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Iris Recognition Techniques: A Literature Survey

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Abstract

Iris is a coloured muscle present inside the eye which helps in controlling the amount of light entering the eye. It has several unique textural information, which does not get altered or tampered easily, making it a best suited trait for biometric systems. Due to its uniqueness, universality, reliability and stability, Iris patterns serve a major role in several potential recognition or authentication applications. In biometric identification and authentication systems, iris recognition techniques have been made tremendous growth over the past two decades, since its evolution. The main aim of this paper is to provide a timeline review of various iris recognition techniques, developed since 1993.

Keywords— Iris Recognition Technique, Segmentation, Feature Extraction, Texture matching, Iris databases

1. Introduction

Developing a high end security system for either identification or authentication purpose have always been an active research area and attractive goal in almost all fields. Traditional security systems provide security to a process or a product with the help of "something that we have or we know", i.e., a key or a password, whereas a biometric security system uses "something that we are", i.e., a person's physical or behavioral traits. Physiological or behavioural traits of a person may include, but not limited to the following: face, finger print, iris, retina, voice, DNA, gait, etc.

Biometric traits have highly reliable and unique features that make it best suited for security systems over a traditional or conventional security system. Jain et al. (1999) [1], identified seven factors that could be used to identify a person's physical or behavioural characteristics as a biometric trait to be used in biometric security systems. They are

(1) Universality (ease of availability in an individual),
(2) Uniqueness (distinct characteristics),
(3) Permanence (stability or durability),
(4) Measurability or collectability (ease of acquisition),
(5) Performance (quality of being efficient),
(6) Acceptability (degree of approval) and
(7) Circumvention (ease use of a substitute).

Though a biometric trait cannot satisfy all of these, some of them must be satisfied to make a characteristic a biometric trait. Table 1 shows a comparison of various biometric traits against these factors, according to A.K. Jain [2](H=High, M=Medium, L=Low). For circumvent ability low is desirable instead of high.

Based on the above observation, Iris satisfies almost all the factors with good score and hence used as a popular biometric trait in biometric recognition systems, among various other identifiers. Iris is a well protected muscle present inside the eye with unique and rich patterns like furrows, rings, freckles and crypts. It has a distinguishable colour, which is immutable and invariant over time. It has been proved that for an individual, there are differences in iris patterns even between right and left eye. Even iris patterns differ for twins, who are identical. Thus recognition techniques developed using iris patterns could be considered as a best suited identification and authentication technique, especially in areas like, physical or personal authentication systems, time and attendance maintenance systems, law enforcement systems, banking applications, etc.

Table 1 Biometric Trait vs. Factors

Biometric trait \ Factors	Universality	Uniqueness	Permanence	Measurability	Performance	Acceptability	Circumvention
Face	H	L	M	H	L	H	H
Finger Print	M	H	H	M	H	M	M
Iris	H	H	H	M	H	L	L
Retina	H	H	M	L	H	L	L
DNA	H	H	H	L	H	L	L
Voice	M	L	L	M	L	H	H
Gait	M	M	H	M	M	H	M

Basic principles of operations of an iris recognition technique are as follows:

1. Image acquisition or data capture;
2. Preprocessing and Iris Segmentation;
3. Normalization;
4. Feature extraction;
5. Match generation or comparison of templates against enrolled data for recognition or authentication purpose.

This paper presents a collective study which is formatted as follows: Section 2 provides background concepts about iris anatomy, history behind using iris as a biometric trait and a brief about Iris recognition System (IRS). Section 3 provides a survey on frequently cited iris recognition techniques and Section 4 includes information about iris databases and the paper conclude with Section 5.

2. Background Concepts

2.1 Iris Anatomy

The heterogeneous behaviour of the human eye provides two accurate biometric traits, the iris and the retina. When eye is viewed from the front it has two distinct regions: sclera and cornea. Sclera is white or pale white in colour with closely interwoven fibres. Iris is present well protected behind cornea, a transparent membrane and aqueous humor, providing an individually distinguishing pattern or texture [3]. Cornea covers both pupil and iris, where pupil is the central aperture of iris, normally dark in colour when compared to iris. Fig. 1 shows the front view of a human eye with blue iris and a top view of the right eye [7].

During the third month of the foetus growth, iris is said to be developed, through a process of tight forming and folding of the tissue membranes [4]. Prior to child birth, degeneration occurs resulting in pupil opening and the random unique patterns of iris [5]. Dilator and sphincter are two muscles present in iris, responsible for controlling the amount of light entering into pupil by adjusting its size [6]. Though the pigmentation and structure of iris are genetically linked, it has more than 200 distinct feature points, which could be used for identification or recognition purpose including rings, furrows, crypts, freckles, collarette, etc. Fig. 2 depicts the structure of the iris along with its distinct features [8].

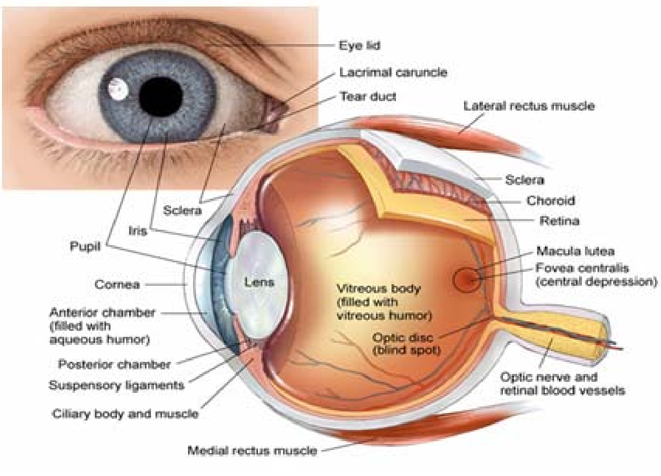

Fig. 1 Right Eye Viewed from Above

One important quality of iris for making it a best suited biometric trait over retina is that, it is visible even to naked eye. When seen in visible light spectrum, iris is seen as a pigmented mosaic of textures, whereas under IR regions, features could be seen more easily. It has been proved by the iris research community and ophthalmologists that for an individual the iris present in the left and the right eyes are distinct and in case of genetically identical twins also it is dissimilar, thus making iris an ideal biometric trait that could be used in iris recognition techniques.

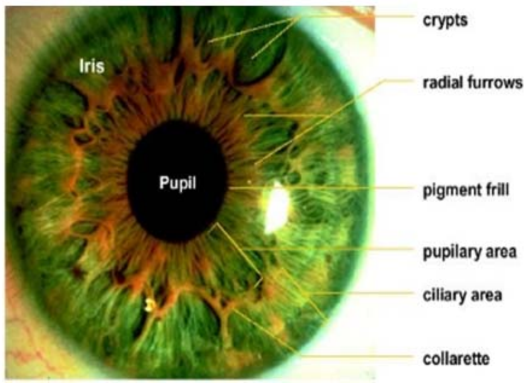

Fig. 2 Structure of iris

2.2 Iris: A Biometric Trait

In the ancient civilizations, Egypt to Chaldea in Babylonia, China and Greece believed in a divination concept called “Iridology” [9], which deals with iris patterns of the eye to predict the health status of an organ in the body. They used to compare the iris of the subject with Iris charts and predict the nature of the behaviour of the body organs. Fig. 3 shows the iris charts used in “Iridology” concept [9].

Later in 1885, a French police official, Alphonse Bertillon suggested the use of iris for personal identification based on its texture and colour [10]. James Doggart, in 1949, examined iris pattern complexity and suggested that it could be used instead of finger print. Two ophthalmologists Leonard Flom and Aran Safir in 1987 after making a thorough study, patented Doggart’s concept [11]. Though variation in iris patterns were observed and was suggested to be used for personal identification for the past one century, a practical or commercial iris recognition algorithm was developed and patented by John Daugman, a computer scientist only in 1989.

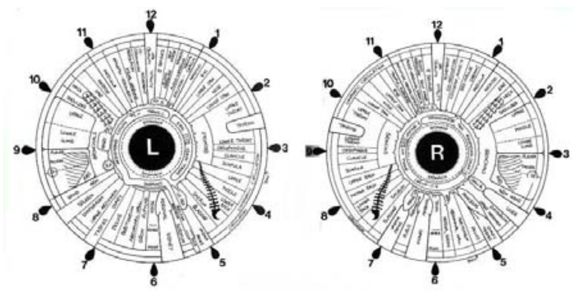

Fig. 3 Iris Charts

After which there is a tremendous growth for the past two decades in developing several automated iris recognition systems. But still John Daugman's algorithm forms the basis for all the commercially available iris recognition systems.

The research growth in various sections of the automated iris recognition techniques have been classified into the following major areas according to [12]:

(i) New iris recognition algorithm development

(ii) Segmenting the iris portion from the eye, either with or without noise factors.

(iii) Extracting the features and normalizing them.

(iv) Creating models for iris recognition system using machine learning algorithms.

(v) Multimodal and fusion of biometric techniques.

All the techniques or algorithms developed so far could be considered advantageous or disadvantageous based on considering the domain area in which it will be applied to work.

2.3 Iris Recognition Frame work

Iris recognition system constitutes several subsystems, also called stages in personal authentication or identification process. The framework of an automated iris recognition system is depicted in the Fig. 4. First stage is the segmentation process or iris localization process. In this step, iris region is segmented or isolated from the eye by performing a pupil separation process followed by approximately identifying two circular boundaries,

(i) Pupillary/ inner boundary and

(ii) Sclera/ outer boundary.

Occlusion of eyelids in the upper and lower parts of iris and specular reflections occurring inside the iris region and pupil region are considered as noise and to be treated properly. Thus in any iris recognition system, the quality of the output produced in segmentation stage results in better performance of the final system.

Second stage is the normalization process, in which the segmented iris region is transformed to have fixed dimensions, so that feature extraction and matching becomes easier. Inconsistencies in the dimensions of the segmented iris region between eye images are due to its functionality, i.e., size adjustment to allow the light entering into the eye, resulting in pupil dilation. Other reasons may include but not restricted to are,

(i) Distance of the eye from the scanner.

(ii) Head tilt by the subject.

(iii) Eyeball movement.

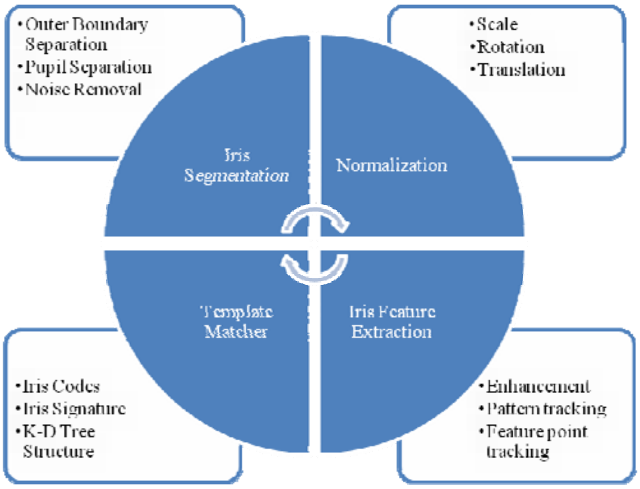

Fig. 4 Iris recognition Frame work

(iv) Illumination settings in the image acquisition area (i.e., whether under visible light or near IR).
(v) Non-concentric nature of iris.

Thus by performing the normalization process, any two isolated iris regions with constant dimensions will have the same spatially located features.

Final stages in the system are the feature extraction and the iris template matching stage. Normally, a single iris is said to have more than 266 distinct information in its patterns, where approximately 173 are used in creating templates [13]. This information must be extracted from the normalized iris and should be used for comparison purposes for either personal authentication or identification based on the application area. Thus at the end of the feature extraction stage, a biometric template is created, which is then used for template matching. A biometric template could be an iris code, or an iris signature or a decision tree. These templates are then matched with the help of several available matching techniques, which helps in identifying the similarity levels of two different iris templates. When the two different templates belonging to same eye are matched, it results in a range of values called "intra class variations. Similarly if the templates are from different eyes, range of values is called "inter class variations". Based on these two variation a decision can be made whether the templates belong to sane or two different iris or irises respectively.

3. State-Of-Art Survey

Though several papers have been published in this area in the past two decades, 40 papers have been selected and are presented to understand various Iris recognition techniques available in literature. These articles showed difference from one another in one way or the other. In this paper, a review focusing on all four stages i.e., segmentation, normalization, extraction and template algorithms for iris recognition technique starting from Daugman's initial work in 1993 to some of the recent works have been provided.

In [14], [15], Daugman (1993), presented a novel iris recognition system, which forms the basis for most of the developmental activities in this area till date. This system acquires a human eye with the help of a video camera and identifies it. It localizes two boundaries before segmenting an iris, inner pupillary boundary and the outer sclera boundary with the help of an "Integro differential operator". Since in most eyes, the pupil is not in the centre of the iris, the pseudo polar coordinate system is projected to a "homogenous rubber sheet", by analysing the annular rings of the iris and assigning a doubly dimensionless real coordinates. In this method, iris regions occluded with eyelids, eyelashes and specular reflections are avoided or, eyes images are selected in such a way that there are no such occlusions. A "2-d Gabor filter" is used to extract the features from this doubly dimensionless polar coordinate system resulting in a "256 byte (2048 paired bits) iris codes". The length and universal format of these codes make comparisons between them easy and efficient. Then comes the problem of recognizing a given code as belonging to a particular subject or not. This is achieved by a metric called "normalized Hamming distance" which uses a fraction of bits that disagree and helps in finding the similarity between any two iris codes. This normalized hamming distance metric is simply referred as hamming distance in many papers nowadays. The iris code generated helps in easy handling of the iris bits and matching is also made easier. Many commercial iris biometric systems use this approach as a base till date. In [11] Flom and Safir (1987) had obtained a patent "Iris Recognition System", which gives a generalized concept in using iris as a biometric system, but does not describe any implemented algorithm. But in [15], Daugman has obtained a patent for an operational method which uniquely performs biometric analysis of iris in identifying a person.

In [16] Wilde (1997) tried a different approach, in which a LED point source was included while acquiring the eye image of the subject along with a standard video camera. Inner and outer iris boundary is computed with the help of a gradient based binary edge map followed by circular Hough transform. Wilde's approach applied an isotropic band pass decomposition derived from Laplacian of Gaussian at multiple scales to develop an iris signature template. This template is used to find the similarity by computing the normalized correlation for goodness of match. Wilde used nearly 60 irises acquired from 40 subjects in his experiment. He has also done a comparative study with Daugman's work in this paper. Though Daugman's system is simpler compared to Wilde's, the segmentation process defined by Wilde is more stable pertaining to noise disturbances. He has included eyelid detection in the segmentation stage, which is considered as one of the advantage in this paper. In [17] Wilde has obtained two separate patents for the segmentation technique and the normalized correlation matching technique. Papers [18], [19] provide some additional information to the early Wilde's approach described in [16].

In [20] Boles et al. (1998) used circular edge detection technique to segment an iris image and perform virtual circle analysis to obtain a normalized iris signature. They were the first to perform "Wavelet transforms" on 1-d signals to extract features from the iris signature. Two different dissimilarity functions using a zero-crossing representation is implemented in identifying a match. This approach provides a scale, rotation and translation invariant algorithm for recognizing an iris of a human eye.

In [21] Kong and Zhang (2001), designed a system, which concentrated mainly on the noise disturbances, occlusion of eye lashes and specular reflections, involved while segmenting an iris image. Hough transform was use to isolate an iris followed by application of 1-d Gabor filters in spatial domain and thresholding function to detect eyelid occlusion and specular reflection respectively. Multiple eyelashes were detected with the help of variance of intensity values. 2-d Gabor filters were used to extract features and then to design a binary feature vector. A matching score is obtained to find the dissimilarity between any two irises. This approach provides a noise detection model at the segmentation stage thus resulting with better performance rates.

In [22] Lim et al. (2001), obtained eye images at a distance with the help of a CCD camera and to minimize the reflection effect caused due to illumination, two halogen lamps were arranged for surrounding lights. From the acquired image iris is segmented, initially by detecting the pupil using the centre point detection method followed by edge detection method by finding virtual circles. In the pre-processing stage, an analysis was made with 6000 data to identify the causes of failure at the pre-processing stage. Data involved images both without glasses, with Lens and with glasses. In the normalization stage a 450x60 bit iris image part was obtained. Gabor transforms and Haar wavelet transforms, two different methods, were used to analyse and extract the features from the segmented iris image. A feature vector was designed with only 87 bit patterns and was fed as an input to a competitive classifier, neural network model for recognition. The author had a designed a dataset having 6000 images, with 30 images taken from individual subjects, obtained over a period of 3 months interval.

In [23] Huang et al. (2002), described an efficient iris recognition technique, in which segmentation was performed initially by applying a median filter followed by Candy operator to identify the image edge and then voting the maximum circle to find the sclera or outer boundary. Inner or pupillary boundary is found based on a rectangular inter interval. Then using the rough boundary identified iris image is segmented using an effective Integro differential operator. Eyelids are detected using histogram Hough transformation followed by thresholding for single eyelash and variance of thresholding for multiple eyelashes. A size and rotation invariant concentric circular iris representation is then obtained in the normalization stage. Independent component analysis coefficients were used to extract the features from the 128 x 40 bit unwrapped iris image followed by average Euclidean distance classifier for iris recognition.

In [24] Daugman (2004), has proposed an approach which is an improvement to his early work in [14]. This model is intended to work with the noise disturbances that occur while acquiring an iris image of a human eye. In addition to the Integro-differential operator described earlier, an algorithm was introduced for detecting the eyelids, which involves arcuate edges with spline parameter, instead of circular edges in the Integro differential operator. This paper provides an improvement to his early work by providing a solution to detect the eyelid occlusion.

In [25] Ma et al. (2004), proposed an iris recognition system, which involves Canny operator for edge detection followed by Hough transform to segment the iris. During the normalization stage, the annular iris rings were unwrapped in counter-clockwise manner to form a size invariant rectangular block. This also helps to solve the distortion problem caused due to pupil dilation. Then the low contrast normalized iris image is enhanced, so that subsequent processing becomes easier. A set of 1-d signals are generated and were decomposed using wavelet transforms followed by recording the position of local sharp variation points which help in indicating image features to form a feature vector. This feature vector is then converted into a binary feature vector and goodness of match is found with the help of Boolean XOR function. During the experimentation stage, using a homemade camera they created the CASIA iris database having 2255 iris images using 213 subjects with 306 different eyes.

In [26] Huang et al. (2004), proposed a new segmentation method which involves both segmenting the iris accurately and eliminating the noise factors for better performance in the subsequent stages. To increase the speed of segmentation stage, a rough localization of iris is performed by simple filtering, edge detection and Hough transform. After that the noise factors such as occlusion of eyelids and eyelashes and specular reflections are detected and eliminated. After localizing the iris image, 2-d log Gabor phase congruency filters were applied to extract the edges followed by infusing the edge details with region details to remove the eyelid, eyelash and reflection noises. In this paper they have used the CASIA dataset to verify the results and found to provide better speed and accuracy.

In [27] Dorairaj et al. (2005), developed an algorithm for processing off-angle iris images using PCA and global ICA image encoding technique. During pre-processing stage, they have used Hamming distance to calculate the gazing angle followed by Daugman’s Integro differential operator to segment the iris. They have tested their results using 100 iris class images from CASIA dataset and a special database having off-angle iris images called WVU database having 75 classes with 4 images and checked the performance of this non-ideal iris recognition techniques.

In [28] Proenca et al. (2006), provided a better segmentation algorithm for non-cooperative iris images by initially extracting features from iris followed by applying fuzzy clustering algorithm. Result of this experiment was compared against Daugman's, Camus and Wilde’s, Wilde’s, Martin-Roche et al. and Tuceryan’s segmentation techniques and found to have improved performance rates.

In [29] Miyazawa et al. (2006), described a phase-based recognition algorithm, in which inner boundary is isolated using elliptical contour summation and outer/sclera boundary is isolated using circular contour summation techniques. Only the lower portion of the iris image is unwrapped into a rectangular block to avoid upper eyelid and eyelash occlusion followed by contrast enhancement using Histogram equalization. Using effective region extraction technique and displacement alignment, features are extracted and a match score is identified using phase based image matching technique in 2-d Discrete Fourier Transforms. Experimental results tested using CASIA database V1.0 and V2.0, found to achieve a highly accurate recognition rate even for low quality images.

In [30] Tian et al. (2006), proposed a recognition algorithm, which uses window based filters to identify pupil and Hough transform to mark inner boundary. Daugman's Integro differential operator is used to locate outer boundary followed by eyelid and eyelashes detection using Hough transform' three line model and adaptive threshold technique respectively and then unwrapped to a normalized iris image using Daugman's rubber sheet model. For feature extraction and recognition a low frequency filter followed by 2-d zero crossing detection operator and similarity degree classifiers are proposed respectively. This algorithm is able to provide rotation, translation and size invariant result. Simulation results of this algorithm proves to provide a higher correct accept and reject rate. Results were tested using CASIA database and a database provided by Institute of Automation for 2005 Biometrics Authentication competition.

In [31] Monro et al. (2007), has designed an iris recognition algorithm in which Hough transform is used to segment the iris image from the eye and is normalized to a rectangular image array using bi-linear interpolation of 4-nearest neighbour method. Features from the normalized image is extracted with the help of zero crossing representation of 1-d Discrete Cosine Transform and a matching score is performed with the help of weighted hamming distance metrics. Experiment was tested using 308 image classes from CASIA and 150 image classes from BATH found to provide better performance with no FALSE Accept/ Reject on both databases.

In [32], as an improvement to his early work, Daugman (2007) has proposed a new image processing algorithm to be used during the segmentation stage which helps in handling off-axis iris images..Iris localization is done in three stages (i) segmenting iris as a whole, (ii) gaze estimation for off-axis eye images and (iii) exclusion of upper eyelid eyelashes. Features are extracted using 1-d Log Gabor filters and test for statistical independence is performed to check the match score between two iris codes using the UAE databases.

In [33] Yew et al. (2008), described an effective segmentation method in which an iris image is segmented and the four iris noises namely eyelid occlusion, eyelash occlusion, pupil and specular reflection. Using an appropriate threshold value pupil location is identified and the pupil reflection is removed with the help of a morphological operator. Circular Hough transform is used to identify the inner iris boundary. Iris outer boundary is localized by selecting two search regions, right and left iris boundary based on a threshold value. Search regions are selected based on the pupil position and its intensity values. Sobel edge detection operator is applied to the search regions to locate upper and lower eyelids. Simple thresholding value is applied to remove both the separable eyelash and multiple eyelashes and both specular and pupil reflection noises. Segmented iris image is normalized to a fixed size rectangular block in which 1-d Log Gabor filters are applied to extract the features and then a match score is identified with the help of Hamming distance to measure dissimilarity, followed by a threshold value to decide the identity. This method proved to provide higher accuracy rate when tested in CASIA database.

In [34] Demirel et al. (2008), proposed a system for colour iris image using KLD probability density function between input iris and the training set iris image by applying majority voting and feature vector fusion technique. Input iris image is segmented with the help of a manual binary mask with prior knowledge of the maximum and minimum radius of the iris present in the UPOL database. This system is said to have provided 98.44% recognition rate.

In [35] Abiyev et al. (2008), simulated an iris recognition system using neural networks (NN).Pupil region is detected with the help of a 10x10 rectangular area technique and helps in detecting the iris inner circle. Linear Hough transform is used to remove the effect of eyelids and a thresholding technique is used to remove eyelashes and then the image is enhanced to improve the contrast and brightness. A gradient based learning model is used to classify the pattern which is proposed to provide higher accuracy rate of 99.25%.

In [36] Chandramurthy et al. (2009), presented an algorithm to perform pattern classification. Iris image is localized with the help of Hough transform technique and Canny edge detector by applying it in both horizontal and vertical direction. Annular iris image is mapped to a rectangular fixed block followed by projecting it onto a 1-d Log Gabor wavelet to extract the texture characteristics. From the texture, the patterns are then identified and their similarities and differences are highlighted with the help of a linear transformation scheme called Principal Component Analysis (PCA). In classification phase, a set of training data is used for training classifier and another set for testing the classifier using Bayes, Euclidean and K-NN probabilistic and non probabilistic distance measures. Performance evaluation of the experiment was performed on image datasets present in CASIA V3.0 and MMU databases. Based on the results the author has proved this algorithm to be robust and versatile.

In [37] He et al. (2009), proposed an efficient technique to detect fake iris images using Wavelet Packet transforms followed by radial basis kernel function of SVM classifier. They have manually collected 1000 live iris images out of which 220 were defocused. According to the author, the experimental results make this system more robust against spoofing attacks of iris images.

In [38] Ross et al. (2010), analysed a technique to classify the irises into multiple categories based on their statistical features. Extracted feature vector is compared against several pre-determined clusters to perform iris classification using Principal Direction Divisive Partitioning (PDDP) algorithm. This system was tested using 192 24-bit RGB colour images of both left and right eye present in UPOL database.

In [39] Narote et al. (2010), evaluated the performance of several mother wavelets in extracting the features of an iris image and determined an optimal wavelet transform. A normalized image is decomposed using fifth level decomposition and features are extracted using different mother wavelets: Haar, Daubechies, Coiflet, Symlet and Biorthogonal. By applying these wavelet transforms on different co-efficient levels like horizontal, vertical, diagonal or combination of them, an optimal wavelet transform is determined and its performance is also evaluated. Experiments were performed on SCOE Iris V1 database, having a dataset of 2750 images from 275 subjects and the efficiency and accuracy were tested.

In [40] Hussain (2010) proposed a technique to extract features from the rectangular iris codes in the Eigen space domain. Different numbers of Eigen iris vectors, like 10, 7 and 4 have been considered to evaluate the performance of the system for both iris codes with and without noise.

In [41] Ali Alheeti (2011) proposed an iris recognition technique based on hybrid technology that helps to identify the power of edge detection operators used for generating the minimum features needed in identifying an iris. In this hybrid technique, 2d Discrete Wavelet Transforms with wavelet masks like Haar and Db2 wavelet transform masks are decomposed, followed by applying edge detection operators like canny, Prewitt, Roberts and Sobel to recognize features.

In [42] Rashad et al. (2011), proposed a statistical pattern approach called local binary pattern (LBP) along with histogram properties to extract the iris texture information and then to design a feature vector. This feature is fed as an input to a neural network based classifier called combined LVQ after doing a comparative study. Based on this comparative study, author suggests this system to have higher accuracy rate compared to other systems used in the comparative study.

In [43] Panganiban et al. (2011), implemented a technique to acquire iris image using video camera followed by processing using MATLAB image acquisition tool. Then based on different coefficients normalized image was decomposed using Haar and biorthogonal wavelet at N levels to extract the features. Results were tested using CASIA V3 database and a self database was created with 400 datasets.

In [44] according to Najafi and Ghofrani (2011), once the image is segmented and normalized, the collarette region is extracted and the image is enhanced by applying median filter, histogram equalization and 2-d wiener filters. A new feature extraction technique based on Ridgelet and Curvelet transforms was proposed and these transforms results in creating smaller binary codes with higher accuracy rates. Experimental results were tested using images from CASIA database.

In [45] Farouk (2011) has proposed a system based on Gabor wavelet decomposition and elastic graph matching. In this method, iris is segmented using circular Hough transform and Gabor wavelets were used to decompose the texture information followed by a technique called elastic graph matching to determine the similarity and dissimilarity between any two iris codes. Experiment is tested using CASIA V3 and UBIRIS database.

In [46] Roy et al. (2011), proposed a system for non-ideal iris recognition. In this technique pupil is isolated using level set based curve evolution approach and then iris is localized using Mumford-Shah energy minimization segmentation algorithm. Feature subset information was selected by decomposing Daubechies wavelet transforms followed by genetic algorithm. An Adaptive asymmetrical Support Vector Machines (AASVM) to match and control misclassification error. Results were tested in ICE 2005, WVU database and UBIRIS V1 database and found that the proposed GA reduces the feature dimension without affecting the recognition rates.

In [47] Sathish (2012) has proposed a multi algorithmic iris recognition system, in which iris is segmented by performing the following steps. Initially a Gaussian smoothing function and then histogram equalization is applied to improve contrast of iris image. Canny edge detector followed by probabilistic circular Hough Transform is then used to segment the iris. Segmented iris is then normalized using Daugman's rubber sheet model and then features were extracted by decomposing 2-d Gabor filters on the normalized image. A match score is obtained using Hamming distance matching classifier called Feed forward neural network (NN) algorithm and the results were tested using CASIA database.

In [48] Szewczyk et al. (2012), uses iris images acquire under unconstrained conditions and proposes a startegy to recognize an iris. In this method a compact signature of size 324 bits wide is used when compared to Daugmans 2048 bit signature.Signature encoding is performed using wavelet transforms on image decomposition and binarization technique followed by score calculation to find the match.

In [49] Wang et al. (2012), designed a recognition system meant for noisy irises using Adaboost and multi orientation 2-d Gabor filters. Iris outer boundary is isolated using a binary segmentation mask. Noises are removed using Circular Gabor and upper and lower eyelids are detected and removed with the help of Random Sample Consensus (RANSAC) technique. Circular integro-differential operator is used to isolate the pupillary boundary. Two types of images are said to be segmented, (i) Accurately Segmented (AS) iris and Inaccurately Segmented (IAS) iris. All the processing is performed separately hereafter for these two types of irises. Rubber sheet model is used to normalize the AS iris whereas a technique called Simplified Rubber sheet model is used for IAS iris.2-d Gabor filters are used to identify both the global and local texture information and then an Adaboost classifier is mused to perform the match score. Experimental results were tested in the database provided by NICE: II competition with 810 images and the system won 2nd place among all 67 participations.

In [50] Z.Z. Abidin et al. (2013) proposed a feature extraction technique based on the epigenetic traits using several edge detection operators. Edge detection operators like Sobel, Prewitt and Canny were applied to extract the features from the iris. Among them Canny operator was found to provide a more accurate results. By applying these operators, the PSNR values of iris texture information before and after processing were calculated. From the experimental results performed using CASIA database, it was found that by applying proper edge detection techniques iris recognition system could achieve higher accuracy rates.

In [51] Zhou et al. (2013) proposed a new code matching technique. During segmentation stage following steps were followed: (i) to localize pupil boundary histogram analysis and morphological processing were performed, (ii) Outer boundary was considered to have twice the size of pupillary boundary and (iii) To detect and remove upper and lower eyelids, Canny edge operator followed by polynomial curve fitting algorithm were used. After segmenting the iris, it was unwrapped to a rectangular block of fixed size with the help of a convolution operator.1-d Log Gabor filter were applied to extract the texture information and were then store in a k-dimension tree structure. With the help of this k-d tree code matching was performed to find the similarity or dissimilarity match between any two codes.

In [52] Liu et al. (2014) proposed a video sequence based iris recognition system which works based on bionic recognition and distance distribution histogram. Same technique was tested against still images as well and resulted with more robustness and stability. Experimental results were tested using JLUBR-IRIS database with videos of 78 subjects and CASIA V1 and V4 databases.

In [53] Rai et al. (2014) proposed a technique to perform code matching based on combination of two techniques to achieve better accuracy rate. Circular Hough transform is used to isolate the iris image followed by finding the zigzag collarette area and then detecting and removing the eyelids and eyelashes using parabola detection technique and trimmed median filters. Haar wavelets and 1-d Log Gabor filters are used to extract features from the zigzag collarette region of iris. Extracted patterns were recognized with the help of combination of techniques called support vector machine and hamming distance approach. Experimental results show an excellent recognition rate when features were extracted from the specific region, where more complex patterns are available followed by combining SVM and Hamming distance approach for pattern recognition.

In [54] Song et al. (2014) proposed a method based on sparse error correction model, since the noise factors like eyelid and eyelash occlusion and specular and pupil reflections are mainly spatially localized. In this approach training sets of all iris images are considered as a dictionary used for the purpose of classification of simple test sample and finally converted to a huge size dictionary. To make this error correction model efficient, a K-SVD algorithm is implemented. It is proved that the dictionary when learned with help of this algorithm is said to have a better representation. To optimize the system further, three sub-optimal parameters were chosen and were applied to this algorithm and a final SEC –DKSVD training algorithm was implemented. Proposed method saves considerable computational time and provides a better recognition rate.

In [55] Pillai et al. (2014) proposed a cross sensor based iris recognition system which works on kernel learning technique. This paper proposes a recognition framework which works on multiple sensors and provides better cross sensor recognition rate. LG2200, LG4000, Iris on the Move portal system by Sarnoff, Combined Face and Iris Recognition System (CFAIRs) by Honeywell, HBOX system by Global Rainmakers Inc., and Eagle-Eyes system by Retica are some popular systems used to acquire iris images. A kernel based learning approach is used for sensor adaptation.

In [56] Sun et al. (2014) provided an iris image classification framework based on texture information using a representation technique called Hierarchy Visual Codebook (HVC).HVC is based on two techniques called Vocabulary Tree (VT), and Locality-constrained Linear Coding (LLC), for representing iris textures sparsely. Experimental results show that this method helps in achieving better image classification for iris liveness detection, race classification, and coarse-to-fine iris identification methods. Gabor filter and ordinal filters are used to extract features from the segmented iris images

4. Iris Databases

While developing a new recognition or a detection system, choosing the appropriate database plays a vital role. In order to promote the research activities, many freely available databases have been created for iris recognition researchers. With the help of these databases following research activities could be performed easily. They 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. Nevertheless developing such a database which satisfies different requirements of a particular problem domain and to make it a benchmark database for future activities is a challenging and difficult task.

Some of the popular iris databases that are publicly and freely available are listed in Table 2 along with its brief description. In Table 2 we have covered only those databases that have mostly been used in the past few years.

Table 2 Iris Databases

Database	Sample Details	Size & Format	Description
CASIA Version 1.0 [58], [59], [60]	756 iris images from 108 eyes Illumination: 850 nm NIR Scanner: Homemade Iris camera All subjects are Chinese except few.	3 images were taken in first session, remaining four in second sessions. Stored as bmp file with 320 * 280 resolutions.	Pupil region was already identified and replaced with constant intensity mask for replacing the specular reflection.
CASIA version 3.0 [60], [61]			
(i) CASIA-IRIS - Interval	2,639 images taken from 249 subjects Illumination: NIR Scanner: Self developed close up iris camera Taken mostly from graduate students	320*280 resolution jpeg files.	As the images were acquired in a very suitable environment, this image set helps in studying the detailed texture features.
(ii) CASIA-IRIS - Lamp	16,212 images taken from 411 subjects Illumination: Various Illumination conditions Scanner: OKI hand held iris scanner, taken mostly from graduate students	640*480 resolution jpeg files.	This dataset is helpful for studying issues related to normalization and robust iris feature representation

(iii) CASIA-IRIS – Twins	3,183 images taken from 200 subjects Illumination: Outdoor Scanner: OKI's IRIS PASS-h camera Taken from children participate in the Beijing twins festival	640*480 resolution jpeg files.	Helps in studying the similarity and dissimilarity between iris patterns of twins.
CASIA Version 4.0 [58], [59], [60], [61], [62], [63]			
(i) CASIA-IRIS - Distance	2,567 images taken from 142 subjects Illumination: NIR Scanner: CASIA long range iris camera Graduate students of CASIA	8-bit grey level jpeg files with 2352*1728 resolutions.	Irises of both eyes and facial patterns are included in this dataset, helping multimodal biometric fusion. First publicly available high quality, long range iris/face dataset.
(ii) CASIA-IRIS - Thousand	20,000 images taken from 1000 subjects Illumination: Various illumination settings Scanner: Irisking IKEMB-100 Subjects with wide range distribution of ages like students, workers, farmers	8-bit grey level jpeg files with 640*480 resolutions.	Helps in developing novel iris classification and indexing techniques. First publicly available dataset with one thousand subjects of different age groups.
(iii) CASIA-IRIS – Syn	10,000 images taken from 1000 subjects Illumination: N/A Scanner: CASIA Iris image synthesis algorithm Source images from CASIA V1.0	8-bit grey level jpeg files with 640*480 resolutions.	Consists of synthesized image set which helps researcher to distinguish genuine and artificial iris.
UBIRIS Version 1.0 [64]	1877 images taken from 241 subjects taken in two distinct sessions. Illumination: N/A Scanner: NIKON E5700 camera with RGB color representation	2560*1740 pixel images stored in jpeg format with lossless compression technique.	Database consisting of noisy images taken from subjects either with or without their cooperation. Helps in developing robust iris recognition techniques.

UBIRIS Version 2.0 [65]	11,102 images taken from 261 subjects with variation in age, gender and iris pigmentation. Illumination: N/A Scanner: Canon EOS 5d with sRGB color representation	400*300 pixel images stored in tiff format.	Helps in developing iris recognition algorithms for images acquired on non-constraint environment(at-a-distance, on-the-move and on the visible wavelength
IIT Delhi Iris database version 1.0 [66]	1,120 images taken from 224 subjects with variation in age comprising 176 male and 48 female subjects Illumination: NIR Scanner: JIRIS, JPC1000 and digital CMOC camera	320*240 pixel resolution images stored in bitmap format.	Provides a large scale iris image database comprising of Indian users taken in real environment.

5. Conclusion

This paper discusses background information's of the anatomy of an iris, a detailed history of how iris has been started to be treated as a biometric trait and a general framework of iris recognition system which are currently being used. The main aim of this work is to provide a timeline view of various iris recognition techniques. Based on this view it is concluded that most of the works carried on iris recognition is more or less similar but the focus was mainly made into 4 major areas namely iris segmentation, normalization which includes noise removal, feature extraction and classification of iris templates. During 1993 - 2002, researchers focused on developing algorithms for all the 4 major areas and were interested in developing their own systems. During 2003 - 2009, major research works had taken place on segmentation stage which involves segmenting the iris and reducing the noises present in it. During 2007 - 2012, majority of the research works were done on developing new feature extraction algorithms and classification of iris further. Until 2006 most of the research works were done on developing new filters and image processing algorithms to enhance the accuracy of the system. But after 2006, this field had seen a tremendous change in which researchers started implementing machine learning algorithms to improve the system accuracy. Recently the focus has moved towards multimodal biometric techniques. A detailed study on various publicly available iris databases is also included after the time-line review. Based on this work it is concluded that though this area has seen a tremendous growth in the past two decades, there are still more possible domain areas available in which this technology can be used by modifying few approaches. The next decade will be more interesting since many robust spontaneous iris recognition systems will be developed and will be deployed in various domain areas like border security systems, immigration checking systems, access control systems both to premises and devices, time and attendance maintenance systems.

6. References

[1] A. K. Jain, R. Bolle, and S. Pankanti, “Biometrics: personal identification in networked society”,vol. 1. 1999, p. 434.

[2] A. K. Jain, A. Ross, and S. Prabhakar, “An Introduction to Biometric Recognition,” IEEE Trans. Circuits Syst. Video Technol., vol. 14, pp. 4–20, 2004.

[3] http://en.wikipedia.org/wiki/Iris_recognition (accessed on Jun, 2014)

[4] Mark Hill, “ANAT2310: Eye Development,” The University of South Wales, 2003 http://anatomy.med.unsw.edu.au/cbl/teach/anat2310/Lecture06Senses(print).pdf

[5] Barbara Westmoreland, Michael Lemp, and Richard Snell, Clinical Anatomy of the eye 2nd edition, (Oxford :Blackwell Science Inc., 1998)

[6] Clyde Oyster, The Human Eye Structure and Function, Sinauer Associates,1999.

[7] http://www.fomosplanejados.com.br/capitulos/assuntos/assunto.asp?codcapitulo=22&codassunto=133&numero =3 (accessed on July,2014)

[8] http://fingerchip.pagesperso-orange.fr/biometrics/types/iris.htm (accessed on July 2014).

[9] http://www.celestialhealing.net/iridology2.htm (accessed on july 2014)

[10] Bertillon. La couleur de Piris. Revue scientifique, Vol. 36, No. 3, pp. 65-73, 1885.

[11] Leonard Flom and Aran Safir, “Iris recognition system”, U.S.Patent 1244552, 1987

[12] UK Essays. November 2013. Iris Recognition Techniques An Extensive Survey Psychology Essay. [online]. Available from: http://www.ukessays.com/essays/psychology/iris-recognition-techniques-an-extensive-survey-psychology-essay.php?cref=1 [Accessed 9 January 2015].

[13] P. Khaw, “Iris Recognition Technology for Improved Authentication”, SANS Security Essentials (GSEC) Practical Assignment, version 1.3, SANS Institute, 2002, pp.5-8.

[14] Daugman J,” High confidence visual recognition of persons by test of statistical independence”. IEEE Trans. Pattern Anal. Machine Intell., 15:1148–1161, 1993.

[15] Daugman J,“Biometric personal identification system based on iris analysis”, United States Patent Number: 5291560, 1994.

[16] Richard P. Wildes. “Iris recognition: An emerging biometric technology”. Proceedings of the IEEE, 85(9):1348–1363, September 1997.

[17] Wildes et al. “Automated, non-invasive iris recognition system and method”. U.S. Patent No. 5,572,596 and 5,751,836.

[18] Richard P.Wildes, Jane C. Asmuth, Gilbert L. Green, Steven C. Hsu, Raymond J. Kolczynski, James C. Matey, and Sterling E. McBride." A system for automated iris recognition". Second IEEE Workshop on Applications of Computer Vision, pages 121–128, 1994.

[19] Richard P.Wildes, Jane C. Asmuth, Gilbert L. Green, Steven C. Hsu, Raymond J. Kolczynski, James C. Matey, and Sterling E. McBride. "A machine vision system for iris recognition". Machine Vision and Applications, 9:1–8, 1996.

[20] W. W. Boles and B. Boashash, "A human identification technique using images of the iris and wavelet transform," IEEE Trans. Signal Process., vol. 46, no. 4, pp. 1185–1188, Apr. 1998.

[21] W. K. Kong, D. Zhang, B. T. Centre, and H. Kong, "Accurate Iris Segmentation Based on Novel Reflection and Eyelash Detection Model," pp. 3–6.

[22] S. L. Lim, K. L. Lee, O. B. Byeon, and T. K. Kim, "Efficient Iris Recognition through Improvement of Feature Vector and Classifier," ETRI J., vol. 23, no. 2, pp. 61–70, Jun. 2001

[23] Y.-P. H. Y.-P. Huang, S.-W. L. S.-W. Luo, and E.-Y. C. E.-Y. Chen, "An efficient iris recognition system," Proceedings. Int. Conf. Mach. Learn. Cybern., vol. 1, 2002.

[24] J. Daugman, "How Iris Recognition Works," IEEE Trans. Circuits Syst. Video Technol., vol. 14, no. 1, pp. 21–30, Jan. 2004.

[25] L. Ma, T. Tan, Y. Wang, and D. Zhang, "Efficient iris recognition by characterizing key local variations," IEEE Trans. Image Process., vol. 13, pp. 739–750, 2004.

[26] J. Huang, Y. Wang, T. Tan, and J. Cui, "A new iris segmentation method for recognition," in Proceedings - International Conference on Pattern Recognition, 2004, vol. 3, pp. 554–557.

[27] Dorairaj, V.; Schmid, N.A.; Fahmy, G., "Performance evaluation of non-ideal iris based recognition system implementing global ICA encoding," Image Processing, 2005. ICIP 2005. IEEE International Conference on, vol.3, no., pp.III,285-8, 11-14 Sept. 2005

[28] Proença, Hugo, and Luıs A. Alexandre. "Iris segmentation methodology for non-cooperative recognition." In Vision, Image and Signal Processing, IEE Proceedings-, vol. 153, no. 2, pp. 199-205. IET, 2006.

[29] Miyazawa, Kazuyuki, Koichi Ito, Takafumi Aoki, Koji Kobayashi, and Hiroshi Nakajima. "A phase-based iris recognition algorithm." In Advances in Biometrics, pp. 356-365. Springer Berlin Heidelberg, 2005.

[30] Tian, Qichuan, Zhengguang Liu, Linsheng Li, and Zhiyi Sun. "A practical iris recognition algorithm." In Robotics and Biomimetics, 2006. ROBIO'06. IEEE International Conference on, pp. 392-395. IEEE, 2006.

[31] Monro, Donald M., Soumyadip Rakshit, and Dexin Zhang. "DCT-based iris recognition." Pattern Analysis and Machine Intelligence, IEEE Transactions on29, no. 4 (2007): 586-595.

[32] Daugman, John. "New methods in iris recognition." Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on 37, no. 5 (2007): 1167-1175.

[33] Ng, Richard Yew Fatt, Yong Haur Tay, and Kai Ming Mok. "An effective segmentation method for iris recognition system." (2008): 548-553.

[34] Demirel, Hasan, and Gholamreza Anbarjafari. "Iris recognition system using combined colour statistics." In Signal Processing and Information Technology, 2008. ISSPIT 2008. IEEE International Symposium on, pp. 175-179. IEEE, 2008.

[35] Abiyev, Rahib H., and Koray Altunkaya. "Personal iris recognition using neural network." Intl. J. Security & its Appl 2, no. 2 (2008): 41-50.

[36] Murty, PSR Chandra, and E. Sreenivasa Reddy. "Iris Recognition system using Principal Components of Texture Characteristics." TECHNIA International Journal of Computing Science and Communication Technologies (2009).

[37] He, Xiaofu, Yue Lu, and Pengfei Shi. "A new fake iris detection method." InAdvances in Biometrics, pp. 1132-1139. Springer Berlin Heidelberg, 2009.

[38] Ross, Arun, and Manisha Sam Sunder. "Block based texture analysis for iris classification and matching." In Computer Vision and Pattern Recognition Workshops (CVPRW), 2010 IEEE Computer Society Conference on, pp. 30-37. IEEE, 2010.

[39] Narote, Sandipan P., Abhilasha S. Narote, and Laxman M. Waghmare. "Iris based recognition system using wavelet transform." IJCSNS International Journal of Computer Science and Network Security 9, no. 11 (2009): 101-104.

[40] Hussain, Md Anwar. "Eigenspace based accurate iris recognition system." InIndia Conference (INDICON), 2010 Annual IEEE, pp. 1-3. IEEE, 2010.

[41] K. M. Ali Alheeti, “Biometric Iris Recognition Based on Hybrid Technique,” Int. J. Soft Comput., vol. 2, no. 4, pp. 1–9, Nov. 2011.

[42] Rashad, M. Z., M. Y. Shams, O. Nomir, and R. M. El-Awady. "Iris recognition based on LBP and combined LVQ classifier." International Journal of Computer Science & Information Technology (IJCSIT) Vol 3 (2011).

[43] Panganiban, Ayra, Noel Linsangan, and Felicito Caluyo. "Wavelet-based Feature Extraction Algorithm for an Iris Recognition System." JIPS 7, no. 3 (2011): 425-434.

[44] Mojtaba Najafi, and Sedigheh Ghofrani "Iris recognition based on using ridgelet and curvelet transform." International Journal of Signal Processing, Image Processing and Pattern Recognition 4, no. 2 (2011): 7-18.

[45] Farouk, R. M. "Iris recognition based on elastic graph matching and Gabor wavelets." Computer Vision and Image Understanding 115, no. 8 (2011): 1239-1244.

[46] Roy, Kaushik, Prabir Bhattacharya, and Ching Y. Suen. "Towards nonideal iris recognition based on level set method, genetic algorithms and adaptive asymmetrical SVMs." Engineering Applications of Artificial Intelligence 24, no. 3 (2011): 458-475.

[47] G. Sathish,Dr. S. Narmadha,Dr. SVSaravanan, Dr. S. Uma Maheswari, "Multi-algorithmic IRIS Recognition", International Journal of Computer Applications,Vol 38 No.11, January 2012

[48] R. Szewczyk, K. Grabowski, M. Napieralska, W. Sankowski, M. Zubert, and A. Napieralski, “A reliable iris recognition algorithm based on reverse biorthogonal wavelet transform,” Pattern Recognit. Lett., vol. 33, no. 8, pp. 1019–1026, Jun. 2012.

[49] Q. Wang, X. Zhang, M. Li, X. Dong, Q. Zhou, and Y. Yin, “Adaboost and multi-orientation 2D Gabor-based noisy iris recognition,” Pattern Recognit. Lett., vol. 33, no. 8, pp. 978–983, Jun. 2012.

[50] Z. Z. Abidin, M. Manaf, A. S. Shibghatullah, S. Anawar, and R. Ahmad, “Feature extraction from epigenetic traits using edge detection in iris recognition system,” IEEE Int. Conf. Signal Image Process. Appl., pp. 145–149, Oct. 2013.

[51] Zhou, Steve, and Junping Sun. "A novel approach for code match in iris recognition." In Computer and Information Science (ICIS), 2013 IEEE/ACIS 12th International Conference on, pp. 123-128. IEEE, 2013.

[52] Liu, Yuanning, Fei He, Xiaodong Zhu, Ying Chen, Ye Han, and Yanning Fu. "Video Sequence-Based Iris Recognition Inspired by Human Cognition Manner." Journal of Bionic Engineering 11, no. 3 (2014): 481-489.

[53] Rai, Himanshu, and Anamika Yadav. "Iris recognition using combined support vector machine and Hamming distance approach." Expert Systems with Applications Vol 41, no. 2 (2014): 588-593.

[54] Song, Yun, Wei Cao, and Zunliang He. "Robust iris recognition using sparse error correction model and discriminative dictionary learning." Neurocomputing137 (2014): 198-204.

[55] Pillai, J.K.; Puertas, M.; Chellappa, R., "Cross-Sensor Iris Recognition through Kernel Learning," Pattern Analysis and Machine Intelligence, IEEE Transactions on, vol.36, no.1, pp.73,85,Jan.2014 doi: 10.1109/TPAMI.2013.98

[56] Chun-Wei Tan; Kumar, A., "Efficient and Accurate At-a-Distance Iris Recognition Using Geometric Key-Based Iris Encoding," Information Forensics and Security, IEEE Transactions on, vol.9, no.9, pp.1518,1526, Sept. 2014

[57] Zhenan Sun; Hui Zhang; Tieniu Tan; Jianyu Wang, "Iris Image Classification Based on Hierarchical Visual Codebook," Pattern Analysis and Machine Intelligence, IEEE Transactions on, vol.36, no.6, pp.1120,1133, June 2014

[58] Ma, Li, Tieniu Tan, Yunhong Wang, and Dexin Zhang. "Personal identification based on iris texture analysis." Pattern Analysis and Machine Intelligence, IEEE Transactions on Vol 25, no. 12 (2003): 1519-1533.

[59] Service note on CASIA version 1.0: http://biometrics.idealtest.org/dbDetailForUser.do?id=1 (accessed on Sep, 2014)

[60] Zhenan Sun, Tieniu Tan, "Ordinal Measures for Iris Recognition," IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 31, No. 12, 2009, pp. 2211 - 2226.
[61] Service note on CASIA Version 3.0, accessed on Sep, 2014: http://biometrics.idealtest.org/findTotalDbByMode.do?mode=Iris.
[62] Zhaofeng He, Tieniu Tan, Zhenan Sun and Xianchao Qiu, "Towards Accurate and Fast Iris Segmentation for Iris Biometrics", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 31, No. 9, 2009, pp.1670 – 1684
[63] Service note on CASIA Version 4.0, access on Sep, 2014: http://biometrics.idealtest.org/findTotalDbByMode.do?mode=Iris.
[64] Hugo Proença, Luís A. Alexandre; “UBIRIS: A noisy iris image database”, Proceed. of ICIAP 2005 - Intern. Conf. on Image Analysis and Processing, Sep, 2005, volume 1, page. 970-977, ISBN: 3-540-28869-4
[65] Hugo Proença, Sílvio Filipe, Ricardo Santos, João Oliveira, Luís A. Alexandre, “The UBIRIS.v2: A Database of Visible Wavelength Iris Images Captured On-The-Move and At-A-Distance”, IEEE Transactions on Pattern Analysis and Machine Intelligence, August, 2010, volume 32, page 1529-1535, ISSN: 0162-8828, DOI: http://doi.ieeecomputersociety.org/10.1109/TPAMI.2009.66.
[66] Service note on IITD database, accessed on Sep 2014: http://www4.comp.polyu.edu.hk/~csajaykr/IITD/Database_Iris.htm