International Journal of Computer Applications (0975 – 8887)
National Symposium on "Modern Information & Communication Technologies for Digital India (MICTDI)

Comparative Analysis of Iris Recognition Techniques: A Review

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ABSTRACT
Iris Recognition system is one of the prominent Biometric authentication system. Among all other biometrics, iris is mainly because of its easy accessibility, efficiency and uniqueness. This system is used in personal security system, access control systems, identification for Automatic Teller Machines (ATMs) and police evidence security. For effective functioning of iris recognition system, researchers have to deal with various challenges like images taken in unconstrained environment, clamorous images, obscure images, occluded image affected by eyelids and eyelashes, and many more. The various challenges involved in iris recognition limit the efficiency of Iris recognition techniques. The purpose of this review paper is to study steps involved in iris recognition system and examine various techniques used for each recognition step. Performance of various Iris Recognition algorithms are compared in terms of performance parameters such as False Acceptance Rate, False rejection Rate and Computation time.

Keywords
Biometrics, Iris, Bidimensional Empirical mode decomposition, Discrete cosine transform, Neural network.

1. INTRODUCTION
Biometric identification is an apparent technology which gains more attention in recent years. It employs physiological or behavioral characteristics to recognize an individual. The physiological characteristics are iris, fingerprint, face and hand geometry. Voice, signature and keystroke dynamics are categorized as behavioral characteristics. Among these characteristics, iris has explicit phase information which spans about 249 degrees of freedom [13]. Among all current biometrics authentication methods, the lowest error recognition rate has been accomplished by iris recognition[9], which has received increasing attention in recent years. Iris is the annular colored portion between the black pupil and white sclera, which is encapsulated with tiny muscles that affect the pupil size and takes up about 65% of the area of an eye. It appears that phenotypic arbitrary patterns are visible in the human iris constituted of lots of irregular blobs, such as freckles, coronas, stripes, furrows, crypts, etc[8]. Therefore, the iris pattern is a unique, stable, and noninvasive biometric feature suitable for individual verification.

The main dilemma of iris recognition comes from the fact that it is hard to find appropriate features in the iris image and keep their uniqueness in an efficient way. Furthermore, feature comparison and classification processes suited for iris patterns are required to reach high accuracy. On the

other hand, iris image quality also plays an essential role at the recognition performance for an efficacious algorithm of iris recognition. Under a controlled image capturing environment, it is possible to obtain iris images with pleasing quality and accomplish splendid recognition accuracy. However, for real applications, it is not practical to capture iris images under so many easily changeable factors. Therefore, the recognition error rate is considerably increased, especially the false rejection rate, when the images do not have enough quality, possibly due to problems in focus, contrast, brightness, iris obstructions, or reflections. This problem had been identified by several researchers[14]. Therefore, how to design a robust method for iris recognition becomes a nontrivial and challenging issue.

The three main stages of an iris recognition system are image preprocessing, feature extraction and template matching. The iris image have to be preprocessed to obtain useful iris region. Image preprocessing include three steps: iris localization, iris normalization and image enhancement. Iris localization detects the inner and outer boundaries of iris. Eyelids and eyelashes that may cover the iris region are detected and removed. Iris normalization modifies iris image from Cartesian coordinates to Polar coordinates. The iris image has low contrast and non-uniform illumination produced by the position of the light source. All these factors can be compensated by the image enhancement algorithms. Feature extraction make use of texture analysis method to extract features from the normalized iris image. The remarkable features of the iris are extracted for accurate identification purpose. Template matching compares the user template with templates from the database using a matching metric. The matching metric will give a degree of similarity between two iris templates. Finally, a decision of high confidence level is made to identify whether the user is an authentic or imposter[6]. In this paper, we will compare various techniques used in each step of iris recognition.

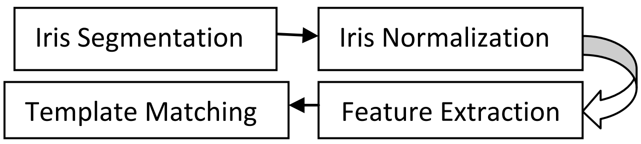

Figure 1. Steps of iris recognition algorithm

2. IRIS SEGMENTATION METHOD
The captured iris image has to be preprocessed to detect the iris, which is a circular portion between the pupil (inner portion) and the sclera (outer portion). The first step in iris localization is to detect pupil which is the black circular part encircled by iris tissues. The inner portion of pupil can be used to find out the outer radius of iris patterns. Segmented iris image is shown in figure 2(b). Segmentation techniques discuss below are Circular Hough transform and Daugman'sIntergro-Differential Operator.

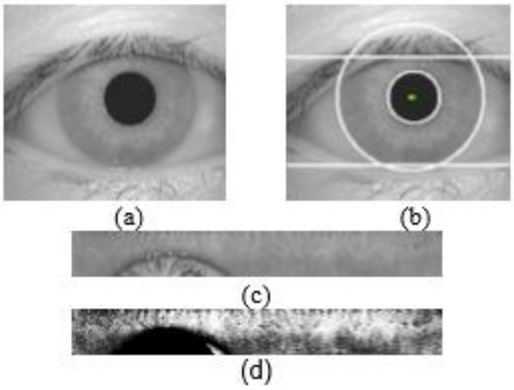

Figure 2. (a) original iris image, (b) Segmented iris image, (c) normalized iris image, (d) enhanced iris image [6]

2.1 Circular Hough Transform(HCT)

The iris image is converted into grayscale to minimize the consequences of illumination. As pupil is the largest black area in the intensity image, its edges can be detected easily from the binarized image by using suitable threshold on the intensity image. But the main problem of binarization emerges in case of people having dark iris. Thus,pupil localization does not happen in such cases the localization. In order to get over these problems, Circular Hough Transformation for detection of pupil can be used.

Firstly, edge image is generated using canny edge detection method. Each edge point is taken as centre and circle is drawn of radius r. The HCT may be carried out for a range of different radius. Usage of HCT is to the outer and inner circle of the pupil. Theprocess is carried out by scanning edge image for pixel (A) having true value and the center detected is with the help of the following equations

$$xc = x - r * \cos(\theta) \quad (1)$$

$$yc = y - r * \sin(\theta) \quad (2)$$

Where x, y are the coordinates at pixel A and r is the possible range of radius values, θ ranges from [0:π].

The disadvantage of Circular Hough transform algorithm is that it requires profound computation and therefore not suitable for real time applications. A threshold value is required to generate the edge image. The selected threshold value may eliminate some critical edge points and result in false circle detection.

2.2 Daugman's Intergro- Differential Method

Intergro-Differential Operator is applied on the raw input image I(x,y). This operator will search for the maximum value of the image domain (x,y) in the blurred partial derivative, y) for the maximum in the blurred partial derivative, with respect to increasing radius r, of the normalized contour integral of I(x, y) along a circular arc ds of radius r and center coordinates (x0, y0).[13]

$$\max_{(r,x0,y0)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{(r,x0,y0)} \frac{I(x,y)}{2\pi r} ds \right| \quad (3)$$

whereconvolution is denoted by * and G,(r) denotes smoothing function such as a Gaussian of scale σ. After convolution with Gaussian kernel, the centre and radius is defined by the maximum difference between inner and outer circle. Then, we change the path of contour integration from circular to parabolic curve to detect upper and lower eyelid.

This operator has more accuracy because it probe the image domain for global maximum. This system is faster because it uses information of first derivative.

3. NORMALIZATION TECHNIQUES

3.1 Daugman Rubber Sheet Model

The concept of automated iris recognition was first proposed by Flom and Safir. On the other hand, Multi-scale quadrature wavelets are used by Daugmanto extract texture phase structure information of the iris to generatea iris code of 2048-bitand the difference between a pair of iris representations is compared by calculating their Hamming distance via the XOR operator.

The pupil dilation was taken into consideration by Daugman in its rubber sheet model and appearing of different size in different images. For this purpose, the coordinate system is modified by unwrapping the iris and mapping all the points within the boundary of the iris into their equivalent polar coordinates.

The following set of equations are used to transform the annular region of iris into polar equivalent [18]

$$I(x(\rho,\theta), y(\rho,\theta) \rightarrow I(\rho,\theta))$$

With

$$x_p(\rho,\theta) = x_{p0}(\theta) + r_p * \cos(\theta) \quad (4)$$

$$y_p(\rho,\theta) = y_{p0}(\theta) + r_p * \cos(\theta) \quad (5)$$

$$x_i(\rho,\theta) = x_{i0}(\theta) + r_i * \cos(\theta) \quad (6)$$

$$y_i(\rho,\theta) = y_{i0}(\theta) + r_i * \cos(\theta) \quad (7)$$

Where r_p and r_i are respectively the radius of pupil and the iris, while $(x_{p0}(\theta),\ y_{p0}(\theta))$ and $(x_{i0}(\theta),\ y_{i0}(\theta))$ are the coordinates of the pupillary and limbic boundaries in the direction θ. The value of θ belongs to [0: 2π], ρ belongs to [0:1].

3.2 Fuzzy Clustering

Many classifications are formed by clustering of numerical data and system modeling algorithms. The main purpose of clustering is to detect natural groupings of data from a large data set to produce a brief representation of a system's behavior.

Fuzzy Logic Toolbox™ tools allow you to find clusters in input-output training data. The rules partition themselves according to the fuzzy qualities associated with each of the data clusters. Use genfis2 or genfis3 to automatically accomplish this type of FIS generation.

Fuzzy Particle Swarm Optimization (FPSO) is proposed by Pang et.al in 2004. This method utilizes the position and velocity of particles in terms of fuzzy values to show the relation between various variables [19]. In Fuzzy Particle Swarm Optimization (FPSO), position of velocity and positions of particles in terms of fuzzy variables can be represented as below:

$$C = \begin{matrix} i_{11} & i_{12} & i_{1l} \\ i_{m1} & i_{m2} & i_{ml} \end{matrix} \quad (8)$$

Above matrix shows the relationship between objects

C = { $c_1.c_2.\ldots\ldots\ldots\ldots c_m$ } of clusters B = {$b_1.b_2\ldots\ldots\ldots\ldots b_m$ }, so C can be expressed in terms of C, in which i_{ok} is the membership function of o^{th} object of k^{th}

cluster and it is the matrix with m and l rows and columns. The elements of above matrix are in the range of [1, -1].

4. FEATURE EXTRACTION TECHNIQUES

4.1 BEMD and Fractal Dimension

The BEMD method is an adaptive and data-driven technique that decomposes an image into a small set of sub-images called 2D IMFs, representing the high and low frequency components of the original image and a residue. The sifting process for finding the 2D IMFs of an image I(x, y) comprises the following steps:

- Identify the extrema (maxima and minima) of the 2D input image h10 = I(x, y) by morphological reconstruction based on geodesic operators.
- Generate upper and lower 2D envelopes by connecting maxima points (respectively, minima points) with a radial basis function (RBF). Denote the upper and lower 2D envelopes eupper(x, y) and elower(x, y), respectively.
- Determine the local mean emean(x, y) by averaging the two envelopes.
- Subtract the envelope mean from the original input image.
- Repeat the process until the stop criterion is met and hlk(x, y) is a 2D IMF. The criterion adopted to stop the sifting process was the normalized standard deviation (SD)
- When the stop criterion is met, the 2D IMF is defined as the last result
- After the 2D IMF is found, define the residue r1(x, y). The BEMD is complete, ideally, when the residue does not contain enough extrema points.

The word fractal means degree of similarity at different scales. Fractal method can be sued to discriminate the texture of similar sets. In this method an image of size R*R is partitioned into grid of s * s size. Then it can be presented as;

N (I, j) = l – K+ 1 (9)

Where N is the different values of r (fractal dimension). And in linear transformation it can be written as;

Log (N) = Log (K) + FD Log ($\frac{1}{r}$) (10)

Where K is constant and FD is the dimension of fractal set.

4.2 Discrete cosine Transform(DCT)

The feature vectors will be obtained from the zero crossings of the differences between 1D DCT coefficients calculated in rectangular image patches. The patches of images are formed by selecting bands of pixel along 45 degree lines through the images. In the horizontal direction, a weighted average under a ¼ Hanning window is formed. In effect, the resolution in the horizontal (iris circumferential) direction is reduced by this step. . In the vertical direction (45 degrees from the iris radial), eight pixels from each patch form a 1D patch vector, which is then windowed using a similar Hanning window prior to application of the DCT in order to reduce spectral leakage during the transform. The differences between the DCT coefficients of adjacent patch vectors are then calculated and a binary code is generated from their zero crossings [4]. The main advantage of this technique is that by taking broad patches, we can make it easier for iris registration. Moreover, by averaging across the width of the patch helps to reduce the degrading effect of noise.

5. MATCHING ALGORITHMS

5.1 Minkowski Distance Measure

The templates generated from the feature extraction stage need a corresponding matching metric. The matching metric compares the similarity between the templates. A threshold is set to differentiate between intra-class and inter-class comparisons.To calculate minkowski distance, firstly consider to vectors:

$x = [x_1, x_2, \ldots \ldots, x_n]$and $y = [y_1, y_2, \ldots \ldots, y_n]$

Minkowski distance of order p is calculated as:

$$d_p(x, y) = \left[\sum_{i=1}^{n}(x_i - y_i)^p\right]^{1/p} \quad (11)$$

Euclidean distance is calculated with p=2 and it is one og the most simple and popular distance measure.

5.2 Neural network

Neural networks are composed of simple elements which operate parallel. A neural network can be trained to perform a particular function by adjusting the values of the weights between elements. Network function is determined by the connections between elements [15].

1. Propagate activation function from input to hidden layer

$$\text{Jo} = \frac{1}{1+ e^{-e1okck}} \quad (12)$$

2. Propagate activation function from hidden to the output layer

Pk = 1/ 1+ $e^{-e2kolo}$

3. Calculate the error based on the actual output pk and the target output uk

δ 2k = pk (1- pk) (uk – pk)

4. Calculate the error in the hidden layer

δ1o= ji (1−ji) Σ δ2k e2ko

5. Adjust the weights between hidden layer and output layer

∆e2ko=$\mu\delta$2k jo

6. Adjust the weights between the input layer and hidden layer

e1ok=$\mu\delta$1o ck

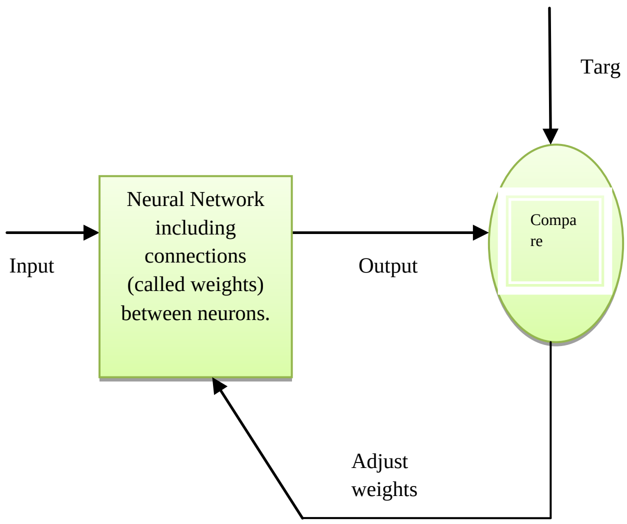

Fig 3. Neural Network

Table1: Recognition rate achieved by different methods.

Methods	CRR (%)	EER (%)	Computation Time(ms)	
			Feature Extracti -on	Match -ing
Daugman [13]	100	0.19	717	21
Ma etal. [20]	99.59	0.39	536	47
Local Texture Analysis [21]	99.53	0.48	775	41
BEMD&FD [1]	100	0.24	397	34

CRR=Correct Recognition Rate, EER=Equal error Rate

6. CONCLUSION

Iris has high uniqueness and stability which makes it a good biometrics that can be used for identifying individuals. The steps involved in iris recognition include segmentation, normalization, feature extraction and matching. This paper provide review on well known techniques for iris recognitionPros and cons of various techniques have been discussed in this paper. . The experimental results with publically available iris image database, such as CASIA, illustrates the effectiveness of the various method. The CASIA is a large open iris Database having little noise in its images. The performance of the iris recognition system depends upon the selection of the biometric traits. Every attribute has its own strength and weakness. The main problem is to exclude eyelid and eyelashes from the segmented image to improve the performance of the system. Moreover, proper image acquisition under restricted environment is also a challenging part.

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