = (1-r)y_p(\Theta) + ry_i(\Theta)$

where, I(x, y) is the iris image, (x, y) are the original Cartesian coordinates, (r, θ) are the normalized polar coordinates corresponding to (x, y), and x_p, y_p and x_i, y_i are the coordinates of the pupil and iris boundaries along the Θ direction.

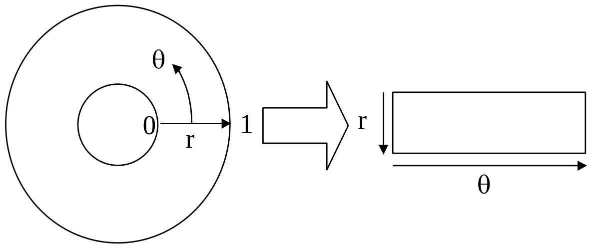

Fig. 4 Unwrapping the Iris

The radial resolution is defined as no of data points selected along each radial line. The number of radial lines going around the iris region is defined as the angular resolution. For every pixel in the iris, an equivalent position is found out on polar axes. The normalized image was then interpolated into the size of the original image. This method does not compensate for rotational inconsistencies.

3.2 Image Registration

The Wildes et al. [9] system uses an image-registrationtechnique to compensate for both scaling and rotation. It geometrically warps a newly acquired image I_n (x, y), into alignment with a selected database image I_r (x, y) according to the mapping function (u(x, y), v(x, y)) such that, the intensity values of the new image are made to be close to those of corresponding points in the reference image. The mapping function must be chosen so as to minimize

$$\int_x \int_y (I_r(x, y) - I_n(x-u, y-v))^2 dxdy \qquad (4)$$

while being constrained to capture a similarity transformation of image coordinates (x, y)to , (x', y')that is

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} x \\ y \end{pmatrix} - sR(\phi)\begin{pmatrix} x \\ y \end{pmatrix} \qquad (5)$$

Where s is a scaling factor and R(φ) is matrix representing rotation by φ.

3.3 Virtual circles

In Boles et al.[17] the maximum diameter of the iris in any image is calculated. The dimensions of the irises in the images will be scaled to have the same constant diameter regardless of the original size in the images. Furthermore, the extracted information from the virtual circles must be normalized to have the same number of data points.Once the two irises have the same dimensions, features are extracted from the iris region by storing the intensity values along virtual concentric circles, with origin at the centre of the pupil.A normalization value N is introduced, so that the whole information available in the iris signature can be extracted. This is same as Daugman's rubber sheet model, however scaling is at matching stage, and is relative to the comparing iris region, rather than scaling to some constant dimensions.

4. Feature Extraction

The next step in the recognition process is to generate the binary code for iris. To make the comparisons only the significant characteristics of iris must be encoded.

4.1 Gabor filter

Dougman et al. [2] employed quadrature 2-D gabor filter to extract the phase information in iris. Frequency and orientation representations of Gabor filters are similar to those of the human visual system, and they have been found to be particularly appropriate for texture representation and discrimination. In Gabor filter sine/cosine waves aremodulated with a Gaussian. Decomposition of a signal is accomplished using a quadrature pair of Gabor filters, with a real part specified by a cosine modulated by a Gaussian, and an imaginary part specified by a sine modulated. The real and imaginary filters are also known as the even symmetric and odd symmetric components respectively. A 2D Gabor filter over the an image domain (x,y) is represented as,

$$G(x, y) = e^{-\Pi[(x-x_o)^2/\alpha^2 + (y-y_o)^2/\beta^2]} e^{-2\Pi[u_o(x-x_o) + v_o(y-y_o)]} \qquad (6)$$

Where (x_o, y_o) represent position in the image, (α,β) are the effective width and length, and (u_o, v_o) represent modulation.Quantizing the phase information into four levels is used to compress the data. These four levels are represented using two bits of data, so each pixel in the normalized iris pattern corresponds to two bits of data in the iris template.

4.2 Laplacian of Gaussian filter

Wildes et al. [9] implemented Laplacian of Gaussian filters to encode features of iris region. The filters are given as

$$\nabla G = -\frac{1}{\pi\sigma^4}\left(1 - \frac{\rho^2}{2\sigma^2}\right)e^{-\rho^2/2\sigma^2} \qquad (7)$$

Where, σ is the standard deviation of the Gaussian and ρ is the radial distance of a point from the centre of the filter. The filtered image is represented as a Laplacian pyramid which is able to compress the data, so that only significant data remains. A Laplacian pyramid is constructed with four different resolution levels in order to generate a compact iris template.

4.3 Zero-crossings of the 1D wavelet

Boles and Boashash [8] employed 1-D wavelets for encoding data. The mother waveletψ(x) is defined as the second derivative of a smoothing function θ(x).

$$\psi(x) = \frac{d^2\theta(x)}{dx^2} \qquad (8)$$

To encode the features the zero crossings of dyadic scales of these filters are then used. The motivation for this technique is that zero-crossings correspond to significant features with the iris region.

4.4 Haar wavelet

Lim at al. [14] make the use of Haar wavelet as the mother wavelet. Haar breaks an image into four sub-sampled images. Fig (5) shows 5 level decomposition using Haar wavelet. It shows all the detail and approximation coefficient of a mapped image. Looking to fig (5) we can say that cD_1^h, cD_2^h, cD_3^h, cD_4^h are almost same, so only one of them is chosen to reduce redundancy. Since cD_4^h is the smallest in size, it is taken as representative of all the information the four levels carry. The fifth level does not contain the same texture so it is taken as a whole. In the same way only fourth and fifth diagonal and vertical coefficient can be taken to express the iris characteristics. Thus each image is expressed as a combination of six matrices.

1. cD_4^h & cD_5^h
2. cD_4^v & cD_5^v
3. cD_4^d& cD_5^d

All these are combined to make a single feature vector. The feature vector is then coded into binary form because it is easy to compare two binary codes as compared to numbers. The vectors that are obtained using haar wavelet have a maximaum value greater than zero and a minimum value less than zero. If Coef is feature vector of anb image then

If Coef(i)>=0 then coef (i)=1

If Coef(i)<0 then coef (i)=0

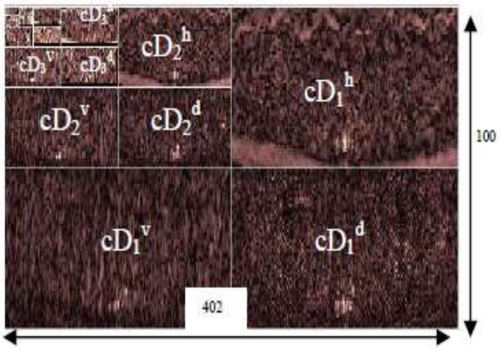

Fig. 5 Conceptual diagram for organizing feature Vector

Lim et al. [14] shows the comparison of Gabor transform and Haar wavelet transform, and conclude that the recognition rate of Haar wavelet is slightly better than Gabor transform by 0.9%

4 Matching

The last step is to match the binary code with the stored code to authenticate the person.

4.1 Hamming distance

John Dougman et al. [2], Libor Masek et al. [10], employed hamming distance to measure similarity between two iris codes.The XOR operator is applied to the feature vector of any two iris patterns to find dissimilarities between them any corresponding pair of bits. The hamming distance between two Boolean vectors is defined as

$$HD=\frac{1}{N}\sum_{J=1}^{N} A(j) \oplus B(j) \qquad (9)$$

Where, A and B are the coefficients of two iris vectors and N is the size of vector. The iris template is shifted right and left by 8 bits to avoid rotation inconsistencies. It may be easily shown that scrolling the template in polar coordinates is equivalent to iris rotation in Cartesian coordinates. John Dougman tested a large iris database and conclude that maximum hamming distance exists between two iris codes of same person is 0.32 [2] so this is used as a threshold in the matching process.

If HD<= 0.32 – Same person

If HD<= 0.32 – different person

4.2 Normalized correlation

Wildes et al.[9] implemented Normalized correlation based matching of the code. This is represented by,

$$\frac{\sum_{i=1}^{n}\sum_{j=1}^{m}(p1[i,j]-\mu1)(p2[i,j]-\mu2)}{nm\,\sigma1\sigma2} \qquad (10)$$

Where, $p_1$and $p_2$are two iris images of size n*m,$\mu_1$and σ_1, and μ_2 and $\sigma_2$are the mean and standard deviation of p_1 and $p_2$respectively.Normalised correlation gives better results as compared to standard correlation, since it is able to account for local variations in image intensity that corrupt the standard correlation calculation.

Table 1: Comparison of different Iris Recognition Algorithms

Method	Correct Recognition Rate (%)	Equal Error rate (%)
Dougman's method	98.60	0.08
Wilde's method	99.90	1.76
Boles and Boshash algo.	92.64	8.13

IV. CONCLUSION

This paper shows how a person can be identified by a number of ways but instead of carrying cards or tokens or remembering passwords we can use biometric recognition technology, it uses physical characteristics of any person for identification. Iris recognition is one of most effective biometric identification method. This paper provides review on various methods proposed by different researchers for iris recognition.

The accuracy of obtained by different algorithms is as shown in above table 1. For segmentation of iris Canny edge detector with Hough Transform gives much better performance compare to other edge detection techniques. Dougman's

Rubber sheet model gives good results for normaliization. For feature extraction wavelets are effective solution we can either use Gabor filter or Haar wavelet. And finally for template matching hamming distance method is best suited. By using these algorithms together we can achieve maximum accuracy.

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