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A Critical Survey of Iris Based Recognition Systems

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Abstract: Iris texture pattern can be used for biometric verification and identification of a person from a large dataset. However, such a biometric recognition system can only recognize those people who have already been enrolled in the system. Iris recognition systems have been an active area of research since long and iris recognition applications are increasing day by day. Traditional iris recognition systems work with cooperative databases (i.e., gaze at the center location). Accuracy of iris recognition is distressed by blurred, defocused and occluded images. It is mostly used for security purpose and has been implemented at points of entry or exit in a building. Researchers have been working from the last decades to extend the application of iris recognition system in other areas like tracing criminals, terrorist and missing children. In this paper, we critically evaluate different iris recognition techniques for both cooperative and non-cooperative databases. Strengths and weakness of different techniques are identified, which could be helpful for future research in this area.

Key words: Iris Recognition · Feature extraction · Pattern Matching · Cooperative and Non-cooperative Databases

INTRODUCTION

Iris recognition is the method of identification and verification of a person from his / her iris pattern. An individual can be identified through biometric systems because of his/her unique features and characteristics. Iris recognition has become an accurate and reliable biometric technology. There are five fundamentals sections of iris recognition systems: image acquisition, segmentation, normalization, encoding and matching. Iris recognition feature extracted schemes can be subdivided into phase base methods, zero crossing, texture analysis and the intensity variation procedures [1]. Iris recognition systems work in different steps and can identify an individual based on the iris characteristics. In the first step, images are processed to extract the iris pattern. Then these patterns are matched with the other iris patterns stored in the database [2]. Accurate segmentation of iris and pupil boundary is a major accomplishment in recognition system. Iris is center gaze in cooperative datasets, whereas in non-cooperative dataset iris region is normally close to the corner of left and right eye. To recognize the image, iris is divided in to multiple regions and detection of single region can recognize a person. Color information is another important aspect in iris recognition and only those dataset images are matched whose color information matches with the input image [3]. Accuracy and performance of the iris recognition is increased if only the quality images are used. Image quality should be checked before it is matched in the enrolled database [4]. It is also key point to differentiate images of left and right eye. Eye lashes are darker and thicker in the medial canthus than to lateral canthus [3].

Human eye is the most complex organ in our body. Main parts of human eye are sclera, iris, pupil, lens, retina and cornea etc. and each part has its special function. The iris is a thin, circular, highly protected, colored and most visible part of the eye. The time light enters in to the eye it passes through the lens and image is focused onto the retina that converts light images into electrical signals and via the optic nerve sends these signals to the brain. In case of bright light, iris contracts to avoid too much light. The dark round in the center of the iris is called the pupil which dilates and constrict by tiny muscles embedded in iris. Iris surface is divided into two major layers: pupillary zones and the ciliary zone. Pupillary zone is the inner part that forms boundary of the pupil. An outer ciliary zone is the remaining part of the iris, and these are separated by the collarette – shows a pattern flower or zigzag. These patterns acquire a high level of randomness which provides robust biometric indication

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for human recognition. Several iris image databases such as CASIA, MMU, Bath, UPOL, ICE, WWU, UBIRIS are freely available for experimentation purposes.

Iris recognition systems ordinarily face the following multiple challenges [5]:

- Iris localization (i.e., iris position from distance) is a key challenge in iris recognition systems. Although technology has evolved enough that "iris on the move" and "iris at a distance" systems have been designed and developed, but iris localization is still a big challenge.
- Processing the blur and noisy image. Different geometric model are developed recently to solve the problem of off-axis iris image.
- Identifying the repeated binary string from the sample of the same iris is another challenge
- Saving facial attributes with iris images. Performance and accuracy level of iris recognition system can be increased by considering other facial attributes such as skin color and texture, facial marks etc.
- Ensuring security and privacy of millions of iris templates stored on a system is also another challenge.

The remainder of this paper is organized as follows: Section II brief literature review of cooperative and non-cooperative iris recognition systems. Section III presents the critical analysis in a tabular format and Section IV describes the gap analysis. Finally, we summarize in the last section.

Literature Review: Azizi and Reza [1] applied phase based method for iris recognition. In the segmentation step, linear Hough transform method is used, two lines are drawn, first a line to the upper eyelid and lower eyelid then a second line is drawn which intersect the pupil boundary. Eye lashes are separated by applying ID Gabor filters and isolate collarette region (i.e., Iris Complex Pattern area). In the normalization step, rubber sheet model is used for collarette area. Normalized patterns are created by converting polar coordinates into Cartesian coordinates. 2D array is generated which consist of horizontal and vertical dimensions of angular and radial resolutions respectively. Collarette area is transformed into rectangular block of fixed dimension by using contourlet transform technique to capture geometry and directionality of the image. By using biometric algorithm, iris texture is extracted and further represented in a binary iris code. Multiple iris code of same eye are aligned and compared to find average value of each bit. Not all values in iris codes have same value as the varied bits in iris codes are fragile bits. Images are transformed to extract the discriminated features from the iris pattern.

Stark and Bowyer [6] described that Human defined iris texture pattern categorization can be used in the analysis of computerized image processing system. The experiment involved grouping images into multiple categories as deemed suitable by the individual experimenter. For experimentation purpose, the author stored the experimental results in an $N \times S$ matrix (where N is the total number of irises and S is the person involved in the experiments). This matrix contained iris assignment and iris categorizes made by each person. That focus of the experiment was to see how many experimenters place the same image in the same category. By an iterative process author scanned the whole matrix for identification of agreement among the experimenters. The authors concluded that if two or more images are placed in the same category by all the 21 subjects then those images are equal. Authors also developed a discovery tree to measure the similarity or dissimilarity across subcategories.

Ramli *et al.* [2] proposed algorithm is based on Hu invariant moment. The authors used CASIA dataset which consists of 108 classes (1 image per iris); however, 100 images were used in the study. The proposed algorithm consists of 5 steps (i.e. Histogram equalization, Filter, Canny Edge Detection Algorithm, Invariant moment and Template Matching). Performance of iris recognition system is measured by calculating FAR and FRR of all 100 images.

Lagree and Bowyer [7] used log Gabor filter for segmentation. Images are segmented to obtain the desired portion and disguise the area containing eyelid-occluded iris portion. Texture examination is 240 x 40 pixel normalized iris image along with the corresponding bitmask of eyelid and eyelash occlusion location – image segmentation and masking are exactly same as "IrisBee" but "log Gabor" filter is not used rather authors used texture feature vector. "Spot detector" and "line detector" filters are used to build a Feature Vector. This vector is calculated for all iris images. For each Iris images by dividing normalized image array into a number of smaller section – compute statistics for sub-regions of the normalized images.

Rose [5] describes five fundamentals sections of iris recognition system including image acquisition, segmentation, normalization, encoding and matching. In the acquisition section, series of images are captured and only quality images are chosen which have maximum iris information. In the segmentation section, iris boundary is detected and undesired areas like eye lids and eye lashes are removed from images. A conventional detection method known as integro-differential" operator for is the most critical section of iris recognition system because accurate detection increases accuracy of the system. In the normalization process, same region of iris is obtained for matching it with other irises. Multiple images of the same iris are captured from different angles due to pupil dilation and distance between eye and video zoom factor - a process referred to "iris unwrapping". It uses "Daugmans rubber sheet model" to achieve polar coordinates of iris image. In fact, iris image is more enhanced in this section. Encoding starts after getting the enhanced image, fist iris textural features are extracted by using "2D Gabor Filter" and then each texture is encoded as 2D binary code named as "Iris Code". Finally, matching is performed by comparing two iris codes by means of the Hamming distance.

Ziauddin and Dailey [8] proposed a hybrid technique for iris localization which uses multiple techniques at the same time; intensity thresholding, detection of edges and Hough transform. It is clear that difference between the boundary of pupil and iris boundary is high as compared to iris and sclera boundary. For pupil segmentation, intensity threshold is applied to localize the pupil region. Iris segmentation is mainly based on circular Hough transform, but requires several improvements to be made to achieve accuracy and performance.

Gupta and Saini [9] evaluated the existing performance of iris recognition systems by using Image Processing Toolbox of Matlab. The proposed solution consisted of several basic step including image acquisition, segmentation (to detect circles of pupil and iris boundary through Daugman's filter), normalization (for creating rectangular block of fixed size through rubber sheet model), image enhancement (to convert low contrast image to high contrast image and minimize non-uniform illumination by applying Gabor filter) and image matching (to perform template matching with the help of Hamming distance). The main advantage of the proposed technique is that promising accuracy and performance can be achieved even if images are taken from a distance.

Belcher and Yingzi [10] expressed a region based Scale-invariant approach for off angle databases. Proposed system does not depend on center gaze, conversion to polar coordinates and accurate segmentation. For experiment purpose, the authors used ICE 2005 and WVU cooperative and IUPUI non-cooperative database. Iris area is divided into three regions (i.e. left, right and bottom) which in turn are further divided into sub regions. Top area of iris is not considered due to occlusion. SIFT approach is applied to achieve dominant orientation and feature point description. The authors report, that even due to scale invariant, comparative location of feature do not transformed. For example, pupil neighboring feature will remain same, left side texture will still be on the left side. Gaussian difference will be applied to locate firm texture points then these points are verified against other images of same iris. Overall average matching score is found for all regions (i.e., left, right and bottom). Quality of cooperative database is tested by considering feature information, occlusion and dilation.

He *et al.* [4] argue that the system accuracy can be increased by discovering clear (i.e., quality) images in real-time in the preprocessing step. The authors propose three quality descriptors by extracting feature of iris parts. Firstly, local frequency distribution is calculated by selecting two 64 × 64 iris regions. In this way, mean of two local descriptors distinguish clear images from occluded and defocused and motion blurred images. Secondly, iris gradient (iris texture change) is determined as a feature point by taking 20 × 20 iris region. Thirdly, to remove noise of eye lashes, lower edge points (left and right 60 degree from the center of pupil) are computed, and then k-mean clustering algorithm is applied which clearly distinguish clear and non-clear images with mean time 0.06 second.

Proenca and Alexandre [11] propose iris classification methodology that requires no cooperation from the subjects and even with a small iris portion; the proposed system can authenticate individuals without matching the whole iris image. The proposed approach partitions the iris image into six regions (i.e., first four quadrants starting at -45 degree, an inner and an outer parts of iris). Features are extracted independently and biometric signatures are created for all the regions. Iris region and different iris images are represented as subscripts and superscripts respectively. The authors defined a function for calculating dissimilarities between iris signatures. Iris classification is achieved by using a defined threshold set to combine dissimilarity values obtained from comparison between iris regions. If dissimilarity is higher than the defined thresholds, then no match is found (i.e., signatures are of dissimilar irises) otherwise a match is obtained (i.e., both the signatures relate to the same iris).

Shin [3] proposed a novel algorithm that consists of three steps; in the first step, left and right eyes are discriminated with the help of eye lashes and specular reflection (SR) points. In the second step color information is used to classify iris images. In the third step, textual information of iris region is classified. Proposed method increases the performance of system for unconstrained (i.e., blurred) images acquisition environment. Rough portion of iris center is calculated due to pupil black pixels. White points inside the black pixels are used to determined pupil center. Correct iris middle area and radius of are distinguished by circular edge detector. Retinex algorithm is applied to reduce illumination dissimilarity and improve uniqueness of input image. Standard deviations, detection of eyelash pixels and number of specular reflection points of left and right portion of iris searching region are measured and compared with thresholds. As a result image is determined as left, right or undetermined, if a image is determined as left or right eye class it is compared only with left or right eye class respectively, while an undetermined image is matched with the whole dataset. Small input eye image portion cannot classify between left and right eye, in the second step, color information is analyzed and interclass and intraclass classification is achieved through red green and blue pixels. After producing the normalized image, Euclidean Distance, Chi square and Hamming distance is calculated between the input and enrolled images by using the color space model. In RGB, if the highest pixel value is red, it is considered as red pixel, ratio of red pixel is determined, same ratio is calculated for green and blue pixels. Then these ratios are subtracted from the enrolled images and are compared with thresholds. Afterwards images are declared as imposter or next classification step is performed. Imposter images will be classified in the third step. Since Hamming distance of red pixels and green pixels ar previously calculated in the second step. In the third step, Hamming distance from gray channel is calculated. At a final step, weighted sum is calculated for red, green and gray channel excluding the blue channel.

Lagree and Bowyer [12] investigate important aspects of demographic attributes and gender of a person rather than identity. These attribute help systems to apply searching criteria based on demographic attributes rather than search the whole dataset. These attributes can be used as another check to prove the identity of a person. Texture filters (i.e. "spot detector", "line detector" and "Law structure S5S5, R5R5 and E5E5") are applied and six summary statistics are calculated to compute features of iris texture excluding pixels belong to occluded portions. Difference between the iris nearest the pupil and near the sclera is identified. The authors used graphs to find ethnicity across gender and gender prediction across ethnicity and conclude that gender prediction is more challenging than ethnicity prediction.

Sgroi *et al.* [13] investigate the relative age (i.e. old / young) of a person from the iris texture pattern and achieved accuracy of 64%. Authors conclude that it is possible to get the age group of a person through iris image. Nine filters (i.e. small spots, large spots, thin vertical lines, thick vertical lines, thin horizontal lines, and thick horizontal lines, S5S5, R5R5 and E5E5) are applied to get texture features.

Xu [14] proposed a new method instead of using the traditional method where images are normalized and then feature vector are extracted. The proposed method first extracts global features by wavelet filter and then by applying SIFT method achieve the local features of an iris. Then different weights are applied to get the similarity distance between them.

Annapoorani *et al.* [15] proposed a robust method for fast and accurate segmentation of iris. The author performed four major steps: elimination of specularities from input image, pupil detection, iris localization and eyelid and eyelashes detection.

Critical Review: Table 1 summarize a critical review of different IRIS recognition techniques.

Gap Analysis: This work suggests that we need to investigate the major texture pattern categories that exist in enrolled iris images datasets, like flower, zigzag etc. And an input image is only tested if it matches the main texture pattern, this can enhance performance of system. Facial attributes such as skin texture should also be included in personal recognition. System should also be capable to examine ethnic background (i.e. Pakistani, Indian, and South East), gender (male/female) and age (old/young) attributes of subjects. Security and privacy of millions of templates is also an important concern in a centralized database. Latest study shows that human iris changes over time so single enrollment of a person is not suitable, we need to investigate proper iris change age so that system should reenroll iris images. Pupil dilation is another attribute that can be added in order to enhance performance of system. Multiple biometric technologies should be able to work together for greater accuracy. Indexing of image dataset can also increase the system performance.

Table 1: Summary of IRIS Recognition Techniques.

Ref	Focus Area	Technique Used	Strength	Weakness
[1]	Application of phase-base approach for optimal set of iris features extraction.	Discriminating features extraction by using contourlet transform. Feature subset selection through PCA and ICA algorithms.	Decreases template matching time and increases classification accuracy.	Noise degrades computation process.
[6]	Human defined iris texture pattern categorization.	Measured similarity and dissimilarity in texture pattern to get best possible classification.	Robustly classification.	Effective only for small dataset.
[2]	Automated recognition and performance measurement using Hu invariant moment.	Authentication algorithm based on Histogram equalization, filtering, Canny edge detection, Invariant moment and template matching.	Enhanced and efficient matching accuracy.	Applicable for small dataset.
[4]	Ethnicity prediction based on iris texture.	"Spot" and "line "detector filters are applied to build feature vector.	Higher accuracy (up to 90.58%) obtained through SMO by using WEKA.	Demographic (local features) ethnicity has not been evaluated.
[5]	Iris recognition pathway.	Multispectral recognition and iris identification challenges.	Problem areas identification for iris recognition.	The paper primarily discusses numerous methods.
[8]	Hybrid approach for iris localization.	Combining of multiple techniques (i.e. image intensity thresholding, detection of dark and light edges and circular Hough transform).	Increased performance and accuracy up to 99.5%.	Requires manual editing of pupil area of each image.
[9]	Iris template generation to verify performance of iris recognition system.	Image Processing toolbox of Matlab	Promising accuracy and performance.	Rely on open source iris recognition system.
[10]	Iris recognition for non-cooperative databases.	Region based SIFT approach. Extraction of stable feature point and dominant orientation.	Recognizes iris images for non-cooperative database where traditional methods fail.	The proposed approach does not perform better for the traditional cooperative databases.
[4]	Quality assessment of iris images by local frequency distribution, gradient energy and coefficient of edge kurtosis.	Application of K-mean clustering algorithm to extract quality images.	Enhanced performance due to adding only the quality images.	Lacks effectiveness for indistinctive iris textures.
[11]	Non -cooperative iris recognition for noisy images.	Iris division into six regions. Classification using threshold. Combining dissimilarity value	An individual can be identified through a small iris region. after comparison among iris regions 40% false rejection rate has been decreased	High Calculation to extract small region textural information
[3]	Noisy iris image	classification between left nd right eye, classifying color information and texture information	Discriminate between left & right eye. Increases accuracy and performance for off angle images	Small input eye cannot be discriminated as left or right
[12]	Demographic predictions from iris image	Texture filters spot, Line and Laws structure are used to predict ethnicity and Gender	Demographics attribute can search iris image by criteria, enhance ethnicity prediction	Gender prediction seems less accurate
[13]	Prediction of age group from iris texture	Nine filters are applied to get iris texture features.	Aging factor could be investigated	Less accuracy level achieved from iris image.
[14]	New approach to iris recognition	Similarity between local & global features of iris image	Not Independent on normalization	Did not follow the traditional recognition method
[15]	Perfect & high-speed iris Segmentation	Removed specular reflection and localized pupil, Iris and eyelid	Effective for noisy iris images	More reflection on pupil and iris region will affect the accuracy of system

Conclusion and Future Work: Iris recognition system has become widely used reliable biometric technology, during study multiple techniques have been discussed to recognize cooperative, noisy, off angle, blurred and occluded images. This work comes to conclusion that iris segmentation is an essential part of recognition system. Detection of iris and pupil boundary, elimination of eyelid, eyelash and reflection areas in lesser time is more challenging tasks for off angle images. To overcome these problem researchers divided an iris image in to multiple regions. Matching of small portion can identify an individual which increases the system accuracy. Performance of the systems can be enhanced if system uses only the quality images and stop matching when a close match is found. MATLAB algorithms are capable to successfully perform image acquisition, segmentation, normalization and matching steps. The future of iris recognition system is very bright particularly if it can examine demographics attributes of subjects.

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