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An Extensive Study of Issues, Challenges and Achievements in Iris Recognition

Sunil Swamilingappa Harakannanavar[1], C. R. Prashanth[2], Vidyashree Kanabur[3], Veena I. Puranikmath[4] and K. B. Raja[5]
[1,3&4]Department of Electronics and Communication Engineering,
S. G. Balekundri Institute of Technology, Belagavi, Karnataka, India
[2]Department of Telecommunication Engineering, Dr. Ambedkar Institute of Technology, Bangalore, Karnataka, India
[5]Department of Electronics and Communication Engineering,
University of Visvesvaraya College of Engineering, Bangalore, Karnataka, India
E-Mail: Sunilsh143@gmail.com
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Abstract - **In recent years biometric identification of persons has gained major importance in the world from its applications, such as border security, access control and forensic. Iris recognition is one of the most booming biometric modalities. Due to its unique character as a biometric feature, iris identification and verification systems have become one of the most accurate biometric modality. In this paper, the different steps to recognize an iris image which includes acquisition, segmentation, normalization, feature extraction and matching are discussed. The performance of the iris recognition system depends on segmentation and normalization techniques adopted before extracting the iris features. It also provides an extensive review of the significant methods of iris recognition systems. In addition to this, the challenges and achievements of the iris are presented.**
Keywords: **Iris Segmentation, Feature Extraction, Performance Metrics, Acquisition, Normalization**

I. INTRODUCTION

Biometrics is defined as the study of various methods for measurements of physiological and behavioral characteristics that can be considered to identify a person. The biometric traits namely face and iris are often thought of as the major general purpose methods. Iris recognition is a process of recognition of an individual by analyzing random pattern of the iris. The iris texture from a human eye can be used for biometric authentication and identification. The use of iris pattern in a specific application involves a set of seven factors to identify the person based on the iris biometric modality.

1. Universality where in every person possesses the iris texture features.
2. Uniqueness means that the iris texture features are sufficiently different for individuals and are distinguished from one another.
3. Distinctiveness means that the randomness of iris patterns has very high dimensionality.
4. Permanence relates that the iris texture remains invariant over the time.
5. Measurability indicates the easy acquisition of iris texture.
6. Performance relates to robustness, speed and accuracy of the adopted technology
7. Acceptability relates to how well individuals accept the adopted technology.

Although the biometric traits cannot satisfy all the factors, but some of them are addressed to make a particular characteristics of biometric trait. The comparison of various biometric traits against these factors is given in Table I.

TABLE I COMPARISON OF VARIOUS BIOMETRICS TRAITS BASED ON THE DESIRABLE FACTORS [8]

Biometric Traits	Circumvention	Permanence	Acceptability	Uniqueness	Universality	Collectability	Measurability
Face	Low	Medium	High	High	High	High	High
Fingerprint	High	Medium	Medium	High	Medium	Medium	High
Ear	Low	High	High	High	Medium	High	High
Iris	Low	Medium	Low	High	Medium	Low	High
Palm Print	Medium	Medium	Medium	Medium	Medium	Medium	High
Signature	High	Medium	Medium	High	Low	Medium	High
Voice	High	Medium	High	Medium	High	High	High
Gait	Low	Medium	High	Medium	High	High	Medium
Keystroke	Medium	Medium	High	Medium	Medium	Medium	Medium

It is observed that Iris satisfies almost all the factors with good scores. This shows that iris is considered as a popular biometric trait among various identifiers in biometric recognition. Iris recognition system operates in two modes.

In identification mode, the device performs a one to many comparisons against an iris images stored in iris database and can be used either for positive or negative recognition. In verification mode, the device performs a one to one comparison of a captured iris images with a specific iris code accumulated in an iris database in order to verify an individual. Nowadays, iris recognition can be considered as one of the most popular biometric recognition techniques but the overall performances of such biometric systems can fall in non-ideal conditions.

A. Background

In 1936, Frank Burch adopted the concept of using iris patterns to recognize an individual. In 1985, Flom and Safir, developed the concept that no two irises are alike and the work was awarded patent for the method of iris identification in 1987 [1]. This resulted in the origin of modern automated iris recognition, without the use of any algorithm. In 1993, Flom approached John Daugman to develop an algorithm for automatic iris recognition model. Further in the same year, the prototype of the model was tested from the Defence Nuclear Agency developed by combined efforts by Flom, Safir, and Daugman which was successfully completed by 1995. The first commercial products on iris became available by John Daugman in the year 1994 and the patent was filed [1]. Bowyer *et al.*, in 2008, shows that iris texture is believed most distinguishable compared among all the biometric characteristics. In 2005, the patent of Flom on the basic concept of iris recognition expired and the patent on the iris code implemented by Daugman expired in 2011 to provide the marketing opportunities for other companies' leads to develop their own algorithms for iris recognition.

B. Biology of Human Iris

The term Iris comes from the Greek terminology "ipis", which means rainbow and it begins to form in the third month of gestation where the structures creating its pattern are largely complete by eighth month [2]. Its pattern can contain distinctive features such as arching ligaments, furrows, ridges etc. Some of them are shown in Fig. 1. The Iris is the colored circular part of the exterior of the eye, which forms the interior of the pupil.

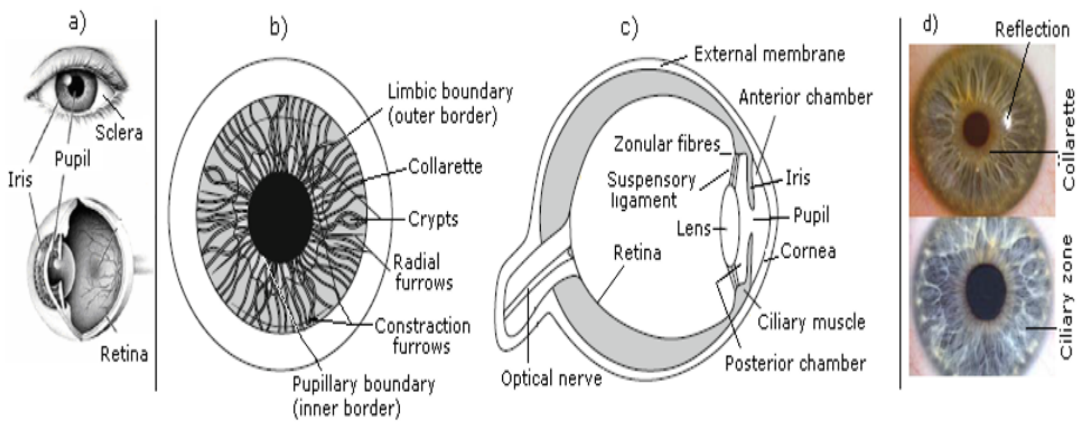

Fig. 1 (a) Iris localization, (b) and (c) Generals biological structures in a frontal and lateral view (d) Iris texture detail.

The human iris is located in between pupil and sclera. A normal iris pattern generates random texture features in its embeeding "trabecular meshwork" and pigmentation and results unique features for each individual even in case of twins. Cornia provides protection to the iris from external factors. The randomness of the iris texture is the main feature exploited in the iris biometric systems to generate reliable and robust biometric templates which results high accuracy of the recognition process.

C. Properties of Iris

The chromatic properties of the iris are as follows

1. Human iris begins to form in the third month of gestation where the structures creating its pattern will complete by eighth month.
2. Layers of the iris have ectodermal and mesodermal embryological origin and its color is determined by density of the stroma and its melanin material content.

The main properties of the human iris as an identifier are as follows

1. Iris is an internal organ highly protected and externally visible from distance up to some meters and it is protected behind the eyelid, cornea and aqueous humors.
2. It is highly textured with random pattern of great complexity and unique which generates their patterns with epigenetic and are having persistent character.

Other characteristics which researchers and developers must take into account

1. The iris is small and moving target to acquire from at a distance.
2. The iris is usually occluded by eyelids, eyelashes, lenses, eyeglasses and light reflections. For some ethnic groups, the iris texture is poor and partly occluded.
3. Iris texture deforms non-elastically when the pupil changes size.

This paper provides the different steps to recognize an iris image which includes acquisition, segmentation, normalization, feature extraction and matching are discussed. The performance of the iris recognition systems depends on segmentation and normalization techniques adopted before extracting the iris features. It also provides an extensive review of the significant methods of iris recognition systems. The rest of the paper is organized as section II deals with the challenges appears in iris recognition. The working principle and its components are explained in section III. The performance measures for recognition of iris is discussed in section IV. The recent achievements on iris are described in section V. The advantages, limitations and applications of iris are explained in section VI. Section VII concludes the work on iris recognition.

II. CHALLENGES IN IRIS RECOGNITION

The critical task of the iris recognition is the extraction of the area occupied by the iris pattern in eye/face images, task called iris segmentation [1]. An incorrect estimation of patterns results in erroneously recognitions. Iris segmentation methods have to deal with the fact that the iris region of the eye is a relatively small area, wet and constantly in motion due to involuntary eye movements. Moreover, reflections and occlusions caused by eyelids and eyelashes can be present in the captured images. These problems are more important for the images captured in non-ideal conditions, such as unconstrained, on-the-move, or non-collaborative setups [2]. These issues, acquisition and robustness, are still the challenging and unsolved problems in this area. So, there is a need for more research and to develop advanced iris recognition system, being able to identify subjects at a distance (1~3m) with a user interface [3].

The main challenges in iris acquisition having less constrained imaging conditions have to be considered.

1. Iris on-the-move (normal walking, 1 meter/sec).
2. Iris at-a-distance (3 meters, even 10+ meters?).
3. Iris off-axis (deviated gaze: not looking at camera).
4. Iris recognition under uncontrolled illumination.
5. Iris recognition in unsupervised conditions.
6. Iris recognition at reduced resolution.

The other challenge in iris recognition is to have an effective algorithm for individual verification or identification under a broad range of image and environmental conditions. So work to be carried in both baseline performance results (verification and identification) for increasing in the iris systems accuracy. The research of last decade indicates that using a combination of biometric avenues for human identification is more effective, but more challenging. The future of identification systems is currently progressing beyond the dependency of a unimodal biometric identifier, as fingerprint or iris, or face, towards multimodal biometrics [5].

III. IRIS RECOGNITION SYSTEM

A typical biometric system based on the iris trait is shown in Fig. 2, which includes iris image acquisition, Iris pre-processing, Iris segmentation, Iris texture normalization, Iris feature extraction, Iris feature codification and Iris matching [6].

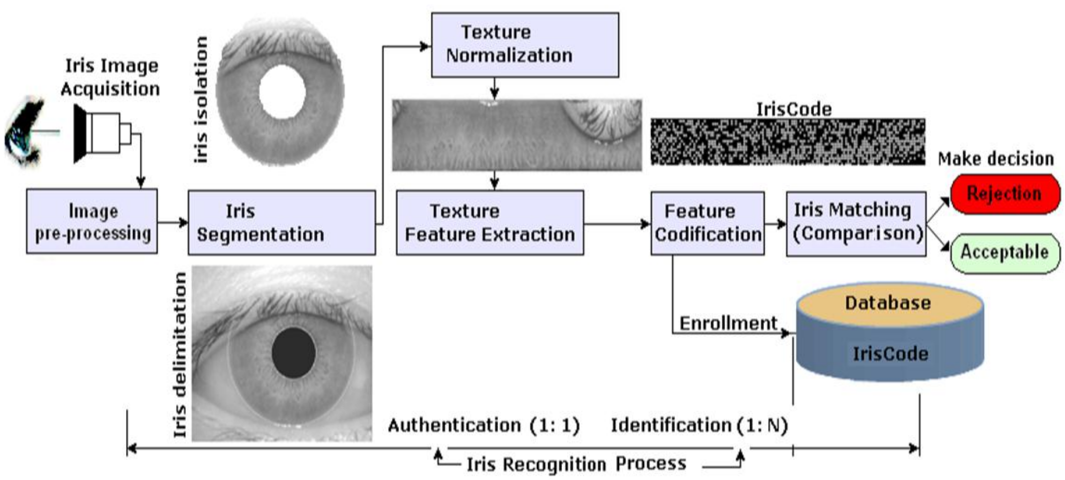

Fig. 2 Block diagram of an iris recognition system

A. Iris Image Acquisition

The image acquisition is done by using monochrome CCD[2] camera which covers the iris radius with at least 70 pixels. Here, the camera is located normally between half to one meter from the subject. The function of CCD camera is to capture the image from optical system and then converts it into electronic data [8]. Once the image was captured then it is analyzed to identify the outer boundary of the iris. The boundaries and centre of the pupil is also located and this results in the precise location of the circular iris. In addition to this, iris recognition system identifies the areas of iris image which are suitable for feature extraction and analysis. This involves in removing of areas that are covered by eyelids, deep shadows and reflective areas. Table II show the parameters of iris image acquisition cameras used in the existing approaches by Daugman and Wildes [1] [2]. Fig 3 shows the samples of iris images.

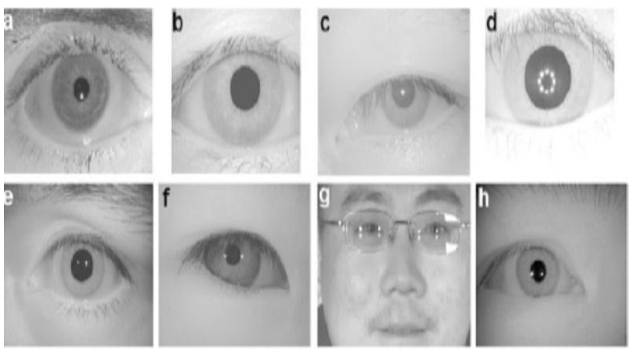

Fig. 3 Samples of real iris images acquired using cameras

TABLE II PARAMETERS OF IRIS IMAGE ACQUISITION CAMERAS

Parameters	**Daugman**	**Wildes**
Type	Monochrome camera	Monochrome camera
Resolution	640x480	Without indication
Light	NIR[3] Source of base	NIR[3] Source of base
Objective	330mm	80mm
Acquisition distance	20 to 45cm	20 cm environ (circular)
Size of iris	140 pixels	256 pixels of diameter

B. Iris Preprocessing

The captured iris image contains most of the unwanted data such as sclera, lashes, pupil etc., along with the region of interest [8]. Because of this reason, the image cannot be considered directly for recognition of iris image. In addition, the brightness variation and change in camera-to-face distance may degrade the recognition rate. Some of the issues related to reflections and occlusions are shown in Fig 4.

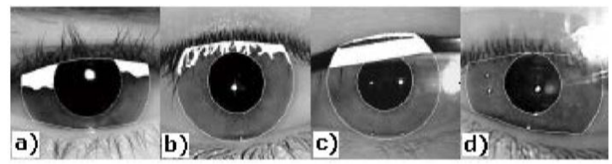

Fig. 4 a) eyelid occlusion b) Eyelash occlusion c) Glass frame occlusion d) Specular reflections

In most of the cases, the iris texture is not completely visible due to the presence of eyelids along with a portion of region of interest. The eyelid and eyelash are present in iris images with severe eyelid occlusion as shown in Fig 4 (a) and (b). The presence of glass frame produces a severe occlusion on the iris texture as shown in Fig 4 (c). Since the eye is a wet convex surface, reflections can occur due to the presence of environmental light sources as shown in Fig 4 (d). In addition, other important problems are related to the size variability of the same iris in different images like defocusing etc. Hence the preprocessing methods are adopted to localize iris, normalize iris and enhances the quality of images for recognition of iris images as shown in Fig 5.

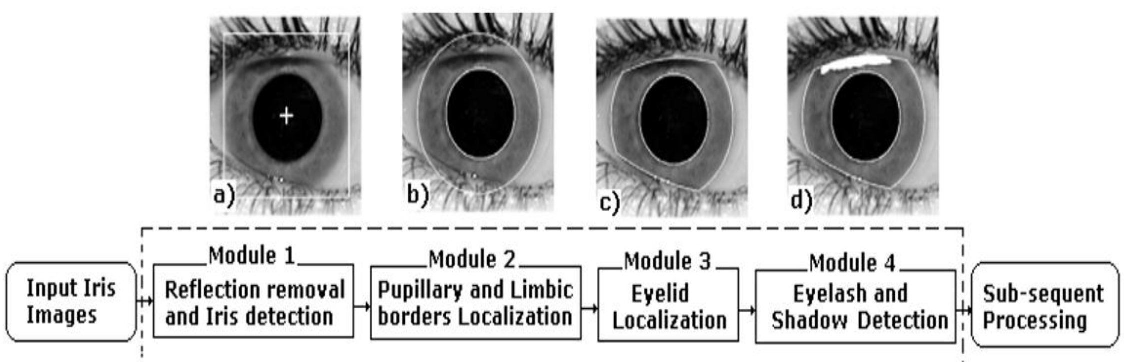

Fig. 5 Block diagram of preprocessing having four modules. 1) Reflection removal and iris detection, 2) Pupillary and limbic boundary localization, 3) Eyelid localization and 4) Eyelash and shadow detection

1. Iris Segmentation

The various significant methods of iris segmentation techniques are discussed. But the techniques based on integro-differential operator and Hough transform are most popular for the segmentation process where the performance of an iris segmentation technique is greatly dependent on its ability to precisely isolate the iris from the other parts of the eye. Both the techniques rely on curve fitting approach of the edges in the image. Such an approach works well with good quality, sharply focused iris images. However, under challenging conditions, the edge information may not be reliable. Table III summarizes the different algorithms for iris segmentation. The best known iris segmentation method is Daugman *et al.*, [7] method using Integro differential operators, which are a variant of the Hough Transform. Here, the operator acts as circular edge detectors used to determine the inner and the outer boundaries of the iris. In addition to this, it is also used to determine the elliptical boundaries of the lower and the upper eyelids.

TABLE III OVERVIEW OF PROMINENT EXISTING METHODS OF IRIS SEGMENTATION

Author	Iris Segmentation Techniques
Daugman *et al.,* [1]	Integro-differential operator
Wildes *et al.,* [2]	Image intensity gradient and Hough transform
Sharkas *et al.,* [24]	Discrete Wavelet Transform
Rizak *et al.,* [26]	Canny edge detection and Hough transform
Ankita *et al.,* [42]	Gabor filtering
Kavita *et al.,* [44]	Log Gabor and HAAR transform
Alkassar *et al.,* [50]	Canny edge detection and Gaussian Filtering
Zexi Li *et al.,* [51]	Canny Edge Detection and Hough Transform

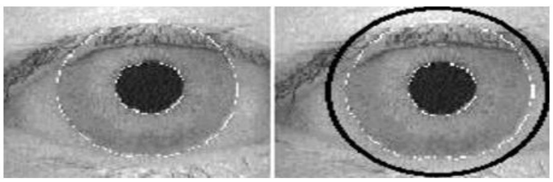

Fig. 6 Segmented Iris image

The Hough transform can be used to determine the parameters of simple geometric objects, such as lines and circles, present in an image whereas circular Hough transform can deduce the radius and centre coordinates of the pupil and iris regions [9]. The segmented iris image from the CASIA database image is shown in Fig 6.

2. Iris Normalization

The normalization process is used to transform the segmented Cartesian coordinate iris image to a fixed dimension rectangular Polar coordinate to achieve fair comparisons. Since non-uniform image size are introduced in the presence of different light source, which causes a variant dilation level in pupil area. Moreover, a varying capturing distance also affects the dimension of the resultant iris image. The various significant methods of iris normalization techniques are discussed, but the two frequent techniques such as Daugman rubber sheet model [1] [7] and Wildes [2] image registration are considered.

a. Daugman Rubber-Sheet

The segmented iris portion is converted into a rectangular image, which can be achieved by converting the segmented portion of the iris to dimensionless pseudo-polar coordinates through Homogenous Rubber Sheet Model [1] [7] [10]. As shown in Fig. 7, it is just like drawing concentric circles of pixels from the iris image where the pixel are extracted from an oval-shaped iris and it should be filled in a linear shape as a rectangle. This can be achieved by extracting the first upper ring of pixels in the iris at the size of iris diameter at 360° and arranging these pixels in a straight line then decreasing the diameter by one and arranging the extracted pixels in the second line and so on until reaching the pupil. From the above discussions, if the first circle of the iris has been parsed with 1° step, the width of the resultant rectangle will be 360° and the height of the rectangle will be equal to the difference in the radius size between the iris and the pupil.

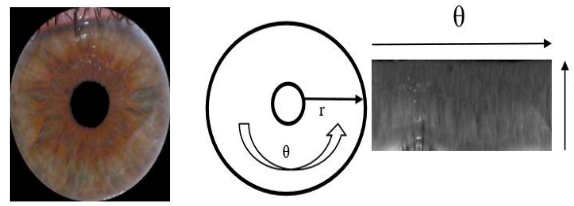

Fig. 7 Rubber Sheet Model (a) segmented iris, (b) radial and angular resolution (c) rectangular image

The homogenous rubber sheet model is given in equation 1.

$$I\ (\ x\ (\ r,\theta\ )\ ,y\ (r,\theta)) \rightarrow I\ (\ r,\theta\ ) \quad (1)$$

where $x\ (\ r\ ,\theta\ ) = (1 - r)xp(\theta) + rxi(\theta)$, $y\ (\ r\ ,\theta\ ) = (1 - r)yp(\theta) + ryi(\theta)$, $I(x,y)$, is the iris image region, (x,y) is the cartesian coordinates, (r,θ) is the polar coordinats corresponds to (x,y), xp,yp and xi,yi are the coordinates of the outer and inner rings along with θ direction.

b. Wildes Image Registration

In order to transform the iris images into a fixed dimension it is required to perform a geometrical wrapping process to the captured image $Ia(x,y)$, in alignment with stored image in database $Id(x,y)$, according to the mapping function$(u(x,y),v(x,y))$ [2]. All image intensity value at $(x) - ((x,),(x,y))$ in Ia must be close to (x,y) in Id. In other words, the mapping function (u) is calculated to minimize the error function, and is given in equation 2.

$$err = \iint (Id(x,y) - Ia(x-u,y-v))^2 dxdyx\ y \quad (2)$$

The mapping function with error minimization is constrained to find the similarity transformation of coordinate $(x,)$ to $(x',')$, given in equation 3.

$$(x',\ y') = (x,\ y) - (\emptyset)\ (x,\ y) \quad (3)$$

Where s is the scaling factor and R is the matrix that represents the rotation by $\emptyset$ angle.

C. Feature Extraction

The special features (such as rough, smooth, silky or bumpy areas) are extracted from the normalized iris image using texture analysis techniques to generate a biometric template for better matching [12]. Some of the techniques often used for features extraction are discussed below

1. *Gabor Filter:* It is defined as the result of multiplying the harmonic function with Gaussian function. In this filter each pixel in the normalized image is modulated into two pits of binary code in the resulting iris template, to be used in the template matching stage [13].

2. *Wavelet Transform:* Here, the normalized iris region is decomposed into components with different resolutions. The transform uses a bank of filters to search for features in the image using varying window sizes and the resulting code will have both frequency and space resolutions.
3. *Laplacian of Gaussian Filter:* In this approach, the filter decomposes the iris image into an analyzed shape called Laplacian pyramid [14], then a bank of Gaussian filters are applied to the resulting image to encode the features.
4. *Key Local Variations:* It deals with the normalized iris image to extract its characteristics and compose it to one dimensional intensity signals. Then Dyadic wavelet transform is applied to count the sharp variation of the signal intensity and finally the maximum and minimum points are encoded into feature vectors which are then converted into a binary template.
5. *Hilbert Transform:* It extracts the information from the iris texture and the technique depends on the frequencies extracted from the iris image and the analyzed frequency known as 'Emergent frequency' is formed [16].

D. Iris Template Matching

The template produced from the feature extraction process is compared with the system data base to obtain the similarity index between two templates. Table IV gives the matching techniques used to measure the similarity index between two iris codes [17].

TABLE IV SIMILARITY INDEX MEASUREMENT BETWEEN TWO IRIS CODES

Measures	Description
Hamming Distance	Measures the numbers of bits for which two iris codes disagree.
Euclidean Distance	Metric for measuring the minimum distance between two Iris Code vectors.
Levenshtein Distance	Metric for measuring the minimum number of edits needed to transform one string into the other.
Series of comparison scores	Instead of optimally aligning two Iris Codes by maximizing the comparison score for several bit shifts, utilizes the total series of comparison scores which avoids information loss.
Multimodal fusion of matching scores	Method for visible light iris image matching by using multiple characteristics of iris and eye images.

TABLE V IRIS DATABASE WITH ITS FEATURES

Dataset	Type	Size	Format	Images	Classes
BATH	NIR	1280×960	J2K	1600	800
CASIA.v1	NIR	320×280	BMP	756	108
CASIA.v2	NIR	640×480	BMP	2×1,200	2×60
CASIA.v3-Interval	NIR	320×280	JPG	2,639	395
CASIA.v4-Interval	NIR	320×280	JPG	2,639	395
CASIA.v3-Lamp	NIR	640×480	JPG	16,212	819
CASIA.v4-Lamp	NIR	640×480	JPG	16,212	819
CASIA.v3-Twins	NIR	640×480	JPG	3,183	400
CASIA.v4-Twins	NIR	640×480	JPG	3,183	400
CASIA.v4-Distance	NIR	2,352×1,728	JPG	2,639	395
CASIA.v4-Thousand	NIR	640×480	JPG	20,000	2,000
CASIA.v4-Syn	NIR	640×480	JPG	10,000	1,000
ICE.2005	NIR	640×480	TIFF	2,953	132
ICE.2006	NIR	640×480	TIFF	59,558	480
IITD.v1	NIR	320×240	BMP	1,120	224
MBGC-NIR Video	NIR	2,000×2,000	Video	571	–
MMU.1	NIR	320×240	BMP	450	92
MMU.2	NIR	320×238	BMP	995	200
ND-Cross Sensor	NIR	640×480	TIFF	264,945	1,352
ND-Iris-0405	NIR	640×480	TIFF	64,980	712
UBIRIS.v1	VW	200×150	JPEG	1,877	246
UBIRIS.v2	VW	400×300	TIFF	11,102	522
UPOL	VW	576×768	PNG	384	128
WVU-Biomdata.v1	NIR	640×480	BMP	3,043	462
WVU-Biomdata.v2	NIR	640×480	BMP	763	144
WVU-OffAxis	NIR	720×480	BMP	597	146

Hamming distance calculates the similarity between two binary codes from the binary image template. A value of zero will represent perfect matching, and a value near 0.5 will represent two independent irises [17]. Weighted Euclidean distance calculates the similarity between two integer values in the integer image template [18]. Normalized correlation calculates the similarity between two points (pixel or dot) in a normalized iris region [19]. The nearest feature line method is an extended version of the nearest neighbor method. The method effectively improves the classification performance when the number of templates per class is small [20].

E. Iris Database

Although to promote the research activities, freely available databases have been created for iris recognition and the research activities could be performed easily [18]. Some of the major goals for developing the common iris databases are (i) a new system could be easily tested, (ii) the state of art of other systems could be compared and (iii) their performance could be detected easily. Some of the popular iris databases that are publicly and freely available are listed in Table V.

IV. PERFORMANCE EVALUATION

A. Performance Measures for Identification System

Performance measures in iris biometrics define quantifiable assessments of the processing speed that is evaluated by performance rate which represents the number of users that can be processed per unit time. Recognition accuracy is the rates of failure-to-enroll and failure-to-acquire rate [19]. It measures the performance of feature extracting component whereas false match, false non-match, false reject and false accept rates measure that of the matching component.

1. Failure to Enroll Rate (FTE) is the proportion of the population for whom the system fails to complete the enrolment process.
2. Failure to Acquire rate (FTA) is the proportion of verification or identification comparison for which the system fails to capture, or locate biometric samples of sufficient quality.
3. False Match Rate (FMR) is the proportion of zero-effort impostor attempt samples falsely declared to match the compared nonself template.
4. False Non-Match Rate (FNMR) is the proportion of genuine samples falsely declared not to match the template of the same characteristic from the same user submitting the sample.

B. Performance Measures for Verification System

1. False Reject Rate (FRR) is the proportion of verification transactions with truthful claims of identity that are incorrectly denied.
2. False Accept Rate (FAR) is the proportion of verification transactions with zero-effort wrongful claims of identity that are incorrectly confirmed.
3. Generalized False Reject Rate (GFRR) is the proportion of genuine users who cannot be enrolled, whose sample is submitted but cannot be acquired, or who are enrolled, samples acquired, but are falsely rejected.
4. Generalized False Accept Rate (GFAR) is the proportion of impostors who are enrolled, samples acquired, and falsely matched.
5. Success Rate (SR) is the value of an iris segmentation system, considering simultaneously the False Accept Rate and the False Reject Rate using the following relation.

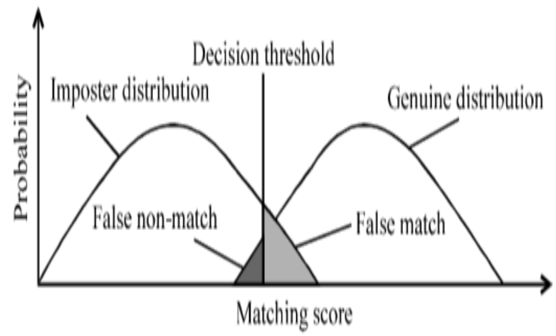

Fig. 8 Performance evaluation graph

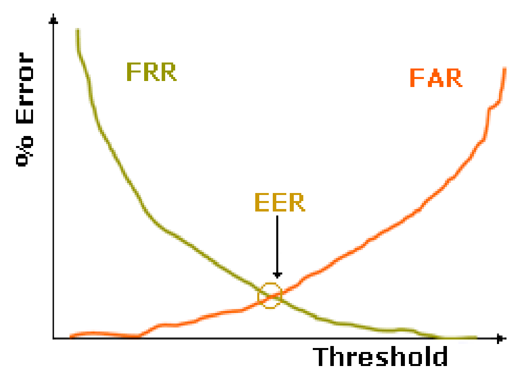

Fig. 9 Trade-off between the FAR and the FRR

6. The Equal Error Rate (EER) is the location on ROC curve, where the false reject rate (FRR) and false accept rate (FAR) are the same as shown in Fig. 9.

V. ACHIEVEMENTS

In this section the achievements to recognize the iris are described. Sharkas *et al.,* [24] proposed canny edge detection and Hough transform to detect and enhances the iris images. The fusion of 2D-DWT and Fourier Transform techniques are used to extract the features. The Artificial Neural Network is used as classifier. The experiments are conducted on CASIA-V3 iris database. Sallehuddin *et al.,* [28] proposed a unique method for matching score fusion. Here Hough transforms and canny edge detection is used to detect and select the area of interest. The Neural Network and Support Vector Machine are used as a classifier to classify the iris images. Experiments were conducted on CASIA database to evaluate the performance of the proposed model. Sheravin *et al.,* [30] proposed VGG-Net for deep feature extraction in iris model. The Canny edge detection is used to detect and enhance the quality of images. SVM is used as a classifier to match the iris images. Experiments are conducted on CASIA database. Joshi *et al.,* [44] used canny edge detection as pre-processing approach to enhance the quality of images. Here log Gabor wavelet and Haar wavelet techniques are applied on normalized images to obtain the iris features. Finally, the database images and test images are compared using Hamming Distance classifier. The experiments are conducted on CASIA database to evaluate the proposed method. Aparna *et al.,* [47] introduced Gaussian filter to enhance the quality of iris images. The combination of HAAR transforms and block sum algorithm descriptors are used to extract the final features. The Artificial Neural Network (ANN) is used as a classifier to match the iris images. The experiments are conducted on CASIA v-1 database. Baqar *et al.,* [49] introduced deep belief networks to recognize iris using contour detection. The specular highlight is removed from an Iris image using Gaussian filter. NN is used as a classifier to match the features of database and test features of iris image. The performance of the proposed method is evaluated using CASIA database. Alkassar *et al.,* [50] explained Sclera Segmentation and Validation Techniques for iris model. The AHE was applied on input images to sharpen the images. The two dimensional Gabor filter used to extract the iris features. Support vector machine used as classifier to match the database and test images. The experiments were conducted on UBIRIS-V-1 database. Table VI gives the various algorithms discussed by the researchers for iris recognition.

TABLE VI RECENT EXISTING ALGORITHMS FOR IRIS RECOGNITION

Author	**Feature Extraction**	**Classifier**	**Database**	**Accuracy**
Rocky *et al.,* [23]	3D-GLCM	Neural Network	CASIA	94.22%
Sharkas *et al.,* [24]	Discrete Wavelet Transform	ANN	CASIA-V3	98.3%
Arif *et al.,* [25]	Discrete Cosine Transform	SVM and Gabor	MMU2	98.57%
Habibeh *et al.,* [27]	Wavelet and Gabor filter	MIR	CASIA-V3	93.5%
Ayu *et al.,* [28]	DOG and LOG	NN and SVM	CASIA	99%
Rangaswamy *et al.,* [29]	Discrete Wavelet Transform	Euclidian Distance	CASIA	97.50%
Shervin *et al.,* [30]	VGG-Net	Multiclass SVM	CASIA	99.4%
Charan *et al.,* [31]	Discrete Cosine Transform	Euclidian Distance	CASIA	98.66%
Kiran *et al.,* [33]	BSIF and SIFT	Support Vector Machine	GMR and FMR	100%
KrishnaDevi *et al.,* [34]	GLCM	Support Vector Machine	CASIA	97%
Simina *et al.,* [35]	LBP, LPQ & DE	Support Vector Machine	UPOL	93.75%
Ujwalla *et al.,* [37]	Local Binary Pattern	Neural Network	CASIA,MMU,IITD	97%
Ritesh *et al.,* [38]	Haar Wavelet Transform	2-D Gabor filter	IITD	96.33%
Sushilkumar *et al.,* [39]	1D Log- Gabor	SVM & ANN	CASIA	95.9%
Kumar *et al.,* [40]	DWT & DCT	-----	IITD	94.59%
Sheela *et al.,* [41]	Hough Gradient	Adaboost classifier	CASIA	95%
Ankita *et al.,* [42]	Gabor filtering	K-out-of-n ED	CASIA	95%
Chun- tan *et al.,* [43]	Log Gabor	Hamming distance	CASIA.V4	95%
Kavita *et al.,* [44]	Log Gabor and HAAR	Hamming distance	CASIA	100%
Khary *et al.,* [45]	Modified Local binary pattern	Support Vector Machine	CASIA	96%
Arunalatha *et al.,* [46]	DTCWT and OLBP	Euclidian Distance	CASIA-V1	98.48%
Aparna *et al.,* [47]	HAAR Transform	ANN	CASIA	98%
Kien *et al.,* [48]	Convolution Neural Network	Support Vector Machine	CASIA	98.8%
Baqar *et al.,* [49]	Gabor filter	Neural Network	CASIA	99.92%
Alkassar *et al.,* [50]	Gabor filter	Support Vector Machine	UBIRIS.V1	98.65%
Zexi Li *et al.,* [51]	2-D Gabor filter	Euclidian Distance	CASIA	96.5%
Ximing *et al.,* [53]	2-D Gabor Wavelet	Support Vector Machine	CASIA	99.8%

VI. BENEFITS AND APPLICATIONS OF IRIS RECOGNITION SYSTEM

This section describes the main advantages, limitations and applications of iris recognition.

A. Advantages of Iris Recognition System

The iris of the eye has been described for biometric identification for several reasons.

1. Iris is an organ with pre-natal morphogenesis.
2. Limited genetic penetrance of iris patterns. Means the iris patterns are not hereditary.
3. Iris patterns are apparently stable throughout the human life.
4. Changing pupil size confirms natural physiology.
5. Natural protection from external environment.
6. Impossibility of surgically modifying the iris without risk of the vision.
7. Iris is externally visible and its patterns can be scanned from a distance.
8. Iris is mostly flat, and its geometric configuration is only controlled by two complementary muscles that control the diameter of the pupil.
9. Iris of each person is unique, because iris patterns possess a high degree of randomness.
10. Encoding and decision-making are tractable.

B. Disadvantages of Iris Recognition

The limitations of the iris identification are listed below

1. Small target (1 cm) to acquire from a distance.
2. Moving target periodically and involuntary.
3. Located behind a curved, wet and reflecting surface.
4. Obscured by eyelashes, lenses and reflections.
5. Partially occluded by eyelids, eyelashes and shadows.
6. Deforms non-elastically as pupil changes size.

C. Applications of Iris Recognition

The use of biometrics within Physical Access Control [28] systems is one of the most broadly commercialized sectors of biometrics, outside of forensic applications. In the last decade, research on the automated recognition of human's iris has evolved to cover a large number of applications.

1. Iris applications in national borders control, where the iris as a living passport for the security control in frontier [30]. This task is related with the entrances and exits to the country of nationals and non-national peoples as part of the daily exchange with other countries of the world. However places such as airports, marine and industrial areas linked to the marine fishing and the external commerce of merchandise [31]. The major task is the identification of travelers, immigrants, employees, temporal workers, etc.

Fig. 10 Examples of iris recognition system in statics services

2. Iris applications in homeland security, to secure as well as identify people.
3. Iris applications in forensics science [42], wide range of sciences to solve issues of interest for the legal system such as Authentication of persons, credit-card, governmental documents, official documents, etc., authentication of "rights to services" such as "birth certificates", tracing missing or wanted people. Missing people's identification which doesn't remember their home address [44].
4. Iris recognition in commercial applications give possibilities to develop service, devices and apparatus related with iris person recognitions such as authentication using cell phone and other wireless device (electronic commerce, telephony), ticketless travel, automobile ignition and unlocking and anti-theft devices [49].

Fig. 11 Iris applications are designed for the internal security control and forensic services

VII. CONCLUSION AND FUTURE SCOPE

Biometric identification of persons has gained major importance in the world from its applications, such as border security, access control and forensic. Iris recognition is one of the booming biometric modalities due to its unique characteristics. Iris recognition is a process of recognition of an individual by analyzing random pattern of the iris. The iris texture from a human eye can be used for biometric authentication and identification of humans. In this paper, the different steps to recognize iris images are discussed which includes acquisition, segmentation, normalization, feature extraction and matching. The challenges and achievements are presented to provide a platform for the development of the novel techniques in this area as a future work.

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