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A Survey and Technical Overview of Iris Recognition System

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Abstract: Biometrics systems have recently drawn attention for their application in diverse sectors. Biometrics is robotized strategy for perceiving a man because of a physiological or behavioural trademark. A system that automatically recognizes individuals based on biometric traits has been an attractive goal for researchers for a long time. The most significant field of study is protection for several years. However, the demand for this is growing exponentially, mostly with rising in sensitive data. The elements measured are the face, fingerprints, hand geometry, penmanship, iris, retinal, vein, and voice. Automated person identity authentication systems based on iris recognition are considered as most reliable among biometric methods. Because of its high accuracy and uniqueness, it is used in various fields of access control and for security at border areas. Iris recognition identifies people based on unique patterns within the ring-shaped region surrounding the eye pupil. This paper presents a timeline technical overview and survey of various iris recognition techniques available in the literature.

Keywords: Biometrics, Iris recognition, Techniques.

Introduction

A Biometric system is an automatic method of recognizing a person based on physiological and behavioural traits biometric recognition system analyses unique physiological traits or behavioural characteristics for identification or verification. The physiological traits include an iris, face, fingerprint, retina, voice or hand geometry, while behavioural traits include handwriting, walking gait, signature, and typing keystrokes. Among these traits, iris recognition is considered the most accurate and reliable biometric system.

Iris patterns possess a high degree of randomness and uniqueness even between identical twins and remain stable throughout adult life (Mohammed et al., 2014). Iris recognition identifies people based on unique patterns within the ring-shaped region surrounding the eye pupil. The uniqueness of the iris patterns comes from the richness of the texture details from the crypts, radial furrows, filaments, pigment frills, dots, stripes and arching ligaments. These give rise to complex and irregular textures randomly distributed to make the human iris one of the most reliable biometric characteristics. (Rana et al., 2019)-

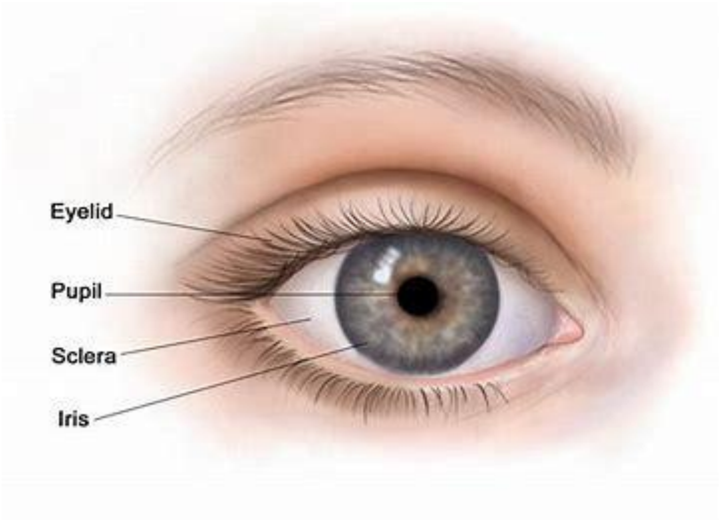

Figure 1. Human Iris

The human iris is one of the most reliable biometric systems because of its stability, uniqueness and non-invasive nature. The iris patterns are unique because there is no match between any two alike irises, even if they are taken from identical twins or the left to right eye in the same person. A front outlook of the iris is shown in Figure 1. Iris recognition system is advantageous and applicable in information security and authentication of individuals in different fields such as controlling access to security zones, verifying passengers at airports, and stations, computer access at defense establishments, Research companies, and database access control in distributed systems etc.

Literature Review

The concept of iris recognition has initially proposed by an ophthalmologist named Dr Frank Burch, who used iris patterns for personal identification in 1936. Two other ophthalmologists, Aran Safir and Leonard Flom 1987 patented this idea, and they asked John Daugman to create applicable algorithms for iris recognition in 1989 (Bakk et al., 2002). Much work has been reported on iris recognition till now, and recognition algorithms usually need various techniques. Several research papers have been published on iris recognition systems, strategies and their application in the past two decades. This review paper presents multiple stages of the iris recognition technique available in the literature, from Daugman's initial work in 1993 to some of the recent ones.

(Daugman, 1993) proposed the first working methodology on iris recognition which forms the basis for most of the developmental activities in iris biometrics to till date. He acquired a human eye with the help of a video camera and identified it. Daugman applied an integrodifferential operator for locating the circular iris and pupil region and the arcs of the upper and lower eyelids. The users search for the circular path with the maximum change in pixel values by varying the circular contour's radius and centre x and y position. The researcher is applied iteratively with the amount of smoothing progressive reduced to attain precise localisation. Eyelids are localised in a parallel manner. The integro-differential can see as a variation of the Hough transform since it too uses the first derivatives to the image and performs a search to find geometric parameters. Since it works with basic derivative information, it does not suffer from threshold problems of the Hough transform.

(Boles and Boashash, 1993) proposed an algorithm that locates the pupil centre using an edge detection method. It records grey level values on virtual concentric circles and then constructs the zero-crossing representation on these virtual circles based on a one-dimensional dyadic wavelet transform. Corresponding virtual circles in different images are determined by rescaling the photos to have a common iris diameter. They create two dissimilarity functions for matching, one using every point of the representation and the other using only the zero-crossing points. The algorithm was tested successfully on a small database of iris images, with and without noise.

(Wilde, 1997) introduced a novel approach, in which a LED point source was included while acquiring the eye image of the subject along with a standard video camera. The inner and outer iris boundary is computed with the help of a gradient-based binary edge map followed by a 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. The templates are used to find the similarity by computing the normalised correlation for the goodness of the match.

(Boles et al., 1998) applied circular edge detection technique to segment an iris image and perform virtual circle analysis to obtain a normalised 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 are implemented in identifying a match. This approach provides a scale, rotation and translation invariant algorithm for recognising an iris of a human eye.

(Kong and Zhang, 2001) developed a system which concentrated mainly on the noise disturbances, occlusion of eyelashes and specular reflections involved while segmenting an iris image. Hough transform was used to isolate an iris, followed by the application of 1-d Gabor filters in the spatial domain and threshold function to detect eyelid occlusion and specular reflection, respectively. Multiple eyelashes were detected with the help of variance of intensity values. The 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 in better performance rates.

(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. The inner or pupillary boundary is found based on a rectangular inter interval. Then, the rough edge identified iris image is segmented using an effective Integro differential operator. Eyelids are detected using histogram Hough transformation followed by thresholding for single eyelashes and variance of thresholding for multiple eyelashes. Size and rotation invariant concentric circular iris representation is obtained in the normalisation stage. Independent component analysis coefficients were used to extract the features from the 128 x 40 bit unwrapped iris image, followed by an average Euclidean distance classifier for iris recognition.

(Daouk, 2002) proposed an iris recognition scheme involving a fusion mechanism of the Canny Edge Detection scheme (CED) and a Circular Hough Transform (CHT) to detect the iris's boundaries in a digital image of an eye. Then Haar wavelet pulls out the deterministic patterns in a person's iris as a feature vector. Wavelet tree was utilised for image coefficient mapping where a database of 60 pictures was used, and the accuracy to recognition is about 93%. However, this work has a few limitations that this methodology has not performed better in bad lighting conditions, occlusion by eyelids, noises or inappropriate eye positioning.

(Noh et al., 2003) introduced a new technique of feature extraction. Instead of using wavelet transform, an adaptive feature extraction method was introduced in which two types of Global and Local features. The analytical modeling of the system was done by using the polar coordinates. The global features are invariant to the eye image rotation and the imprecise iris localisation. The customised geometric moment is used to represent the global iris feature. Local features provide precise information regarding the iris. The motive to introduce this technique had the absence of the Shift-Invariant (SI) property in Discrete Wavelet Transform. The methodology does not include shift-invariant property and can't provide exact texture analysis.

(Daugman, 2004) proposed an approach which is an improvement to his earlier work. 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 parameters instead of circular edges in the integro-differential operator. This paper improves his early work by providing a solution to detect the eyelid occlusion of the iris image is unwrapped into a rectangular block to avoid upper eyelid and eyelash occlusion, followed by contrast enhancement using Histogram equalisation. Experimental results were tested using CASIA database V1.0 and V2.0, which can achieve a highly accurate recognition rate even for low-quality images.

(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 used Hamming distance to calculate the gazing angle, followed by Daugman's Integro differential operator to segment the iris. They tested their results using 100 iris class images from the CASIA dataset, and a unique database with off-angle iris images called the WVU database, having 75 classes with four images and checked the performance of these non-ideal iris recognition techniques.

(Tian et al., 2006) proposed a recognition algorithm, which uses window-based filters to identify pupils and Hough transform to mark the 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. Then, unwrapped to a normalised iris image using Daugman’s rubber sheet model. A low-frequency filter followed by a 2-d zero-crossing detection operator and similarity degree classifiers is proposed for feature extraction and recognition. This algorithm can provide rotation, translation and size invariant results. Simulation results of this algorithm provide a higher correct accept and reject rate. Effects were tested using the CASIA database and a database provided by the Institute of Automation for the 2005 Biometrics Authentication competition.

(Xu et al., 2006) proposed an improved system that deals with eyelids and eyelashes detection and an alternative image enhancement method because the eyelids and eyelashes detection affects the iris image and produces noise which degrades the system performance. Sub-block of eyelids/eyelashes models compared for detection purposes. To enhance the iris image, they subtract the background and then filter the image by histogram equalising and wiener filtering—derivation used for eyelids/ eyelashes detection. The finding rate of iris location is 98.42% in the case of the CASIA database.

(Monro et al., 2007) designed an iris recognition algorithm in which Hough transform is used to segment the iris image from the eye and is normalised to a rectangular image array using bi-linear interpolation of the 4-nearest neighbour method. Features from the normalised image are extracted with the help of a zero-crossing representation of 1-d Discrete Cosine Transform, and a matching score is performed with the help of weighted Hamming distance metrics. The experiment was tested using 308 image classes from CASIA and 150 images from BATH to perform better with no false Accept/ Reject on both databases.

(Daugman, 2007) as an improvement to his previous work proposed a new image processing algorithm to be used during the segmentation stage, which helps in handling off-axis iris images. Iris localisation 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 a test for statistical independence is performed to check the match score between two iris codes using the UAE databases.

(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 for 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 localised by selecting two search regions based on a threshold value, the right and left iris boundary. Search regions are selected based on the pupil position and its intensity values. The search regions ' Sobel edge detection operator is applied to locate upper and lower eyelids. A simple thresholding value removes both the separable and multiple eyelashes and specular and pupil reflection noises. A segmented iris image is normalised to a fixed-sized rectangular block in which 1-d Log Gabor filters are applied to extract the features. 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 provided a higher accuracy rate when tested in the CASIA database.

(Abiyev et al., 2008) simulated an iris recognition system using neural networks (NN). The Pupil region is detected with the help of a 10x10 rectangular area technique, which helps see the iris's 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 a higher accuracy rate of 99.25%.

(Azizi et al., 2009) a work proposed a work that uses features extraction and subset selection. Iris features were extracted using contourlet transform, which captures the intrinsic geometrical structures of iris images. Further, the iris's image was decomposed into sub-blocks that contain all texture information. This technique utilises a Support Vector Machine (SVM) for matching the iris templates. The Gabor filter and Haar wavelet were used in this work for coding purposes. The iris vector was created using Principal Component Analysis (PCA). The compare the performance of the proposed system with the CASIA image database.

(Sheela and Vijaya, 2010) introduced a fast and efficient iris segmentation methodology which has three major procedures. The first is pupil detection, the second is limbic boundary localisation, and the third is eyelid and eyelash detection. The proposed system is designed to prevent unnecessary and redundant image processing and, most importantly, preserve iris texture information's integrity. The proposed iris segmentation algorithms performed some well-known methods in both processing speed and accuracy. The iris recognition system that includes the proposed iris segmentation algorithm is capable of recognition performances comparable with those reported by other methods.

(Patil and Patilkulkarni, 2010) developed a lifting integer wavelet-based algorithm that enhances iris images, reduces noise to the maximum extent possible, and extracts the features from the image. Then the similarity between two iris images is estimated using Euclidean distance and threshold comparison. The proposed technique is simple and computationally effective.

(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 normalised image is decomposed using fifth-level decomposition, and features are extracted using different mother wavelets: Haar, Daubechies, Coiflet, Symlet and Biorthogonal. Applying these wavelet transforms on different co-efficient levels like horizontal, vertical, diagonal or a combination determines an optimal wavelet transform and evaluates its performance. Experiments were performed on the SCOE Iris V1 database, having a dataset of 2750 images from 275 subjects. The performance of the system was tested and compared.

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

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(Ali Alheeti, 2011) proposed an iris recognition technique based on hybrid technology that helps identify the power of edge detection operators to generate the minimum features needed to identify 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 recognise features.

(Gupta and Saini, 2011) evaluate the existing iris recognition systems' performance using Matlab Image Processing Toolbox. The technique consists of basic steps, (i) image acquisition, (ii) Segmentation (to detect circles of pupil and iris boundary through Daugman's filter), (iii) Normalisation (for creating rectangular block of fixed size through rubber sheet model), (iv) image enhancement (to convert low contrast image to high contrast image and minimize non-uniform illumination by applying Gabor filter) and (v) image matching (to perform template matching region and different iris images are represented as with the help of Hamming distance). The main advantage of the proposed technique is that accuracy and performance can be achieved even if images are taken from a distance.

(Panganiban et al., 2011) implemented a technique to acquire iris images using a 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 the CASIA V3 database, and a self-database was created with 400 datasets.

(Roy et al., 2011) proposed a system for non-ideal iris recognition. In this technique, the pupil is isolated using the level set-based curve evolution approach, and then the iris is localized using the Mumford-Shah energy minimization segmentation algorithm. Feature subset information was selected by decomposing Daubechies wavelet transforms followed by a 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.

(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 design a feature vector. After a comparative study, this feature is fed as an input to a neural network-based classifier called combined LVQ. Based on this comparative study, the author suggests this system has a higher accuracy rate.

(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 histogram equalisation is applied to improve the contrast of the iris image. Canny edge detector followed by probabilistic circular Hough Transform is then used to segment the iris. The segmented iris is then normalised using Daugman's rubber sheet model, and then features were extracted by decomposing 2-d Gabor filters on the normalised image. A match score is obtained using Hamming distance matching classifier called the Feed forward neural network (NN) algorithm, and the results were tested using the CASIA database.

(Verma et al., 2012) proposed a new iris recognition method based on a robust iris segmentation approach for improving iris recognition performance. They used a robust iris segmentation approach on power-low transformation to increase the accuracy of the pupil region; it significantly reduces the people's limbic boundary search region for increasing accuracy and efficiency in detection. The limbic circle has a centre within close range of the pupil is detected and approaches the improved iris recognition system.

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

(Shaaban, 2013) applied various techniques for pupil segmentation using CHT (Circular Hough Transform remodel), they proposed a formula to segments iris images captured in visible wavelength under unconstrained environments. The proposed algorithm reduces the error percentage even within the presence of noise that embraces iris obstructions and specular reflection. The proposed formula starts with deciding the expected region of the iris using the K-means cluster algorithm. The Circular Hough transform remodel (CHT) is then used to estimate the iris radius and centre, and the non-iris regions are removed. Applying the projected algorithm on UBIRIS iris image databases improves the segmentation accuracy and time.

(Jan 2014) introduced a multi-stage iris segmentation framework for localizing papillary and limbic boundaries of human eyes images. Instead of using time-consuming, exhaustive search approaches, like traditional circular Hough Transform or Daugman’s integrodifferential operator, they used an iterative approach. Decoupling coarse centre detection and good boundary localisation increased processing speed, and modular design can be achieved. This alleviates more sophisticated quality control and response during the segmentation process. The system is evaluated using multiple open iris databases compared to existing classical approaches.

(Rai et al., 2014) was proposed a technique to perform code matching based on a combination of two strategies to achieve better accuracy. The Circular Hough transform is used to isolate the iris image, find the zigzag collarette area and detect and remove the eyelids and eyelashes using the 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 recognised with the help of a combination of techniques called support vector machine and hamming distance approach. Experimental results had shown an excellent recognition rate when features were extracted from the specific region, where more complex patterns are available, followed by combining the SVM and Hamming distance approach for pattern recognition.

(Song et al., 2014) proposed a method based on a sparse error correction model since the noise factors like eyelid and eyelash occlusion and specular and pupil reflections are mainly spatially localised. In this approach, training sets of all iris images are considered a dictionary used to classify the simple test sample and converted to an extensive dictionary. To make this error correction model efficient, a K-SVD algorithm is implemented. It shows that the dictionary when learned with the help of this algorithm, is said to have a better representation. Three sub-optimal parameters were chosen and applied to this algorithm to optimise the system further, and a final SEC –DKSVD training algorithm was implemented. The proposed method saves considerable computational time and provides a better recognition rate.

(Abikoye et al., 2014) used Fast Wavelet Transform (FWT) to extract the feature of the iris, and the significant features were encoded and compared between templates. The encode features were used to generate its iris feature codes. The algorithm is fast and has a low complexity rate.

(Oyeniran et al., 2019) proposed a multi-algorithmic technique for personal recognition using iris using the multiple classifiers approach. They applied Hough Circular Transform for the localisation and segmentation techniques to isolate from whole eye iris image and noise detection. The normalisation procedure was carried out using Daugman Rubber Sheet Model, while the feature extraction was done using Continuous Wavelet Transform. The classification stages such as h

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Hamming Distance, Nearest Neighbour and Euclidean Distance were adopted in this system. This system has trained with five hundred iris images compared to another, which had been unregistered with one hundred iris images to verify the system. The method has an accuracy of 70%, FAR of 0.00% and FRR of 0.03%

(Khanam et al., 2019) implemented a neural network and discriminant analysis of machine learning method for iris recognition using MATLAB 2016a. The proposed method gives a better recognition rate than the SVM technique with less computational complexity. Neural network and discriminant methods are used for matching and finding recognition accuracy. Thus, the accuracy obtained from the neural network is 94.44%, whereas the accuracy obtained from the discriminant analysis is 99.99%.

(Oyeniyi et al., 2020) proposed an enhanced iris feature extraction using continuous wavelet transform. The method considerably reduces the computation time and improves the accuracy compared with the Gabor filter, Fourier transforms, and other wavelet transforms. The performance of continuous wavelet transform (CWT) for the feature extraction shows to be more stable and consistent even with a very high level of noisy data compared to discrete wavelet transform (DWT). When implemented on the CASIA database, they obtained 0.8% FAR, 1.4% FRR and 97.8% performance recognition accuracy.

Generic Architecture of Iris Recognition System

Iris recognition comprises of four stages; image acquisition, iris pre-processing (i.e. localization, normalization and enhancement), feature extraction and matching.

a. Image Acquisition: Image acquisition captures the iris image. It is also known as data capture. This is the initial phase of any biometric system to collect the sample using the biometric sensor. Different free databases are available on the internet where the iris image can be taken from the system. A well-known database is the CASIA Iris Image Database. Another database exists, such as the LEI and the UPOL, UBRIS.

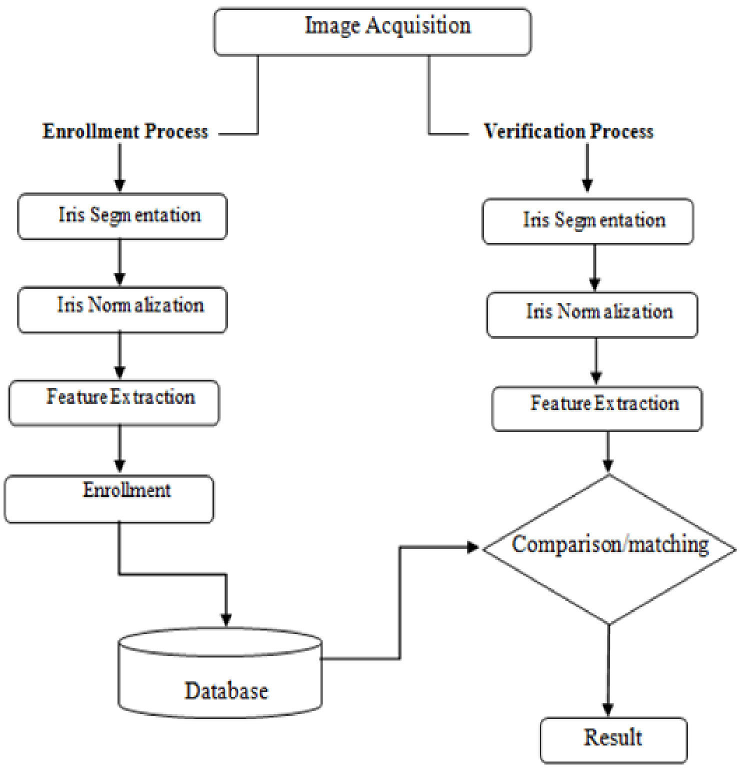

Figure 2: Iris Recognition System

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b. Localization and segmentation: The data present in the real world contains a lot of quality and noise, inaccurate and incomplete. The first step in pre-processing is to localise the iris region in the image; the iris' outer and inner boundaries are localised and calculated. Most localisation algorithms employed gradient-based methods to find edges between the pupil and iris and the sclera of the iris. The noise processing is also included in the segmentation stages of the recognition system. Possible noise sources are eyelid occlusions, eyelash occlusions and specular reflections (Daugman, 2001). Some methods used by researchers, among others, are the threshold method (Ruggero et al., 2009), Hough's algorithm (Guangzhu et al., 2006), iterative algorithm (Sreecholpech and Thainimit, 2009; Camus and Wildes, 2002), Circular Hough's transform (Roche et al., 2001), and Chan-Vese active contour method (Niladri et al., 2011).

c. Feature extraction: This technique is based on transforming the iris in polar coordinates to make it persistent and unvarying against the effect of variation in pupil size. The normalisation process is carried out by unwrapping of iris region into the rectangular strip. Daugman's Rubber Sheet model is the most commonly used.

d. Matching: The feature extraction stage encodes the iris image features into a bit vector code. Feature extraction identifies the most distinct features for classification, and a convenient threshold level is chosen as the ceiling value for feature encoding. Researchers used methods including wavelet transforms, principal component analysis, Gabor filter and Fourier transform.

e. Normalization: After generating of iris code, we need to compare this iris template with a stored template in the database during enrollment and see if any match occurs. The feature vectors are classified with the help of different thresholding techniques like hamming distance, weight vector and winner selection, dissimilarity function, etc.

Conclusion

Iris recognition is one of the most effective methods for authentication purposes as it is highly distinctive, stable with age and well protected. The morphogenesis of the iris occurs during gestation which leads to patterns and colors which are random and unique to each person. This paper provides a timeline technical overview and literature review of various iris recognition techniques available in literature by different researchers. The survey can be a good platform for fresh and intermediate researchers in the field of iris recognition. The focus was mainly made into four major areas namely iris segmentation, normalization, feature extraction and matching. Most of the works carried on iris recognition is more or less similar. However, there is considerable improvement on techniques to enhance recognition accuracy.

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