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An overview and examination of iris recognition Algorithms

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Abstract: ***Iris recognition has become a popular research in recent years. Since its initial introduction by J. Daughman many methods have been proposed to enhance the performance. Due to its reliability and nearly perfect recognition rates, iris recognition is used in high security areas. This paper provides a review of major iris recognition researches. Iris recognition system consists of four main steps: iris localization, normalization, features extraction and iriscode matching. Comparison table of techniques of different iris recognition algorithm is also presented in brief.***

Keywords: Biometric system, Iris recognition, Iris localization, Iris normalization, Feature extraction, Iriscode matching.

I. INTRODUCTION

Biometrics is derived from Bio (means life) and Metrics (means system used for measurement). So, biometrics is a methodology of analyzing and measuring physical or biological characteristics of human body for the identification and verification of person. Biometric Systems are automated methods of verifying or recognizing the identity of a living person on the basis of some physiological features (face, finger print, palm print, retina, iris) as well as behavioural features (signature, key stroke, voice).Some of the most used biometric characteristics are shown in the fig-1. A biometric system based on **physiological** characteristics is more reliable than one which adopts **behavioral** features.

Some common biometric methods are : Face recognition, Finger print, voice recognition, Hand geometry, iris recognition etc. but iris recognition is most reliable method as compared to all other methods due to its advantages such as reliability,stability etc. Biometric methods involve two important processes: verification and identification. Verification involves one-to-one match i.e matching captured biometric with specific ID stored in database whereas identification involves one-to-many match i.e matching captured biometric among many known ID's.

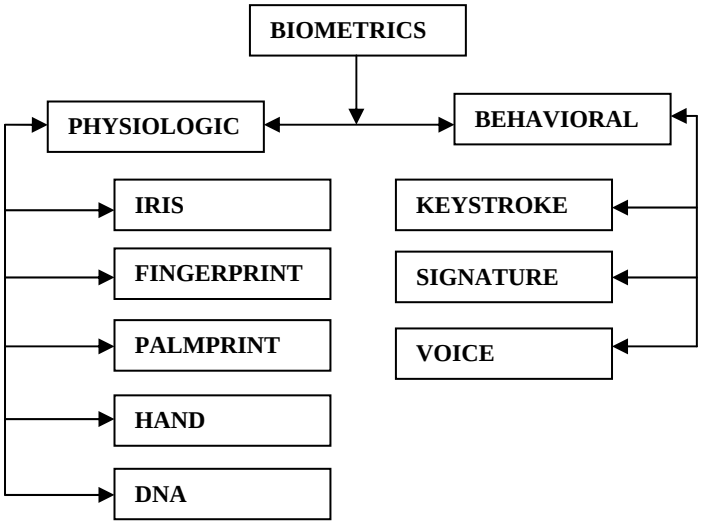

Figure 1 Types of Biometrics

Comparison of some biometric methods with iris recognition is given as:

- **Finger print Vs Iris recognition**

Both biometric methods have some common characteristicsand both are reliable and accurate but iris recognition system is better than fingerprint due to some advantages: 1) iris recognition system(1 in 131,000) has low error rate as compared to the finger print(1 in 500+). 2) There is more risk of forgery in finger print as compared to iris system because damage to iris is not as easier as finger. 3) Finger print requires physical contact with device whereas in iris recognition system no 23physical contact is required to create iris template.

- **Voice recognition Vs Iris recognition**

Voice recognition is less accurate than iris recognition system because of very high error rate(1 in 50) as compared to the error rate(1 in 131,000) of iris recognition system. Voice recognition is easy to use, cheap and non-intrisive but occurance of errors in this system is high due to cold and some external factors such as cold. Voice recognition system is only used for verification whereas iris recognition system is used for both identification and verification.

- **Face recognition Vs Iris recognition**

Face recognition is also non-intrusive like iris recognition but less reliable than iris recognition due to low level of stability in face (as face changes with time as compared to iris which remains same after eight months of age throughout life). Both technologies differ in terms of False acceptancerate(FAR) as FAR of face recognition is 1:100 whereas 1:1.2 million for iris recognition.

- **Hand geometry Vs Iris recognition**

Hand geometry is easy to use and cheaper but less accurate than iris recognition system because error rate of hand geometry is 1 in 500 which is very high as compared to iris recognition system(1 in 131,000). It produces false negative easily because hand features are not unique so this system is not as much reliable as iris recognition (iris has significant property of uniqueness i.e no two twins have same iris, even it differs in left and right eye of person).

II. IRIS RECOGNITION TECHNOLOGY

Iris recognition system becomes such a popular area of research in recent year's makes the uniqueness, stability, as its properties is the most reliable among other biometic methods. Iris is the colored part of human eye which lies between the white sclera and the dark black pupil. Iris is circular in shape, present in front of the eye lens and cornea. Eyelid protects the Iris. Color of the iris gives the color to the eye. Iris is 'coloured ring of tissue around pupil through which light enters the interior of

eye'[8].It controls the light entering the eye through the pupil, by contracting or expanding the diameter of the pupil. Iris sphincter and Dilator muscles are responsible for adjusting the size of the pupil.In spite of being an internal body part, Iris is easily externally visible. Iris gets completely developed when human is at the age of eight months or so and does not change the whole life. Diameter of the iris is about 10%- 80% more than that of the pupil. It is the most unique part of our body. No two persons in this world can ever have same iris pattern. Even the two eyes of the same person have different iris pattern. Not even the twins can have same iris pattern. This is the reason for using the Iris pattern for verifying and identifying an individual.The demand for the automatic identification of the person is increasing day by day, gave rise to the biometric recognition system. An individual can be identified by his/her finger prints, voice, signature, hand print, iris, DNA etc. But, iris being the most unique part of the human body is the best of all. Iris recognition system is the most famous person identification system and is highly accurate. In the Iris recognition system the color of the eye is not important, rather the rings, cilia, crypts, connective tissues and corona are used to identify the individual. These are the features that distinguish the human Iris.

Firstly, the eye image is captured by a camera or a scanning device. Then the captured image is fed as the input to the software that contains some algorithm to extract the unique feature from the Iris. The algorithm basically consists of different image processing techniques. After that the unique feature of the iris is converted into some code which is compared with the stored iris codes in the system database. If the code matches with any of the stored code, then the person is authenticated otherwise he/she is not allowed for the access. In this way Iris recognition system ensures the security as it only allows the person for access, who has already enrolled to the system.

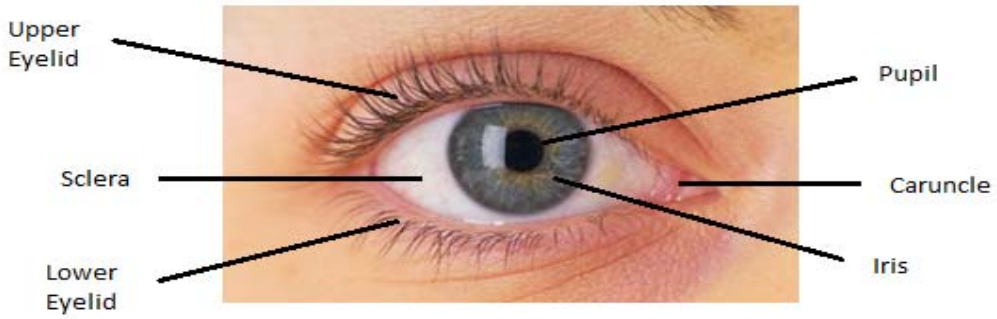

Figure 2 Human eye

Iris recognition system was first implemented by John Daugman, his system is patented and successful with correct recognition rate of 100, but after that many other systems have developed such as system developed by Boles and Boashash [5], Li Ma et al [6], Steve Zhou et al. [4].

III. Steps in IRIS Recognitions System

Iris recognition system involves five main steps: Image acquisition, iris localization, normalization, feature extraction, iris code matching.

1. Image acquisition

Eye image acquisition is first and most challengeable step in iris recognition system. High quality iris image must be required for recognition system. Image quality depends on two main aspects: lighting system and positioning system of image capturing device. Some other factors should be considered while taking iris image for recognition:1) capture image having sufficient resolution and sharpness. 2) artifacts should be removed from the images for better recognition.

2. Iris Localization

It is not possible from the image acquisition process to acquire the exact iris image so iris localization must be performed to locate the iris by detecting the iris/scalera boundary and iris/pupil boundary,and also detects upper and lower eyelids, if they are occluded in acquired images. This whole process of detecting boundaries is called segmentation and performed by various edge detection techniques.

3. Iris Normalization

Iris captured may appear in different size for different people, and even different in case of same person due to some factors such as illumination variations, camera- to-eye distance. This size inconsistency in iris texture will affect the recognition rate of system. So normalization must be performed to remove the size inconsistency by mapping iris ring of different size into fixed size rectangular blocks for performing further operations such as feature extraction and iris code matching.

4. Feature Extraction

"One of the most interesting aspects of the world is that it can be considered to be made up of patterns. A pattern is essentially an arrangement. It is characterized by the order of elements of which it is made, rather than by intrinsic nature of these elements"(Nobert Wiener)[ ].Iris consists of many minute unique charactersticssuch as stripes, coronas, freckles etc which forms the texture of iris. So several different algorithms are applied to extract these unique features e.g Gabor filter, log Gabor filter, Haar wavelet etc.This step extracts the pattern of iris by considering correlation between adjacent pixels.

5. Iris Code Matching

In iris matching, iris features that are extracted through feature extraction are compared with the iris samples stored in the database. The matching process of iris leads to the final result that whether there is exact match of extracted iris image with iris images stored in database or not. Various techniques can used for feature matching are hamming distance, weighted Euclidean distance, normalized correlation etc.

IV. Overview of some Existing IRIS Recognition Algorithms

A. Iris recognition algorithm by J. Daugman

Daugman[2] described a method for visual recognition of personal identification based on failure of statistical test of independence i.e the test will fail if iriscode for same eye are compared and will fail if iriscode for two different eyes are compared. In real time video image, the visual texture of individual iris is encoded into compact sequence of multiple quadrature 2-D Gabor wavelet coefficients, whose most significant bits comprise a 256 byte "iris code". Daugman system resolves some questions and describes a working system such as;-

1) It proves mathematically that there were sufficient degrees-of-freedom, or forms of variation in iris among individuals, to impart it as same singularity as conventional fingerprint.
2) Efficient algorithms were developed to extract a detailed iris description from a live video image, generate a compact code for iris (of minuscale length compared with image data size), and render a decision about identity with hiqh statistical confidence.
3) It also solves the problem that algorithms involved could be executed in real time on general purpose computer.

Daugman's system involves following steps

1. Iris Localization

In this step, inner and outer boundaries of iris are located (iris/pupil boundary and iris/scalera boundary) and also locates arcs of upper and lower eyelids using intergro-differential operators. Integro-differential is given as:

$\max_{(r,xo,yo)} |G\sigma(r) * \partial/\partial r I(x,y)/2\pi r ds|$

Here I(x,y) depicts the input image, $G\sigma(r)$ is the Gaussian smoothing function, r is the radius that is to be searched over the image I(x,y), s depicts the contour of circle given by r,x_0,y_0. With the variation in radius and x and y postion of circular contour, intero differential operator which is applied to an image, searches the circular path by considering the pixel values having maximum change and for accurate and complete localization this operator is applied repeatedly and in eyelids localization the path of contour intergration changes from circle to arc.

2. Iris normalization

Rubber sheet model was invented by Daugman[2] for normalization of iris image. In this model, each point in iris region is remapped into a pair of polar coordinates (r,θ) where r lies on interval [0,1] and θ is angular quantity over $[0,2\pi]$. This model produces a normalized representation of iris image with constant dimensions.

Raw coordinates (x,y) of iris image I(x,y) remapped to nonconcentric polar coordinate system (r,θ) are represented as

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

Here (x,y) are original iris image coordinates, (r,θ) are nonconcentric polar coordinates which are defined as

$x(r,\theta) = (1-r)x_p(\theta) + rx_s(\theta)$

$y(r,\theta) = (1-r)y_p(\theta) + ry_s(\theta)$

Here x_p and y_p are coordinates of pupil/iris boundary and x_i and $y_i$are coordinates of iris/scalera boundary.

3. Feature Extraction

For extracting detailed texture of iris i.e extracting both coherent and incoherent textual information from images Daugman[2] uses 2-D Gabor filter. Two dimensional Gabor filter over the image domain(x,y) is given as:

$G(x,y) = e^{-\pi[(x-x0)2/x2+(y-y0)2/\beta2]} e^{-2\pi i[u0\,x-x0+v0\,y-y0]}$

Here$(x0,y0)$specify position in the image, (α,β) specify the effective width and length, and $(u0,v0)$ specify modulation, which has spatial frequency$\omega0 = u02+v02$

Now the output of Gabor filter is demodulated by quantizing the phase information into four levels. Two bits of data are used to represent these four level i.e in normalized iris pattern every pixel corresponds to two bits of data in iris template.

4. Iris Code Matching

Comparing iriscode by performing Boolean XOR operations and hamming distance was used by Daugman for iris code matching. Bits used for calculating hamming distance are generated from actual iris region. Hamming distance gives the measure that two patterns belong from same iris or different one by calculating how many bits are same between two bit patterns. For comparing two bit patterns (A and B) Ex-OR operation is used between A and B, so hamming distance is calculated as

$$\text{Hamming Distance (HD)} = 1/N \sum_{\square} A_j(XOR)B_j$$

Now by calculating hamming distance, it concludes that iris patterns from same iris are not unique whereas iris pattern from different iris are independent of each other based on their features. If the hamming distance between two bit patternis 0.5, it means two bit pattern arises from different iris whereas if hamming distance between two bit pattern is 0, it means two bit pattern arises from same iris.

B. Iris recognition algorithm by Lin and Lu

Iris recognition method proposed by Lin and Lu make use of imaginary coefficients of morlet wavelet transform for feature extraction. Firstly iris localization and normalization is done to convert iris image into rectangular blocks of fixed size i.e 512 columns by 64 rows and then morlet wavelet transform is used for feature extraction and then pattern matching method sorts the different iris patterns and gives recognition results. In his work, iris recognition system is divided into four steps

- Iris localization
- Iris normalization
- Feature Extraction
- Feature matching

1. Iris localization

When iris image is captured, it is not possible to capture the exact iris image, so for performing exact iris recognition some other parts of eye such as eyelids, eyelashes which affects the iris recognition must be eliminated. So iris localization must be performed to locate iris for perfect iris recognition. In this[], by using gray projection and pupil centre detection operator, sketchy pupil center is located and then it finds four iris inner and four iris outer boundary points. Four iris inner boundary points are located by using direction edge detection operator and voting mechanism beginning from sketchy pupil centre and outer boundary points by direction edge operator and voting mechanism beginning from center of pupil. Localization method given by Li and Lu is accurate.

2. Iris normalization

In this step, each primitive image is adjusted to same size and position. Polar coordinate transform is used for carry on normalization i.e unwrapping of ring like iris to rectangular iris of 512 columns*64 rows giving effective iris area for perfect matching and after unwrapping bilinear interpolation is used for computing gray values of pixels.

3. Feature Extraction

In feature extraction[3], an imaginary coefficients of morletwavelet transform are used. In this. 1-D morlet wavelet transform are applied row by row to iris image in effective iris area and series of imaginary coefficients at different scales and distribution figure of these coefficients at different scales is provided. The definition of morlet wavelet is given as

$$\square(x) = л^{-1/4}(e^{i\varpi x} - e^{-\varpi^2/2})e^{-x2}/2$$

The imaginary coefficients of morlet wavelet transform computed at different scales, as these coefficients reflect the iris texture information well for feature extraction.

4. Iris Code Matching

Two iris codes were used in this: registeringiriscode and entering iriscode. Codes of registering codes and entering codes are *Registercodei[m][x][y]* and *Enrollcodei[m][x][y]*. 'and' method is used here to compute the match value between registering iris and entering iris. Revolving invariable problem in normalized image is solved in this method. In this method[], when two iris codes are compared, the code of registering iris is maintained and code of entering iris is translated several pixels to left or right along horizontal direction and several pixels to upper or lower along vertical direction, and after translating one pixel match value is calculated with registering iris code and maximum of all match values is chosen as final registering iris and entering iris value.

C. Iris recognition algorithm by Steve Zhou and Junping Sun

Iris recognition system proposed by Steve Zhou and Junping[4], divides the system into five steps: image acquisition, iris localization, iris normalization, feature matching, iris code matching

Firstly in iris localization, pupil was located by using histogram analysis and morphological process and then canny edge detector was applied to iris image and to find upper and lower eyelids polynomial curve fitting algorithm was used. Secondly Daugman'srubbersheet model was used to perform normalization i.e to convert ring like iris structure into rectangular coordinates of fixed size and then 1-D log gaborwavelet was used to encode the iris feature from the normalized image and then quantized into bitwise template. Template was then converted into input string required for matching and finally K-d tree was used for verification and identification Hamming distance and eucledian distance were used for iris code matching.Distance between two equal length iriscode was calculated. If the distance falls within certain threshold then it is considered as match otherwise no match is considered. Major drawback of his algorithm is that only limited number of iris codes can be loaded in the tree because the search efficiency decreases with increase in the tree size. Moreover, they have not mentioned the FRR, FAR and ERR, which are very important parameters to judge the performance of any algorithm

1. Iris localization

Digitized gray scale eye images were used in their work for experiments. Firstly the pupil boundary is located so histogram analysis was used to locate pupil boundary and after that iris boundary was detected. As the diameter of iris was taken twice as that of diameter of pupil. Canny edge detector and parabolic curve fitting method was used to detect eyelids. For obtaining important edge information, Gaussian filter was applied to iris image for convolution process.

2. Iris normalization

In this, Daugman rubber-sheet model was used to un wrap the iris image i.e to convert Cartesian image coordinates to polar image coordinates of original iris image. Original iris image is unwrapped into rows and columns by normalization process and converted by applying into rectangular shape of fixed size.

3. Feature Extraction

In this, feature vectors were formed by set of feature values, which were achieved by applying 1-D log gabor wavelet to normalized iris image. Log gabor filter is applied to normalized iris image row by row thus generating iris code for matching and then these iris codes were saved as input for iris code matching.

4. Iris code searching and matching

In his work [4], K-dimensional tree was used for searching by organizing the feature vectors for known ID's. Homogenous K-d binary tree of iriscode (produced in feature extraction process) was built. In this tree, there is left child node, right child node and iris object which contains data associated with record. Nodes are used for controlling the direction of search.

Hamming distance was used for describing the exact match or inexact match. Input iris code and iris code in K-d tree are compared to calculate the hamming distance. There are two types of match: exact match and inexact match. If the hamming distance between input iris code and iris code of k-d tree is zero then exact match is found. In case of inexact match, range is defined between 0 and 1, if match rate is smaller than defined value then it is considered as match otherwise not.

Table 1 COMPARISON TABLE OF ALGORITHMS DEFINED

Algorithm	Correct recognition rate (%)	Feature Extraction(ms)	Feature Matching(ms)
Daugman [2]	100	682.5	4.3
Li and Lu [3]	99.641	732.3	6.5
Steve Zhou and Junping Sun [4]	99.64	62.5	15 including search

Table 2 COMPARISON TABLE FOR VARIOUS IRIS RECOGNITION ALGORITHMS

Algorithm	Iris localization	Feature Extraction	Feature Matching
Daugman [2]	Integro-differential operator	2-D gabor transform	Hamming Distance
Boles and Boashash [5]	Edge detection operator	Zero crossing Wavelet transform	Dissimilarity function
Steve Zhou and Junping Sun [4]	Histogram analysis + canny edge detector	1-D log Gabor wavelet	K-D tree and hamming distance
Ma et al [6]	Gray level information+ canny edge detector	Spatial filter	Linear discriminant classification
Wildes [7]	Intensity gradient + hough transform	Laplacian of Guassian Filter	Normalized correlation
Lin and Lu [3]	Gray projection + center detection operator	1-D morlet wavelet transform	And operation

V. CONCLUSION

In this review paper a person can be identified by a number of ways. In biometrics we have a number of characteristics which we are using in our recognition technology as fingerprint, palm print, signature, face, iris recognition, thumb impression and so on but among these irises recognition is best technology for identification of a person. Different characteristics of iris makes it best method for automated personal identification.

Theoretically iris recognition system consists of iris localization, normalization, feature extraction and feature matching. Daugman was the first to implement a working iris recognition system and his system is patented having correct recognition rate of 100. Many other systems have also been developed. Recognition is based on the unique features of iris such this paper and review of various algorithms based on some parameters such as feature extraction, feature matching etc have also been discussed.

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