Iris Detection and Normalization in Image Domain Based on Morphological Features

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Abstract

The interface of computer technologies and biology is having a huge impact on society. Human recognition research projects promises new life to many security-consulting. Iris recognition is considered to be the most reliable biometric authentication system. Very few iris recognition algorithms were commercialized. We implemented a system that process two different kinds of iris databases: CASIA and UPOL. The first is grayscale data; noise free of reflections but containing obstructions; e.g. eyelids and eyelashes. While the second is RGB data; noise free of obstructions; because it is segmented, but it contains reflections. The circular iris and pupil of the eye image were segmented using Morphological operators and Hough transform. The localized iris region was then normalized into a rectangular block to account for imaging inconsistencies. This method provides accurate features as well as accurate signature of the human iris in a simple and fast way.

Keywords: *Pupil Detection, Eyelids Detection, Iris Normalization, and Hough Transform.*

1. Introduction

With the fast development of communication technology and internet, automatic authentication is a fundamental problem. Identification numbers (PINs) or passwords are not suitable for authentication methods in some cases; it is based on things that can be easily breached. How to rapidly and correctly recognize a person to ensure information security has become a crucial social problem to be resolved in this information age [1].

Biometric identification is a method of recognizing an individual based on physical and behavioral characteristics. It includes face, fingerprint, eye, and so on. It has received significant attention as it has many advantages over traditional methods in security, credibility, universality, permanence,and convenience. Especially, biometrics, which analyzes the eye, can offer the highest level of accuracy. The human iris is an annular region between the pupil (generally darkest portion of the eye) and sclera as shown in Fig.1. Generally, iris has many properties that make it an ideal biometric recognition component: (i) a unique characteristic of very little variation over a life's period yet, and (ii) genetic independence "no two eyes are the same". Irises not only differ between identical twins, but also between the left and right eye. Because of the hundreds of degrees of freedom the iris gives and the ability to accurately measure the textured iris, the false accept probability can be estimated at 1 in 10^{31}. Another characteristic, which makes iris difficult to fake, is its comparisons of measurements taken a few seconds apart will detect a change in iris area; if the light is adjusted whereas a contact lens or picture will exhibit zero change and flag a false input [2].

Iris recognition systems are the most accurate; because iris pattern is formed before three years of age and is unchanged through one’s life so it will remain stable over time. Moreover, each person has a unique iris pattern. It is extremely data-rich physical structure and physical protection by a transparent window (cornea); that does not inhibit external view ability. These properties make iris recognition particularly promising solution to society [1]. A typical iris recognition system commonly includes: (i) iris image capture, (ii) iris segmentation, (iii) iris normalization, (iv) iris preprocessing (eyelids/ eyelashes detectionand iris image enhancement), (v) feature extraction, and (vi) matching. All steps can be divided into preporcessing and feature extraction; Fig.2 [2-5,13].

This paper has been organized as follows: (2) properties of the iris, (3) system overview, (4) data collection and applied iris detection techniques, (5) iris detection based on morphological features, (6) iris detection based on cht, (7) iris normalization, (8) feature extraction, (9) discussions and results, and (10) conclusions and future work.

2. Properties of The Iris

Iris is composed of elastic connective tissue, the trabecular meshwork, whose prenatal morphogenesis is completed during the 8^{th} month of gestation [6]. It consists of pectinate ligaments adhering into a tangled mesh revealing striations, ciliary processes, crypts, rings, furrows, a corona, sometimes freckles, vasculature, and other features. During the first year of life a blanket of chromatophore cells often changes the color of the iris, but the available clinical evidence indicates that the trabecular pattern itself is stable throughout the lifespan. Because the iris is a protected internal organ of the eye, behind the cornea and the aqueous humor, it is immune to the environment except for its pupillary reflex to light [6]. The elastic deformations that occur with pupillary dilation and constriction are readily reversed mathematically by the algorithms for localizing the inner and outer boundaries of the iris as shown in Fig.3.

3. System Overview

3.1. Iris system challenges

One of the major challenges of automated iris recognition systems is to capture a high quality image of iris while remaining noninvasive to the human operator. Moreover, capturing the rich details of iris patterns, an imaging system should resolve a minimum of 70 pixels in iris radius. In the field trials to date, a resolved iris radius of 80–130 pixels has been more typical. Monochrome CCD cameras (480×640) have been widely used because NIR illumination in the 700–900-nm band was required for imaging to be unintrusive to humans. Some imaging platforms deployed a wide-angle camera for coarse localization of eyes in faces, to steer the optics of a narrow-angle pan/tilt camera that acquired higher resolution images of eyes [1-4]. Given that iris is a relatively small (1 cm in diameter), dark object and that human operators are very sensitive about their eyes; this matter required careful engineering. Some points should be taken into account: (i) acquiring images of sufficient resolution and sharpness; (ii) good contrast in the interior iris pattern without resorting to a level of illumination that annoys the operator; (iii) the images should be well framed (i.e. centered), and (iv) noises in the acquired images should be eliminated as much as possible.

Fig.1 Iris Diagram

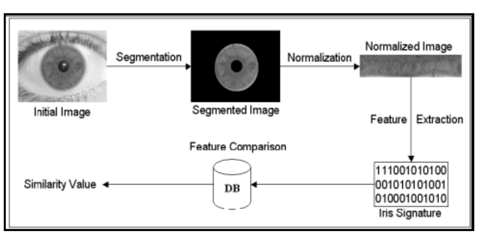


Fig.2 Iris Recognition System Stages

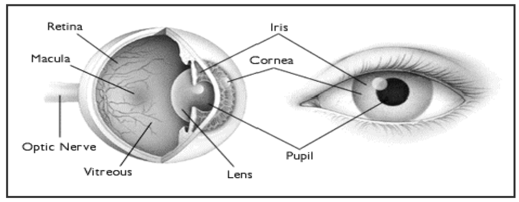


Fig.3 The structure of the eye

3.2. Advantages of iris systems

Iris recognition is especially attractive due to high degree of entropy per unit area of iris; as well as, the stability of iris texture patterns with age and health conditions. Moreover, there are several advantages of iris: (i) an internal organ; (ii) mostly flat with muscles; which control the diameter of the pupil, (iii) no need for a person to be identified to touch any equipment that has recently been touched by strangers; (iv) surgical procedures do not change the texture of the iris; (v) immensely reliable, and (vi) it has responsive nature [3-5,13].

3.3. Disadvantages of iris systems

However, there are some disadvantages of using iris as a biometric measurement are: (i) small target (1-cm) to acquire from a distance (about 1-m) therefore it is hard to detect from a distance; (ii) illumination should not be visible or bright; (iii) the detection of iris is difficult when the target is moving; (iv) the cornea layer is curved; (v) eyelashes, corrective lens and reflections may blur iris pattern, it also Partially occluded by eyelids, often drooping; (vi) iris will deform non-elastically when the pupil changes its size, and (vii) iris scanning devices are very expensive.

4. Data Collection and Applied Iris Detection Techniques

The performance of the proposed system was tested using two different iris databases: the Chinese Academy of Sciences Institute of Automation (CASIA) iris database and the University of Palack´eho and Olomouc (UPOL) database. CASIA database [7]; apart from being the oldest, this database is clearly the most known and widely used as they present very close and homogeneous characteristics and their noise factors are exclusively related with iris obstructions by eyelids and eyelashes. On the other hand, UPOL database [8] explains the higher heterogeneity of its images and the existence of large noisy regions (iris reflections). CASIA iris database beginning with a 320×280 pixel photograph of the eye took from *4 cm* away using a near infrared camera. The near infrared spectrum emphasizes the texture patterns of iris making the measurements taken during iris recognition more precise as shown in Fig.4. UPOL [8] iris images database have the singularity of being captured through an optometric framework (TOPCON TRC50IA) and, due to this, are of extremely high quality and suitable for the evaluation of iris recognition in completely noise-free environments as can be seen in Fig.5. UPOL database contains 284× 7683× 576 iris images captured from 128 eyes of 64 subjects (three images per left and right eye). The images properties are fixed to 24 bit - RGB, 576× 768 pixels, and PNG file format. Its images have maximum homogeneity and inclusively the iris segmentation is facilitated by the dark circle that surrounds the region corresponding to the iris. Its main purpose of this paper is the evaluation of robust iris detection methodologies. This can be used to test and develop segmentation and recognition algorithms that are able to work with images captured under near perfect conditions.

Eye detection can be divided into two categories, active [9] and passive [10]. Active eye detection uses external source for illumination. This will evoke the physical characteristic to utilize the eye localization. The most challenging part for iris detection is to eliminate features with low intensity such as eyebrow, hair, beard and eyelashes. Iris is located using landmark features. These landmark features and the distinct shape of iris allow for imaging, feature isolation, and extraction [11]. In this paper; two techniques had been tested to detect iris boundaries: (i) morphological features and (ii) Wildes algorithm (CHT).

5. Iris Detection Based on Morphological Features

Based on morphological features iris region can be detected using sequences of easily image processing tools to extract human iris region despite of present different type of occlusions and noises and detect information of eyelashes and eyelids in isolated iris area which will be discarded in coding stage. Main stages are (i) Reflection Removal, (ii) sclera removal, (iii) iris segmentation, (iv) iris localization, (v) eyelids detection, and (vi) eyelashes detection.

5.1 Reflection Removal

Preprocessing is used to recover the original image after it has been degraded by known affects; such as geometric distortion within data acquisition system and blur caused by poor optics or movement during capturing iris data; apart from, off-angle iris, faked eye images and interferences with eye images from blinks and eyelashes. Useless parts in the acquired images can cause reduction of the system performance [1-3]. In addition, the size of pupil may change according to the variation of illumination. This deformation of iris can cause interference with the results of pattern matching. Because of nonuniform illumination caused by the position of the light source, the results can be impaired [4,17].

This type of noise regions usually correspond to reflections from artificial light sources near to the subject, although they can appear in the image capturing within natural lighting environments. These reflections have high heterogeneity, as they can appear with a broad range of dimensions and localized in distinct regions of the iris. These areas have intensity values close to the maximum and are exemplified by the region on the upper and left portion of the iris as in UPOL database. Firstly, an eye image is converted to grayscale image as in case the original image is RGB image; UPOL only. Grayscale image is checked for intensity gradients to check on reflection evidence and it will be in UPOL image only and corrective action is initiated to improve it. For selection of outer and inner boundaries for reflected area, gray scale image is converted into binary image as shown in Fig.6 and Fig.7.

5.2 Sclera Removal

Sclera wrongly considered as belonging to the iris similarly to the above described type of noise, when the segmentation of the scleric iris border is not accurate, portions of the sclera are wrongly considered as belonging to the iris and acts as iris border and appear in the lower part of the segmented and normalized iris images. A variety of filters can be used to enhance image quality such as Gaussian filter, and histogram equalization [12]. Then it will be converted to BW image followed by dilation filter [12]. By increasing the size of the lines nearby edge detected components are likely to coalesce into a larger line segment. In this way complete edges not fully linked by the edge detector can form. Thus dilation will give a higher probability that the perimeter of a pupil is a complete circle.

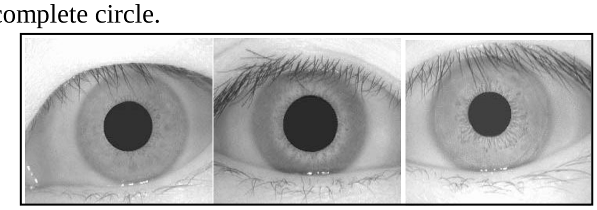


Fig.4 CASIA iris images.

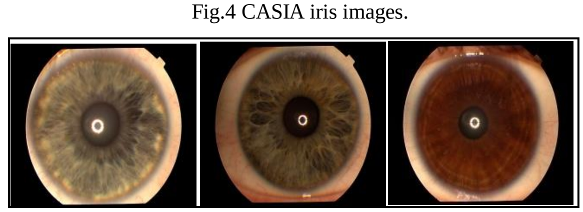


Fig.5 UPOL iris images.

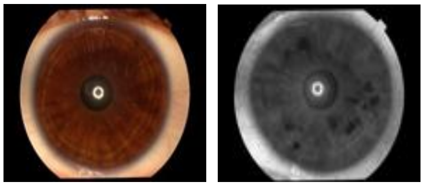
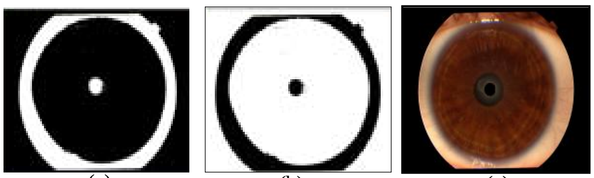


Fig.6 Sample of UPOL image with reflection, and its grayscale image.



(a) (b) (c)

Fig.7 UPOL image reflection detection and removal; (a) binary image, (b) inverted binary image, and (c) reflection removal.

5.3. Iris segmentation

Segmentation is an important part of automated image processing systems, because it is the basis for any further operations, as description or recognition. Segmentation is the assignment of each pixel to an image region, which regarded as a typical classification problem. Regarding the iris biometrics compass, the segmentation stage receives a close-up eye image and localizes the pupillary and scleric iris borders in the image; this is a vital step during CASIA database, whereas UPOL database is already segmented iris images as shown in Fig.8c. So this stage important in removing undesired parts in captured image as eyelids and sclera also reduce time and memory used in all following stages; by selecting suitable threshold according to variation of intensity between the eye parts [10].

5.4. Iris Localization

Localization of iris is an important step in iris recognition because, if done improperly, resultant noise (e.g., eyelashes, reflections, pupils, and eyelids) in the image may lead to poor performance. The first step in iris localization is to detect pupil which is the black circular part surrounded by iris tissues. The center of pupil can be used to detect the outer radius of iris patterns. Iris localization can be done via: (i) pupil detection, (ii) edge detection, (iii) image clean up, (iv) pupil information extraction, and (v) outer iris localization [11, 12].

5.4.1. Pupil detection

Iris is located using landmark features. These landmark features and the distinct shape of iris allow for imaging, feature isolation, and extraction. Iris image is converted into grayscale to remove the effect of illumination. Where, pupil is the largest black area in the intensity image, its edges can be detected easily from the binary image, using suitable threshold. However, the problem of binarization arises in case of persons having dark iris. Thus, the localization of pupil fails in such cases.

5.4.2. Edge detection

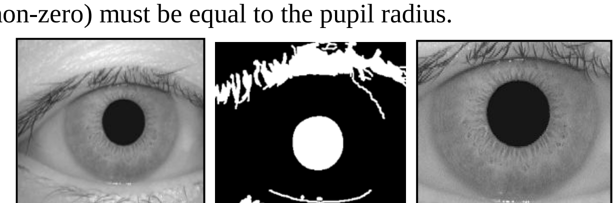
Pupil is a very distinct black circle, in fact so black relative to everything else in the picture. Simple edge detection should be able to find its outside edge very easily. Furthermore, thresholding on the edge detection can be set very high as to ignore smaller less contrasting edges while still being able to retrieve the pupil entire perimeter. Due to its structure, we have used Canny [12,18] operator; Fig.9.

5.4.3. Image clean up

A variety of filters can be used to decrease the extraneous data found in edge detection stage. The first step in cleaning up the image is to dilate all the edge detected lines. Assuming the image is centered, a filter can be used to fill in the circle defined by the pupil's perimeter. In this way, we clearly define the entire area of the pupil. After that, a filter which simply throws out sections of connected pixels with an area below the threshold can be used effectively to throw out smaller disconnected parts of the image that edge detector found. Finally, any holes in the pupil caused by reflections or other distortions can be filled, by looking for sections of blank pixels with an area below the threshold. After this processing we achieve a picture that highlights the pupil area while being fairly clean of extraneous data; Fig.7b, and Fig.8b.

5.4.4. Pupil information extraction

Having preprocessed the image sufficiently the extraction of the pupil center and radius can begin. By computing the Euclidean distance from any non-zero point to the nearest zero valued point an overall spectrum can be found. This spectrum shows the largest filled circle that formed within a set of pixels; Fig.11. Since the pupil is the largest filled circle in the image, the overall intensity of this spectrum will peak in it [14]. In the pupil circle, the exact center will have the highest value. This is due to the simple fact that the center is the one point inside the circle that is farthest from the edges of the circle. Thus, the maximum value must correspond to the pupil center, and furthermore the value at that maximum (distance from that point to nearest non-zero) must be equal to the pupil radius.



(a) (b) (c)

Fig.8 Segmentation original sample of CASIA iris image; (a) original image, (b) sclera removal, and (c) segmented image.

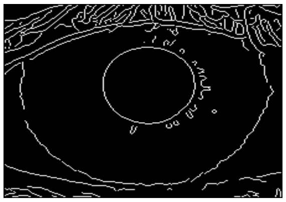


Fig.9 Sample of detected outer edge for CASIA iris image using Canny operator.

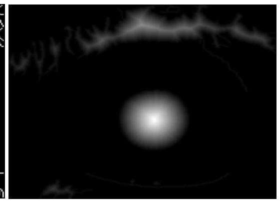


Fig.10 Sample of pupil center detection for CASIA iris image.

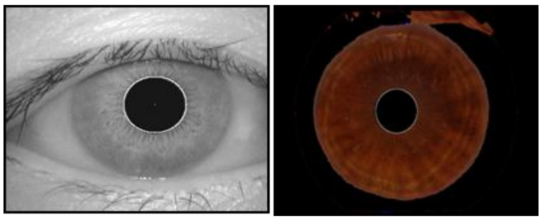


Fig.11 Detected pupil center and perimeter for CASIA and UPOL image.

5.4.5. Outer iris localization

External noise is removed by blurring the intensity image. Too much blurring may dilate the boundaries of the edge or may make it difficult to detect the outer iris boundary, separating the eyeball and sclera. Thus, a special smoothing filter such as the median filter is used on the original intensity image; which eliminates sparse noise and preserves image boundaries. After filtering, the contrast of image is enhanced to get sharp variation at image boundaries using histogram equalization [16]; Fig.12.a. This contrast-enhanced image is used for finding the outer iris boundary by drawing concentric circles, as in Fig.12.b of different radii from the pupil center and the intensities lying over the perimeter of the circle are summed up. Among the candidate iris circles, the circle having a maximum change in intensity with respect to the previous drawn circle is the iris outer boundary. An example of localized iris image is in Fig.12c.

5.5. Eyelids detection

Every person has different type of eyelids occlusion on iris portion, a problem occurs if the system fixes the predefined region but it is partially occluded by eyelid. However, a faster way can be done by detecting the upper and lower eyelids to check if they exist within the iris region. It is possible to use the contrast between the iris portion and eyelids to identify the iris portion, which is not occluded, by the eyelids [3, 4]. By calculating the average intensities of pixels in the iris portion in radial direction for every direction from the center of the pupil, it is noticed from Fig.6 that the iris portion not occluded by the eyelids can be detected easily (segmented UPOL database). Fig.13a shows an example of upper eyelid occlusion with high average intensities at upper portion of iris. On the other hand, Fig.13b shows an example of lower eyelid occlusion with high average intensities at lower portion of iris. As a result, the noise free iris region can be chosen based on the angle with low average intensities.

5.6. Eyelashes detection

A modified unsharp mask is used to detect the eyelashes within the iris portion. This method does not require any threshold or edge detection. Moreover, it is very fast; by reusing a Gaussian smoothing results already done during the iris localization step. The modified unsharp mask is composed of: (i) calculating the difference between the original and smoothed image, and (ii) retaining the high frequency components in iris image. Next, all of the high frequency components are digitally enhanced to show the strong edge points. The edge points that fall within the inner and the outer boundaries of iris are considered as eyelashes. The proposed method can be done automatically as it does not involve edge detection method like Canny edge detector which need user to provide high and low threshold values [18]; Fig.14. After performing the above steps one can detect the human iris region, get isolated iris region, and detect eyelids and eyelashes information (Pixel position + intensity) as shown in Fig.15.

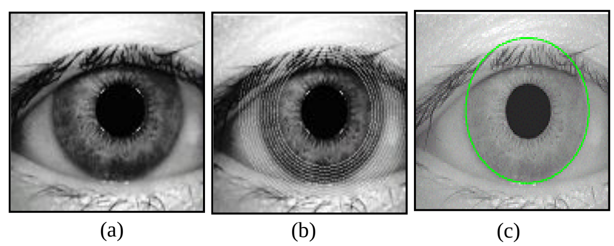


Fig.12: (a) Contrast enhanced image (b) Concentric circles of different radii, and (c) Localized Iris image.

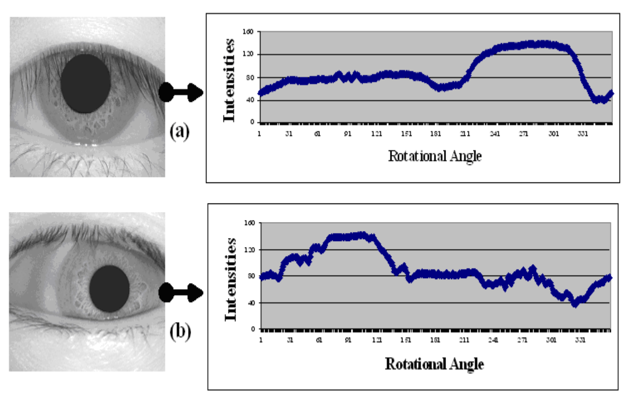


Fig.13: Different type of eyelids occlusion in the iris portion: (a) upper eyelid occlusion and (b) lower eyelid occlusion.

6. Iris Detection Based on CHT (Wildes' Approach)

Wildes [19] uses Hough transform to localize irises. This approach involves two parts first is edge detection, the purpose of the edge detection is to decrease the number of the points in the search space for the objects. Then use Canny edge detection to maximize signal to noise ratio (S/N) and minimize the false positives in edge detection. The second is voting in a circular Hough space is analyzed to estimate three parameters of circle (x_0 , y_0 ,r); the basic idea of CHT is to find curves that can be parameterized like straight lines, polynomials, circles, etc., in a suitable parameter space. Circular Hough transform is very tolerant of gaps in the actual object boundaries or curves; it can overcome the problems of different iris colors, see Fig. 16.

7. Iris Normalization

The size of pupil may change according to the variation of illumination. This deformation of the iris can cause interference with the results of the pattern matching. To reduce this interference, and to make a detailed comparison between two images, it is advantageous to establish a precise correspondence between characteristic structures across the pair. Iris localization is charged with isolating an iris in a larger acquired image and thereby essentially accomplishes alignment for image shift. The zones of analysis are established on the iris in a doubly dimensionless projected polar coordinate system. Its purpose is to maintain reference to the same region of iris tissue regardless both of pupillary constriction and overall image size, and hence regardless of distance to the eye and video zoom factor. This pseudo polar coordinate is not necessarily concentric, since for most eyes the pupil is not central in the iris [14, 17]. Due to the varying size of the pupil and of the distance and angle of the image-capturing framework, the size of the captured irises can have high variations, increasing the complexity of the recognition task. Robust representations for pattern recognition must be invariant to changes in the size, position, and orientation of patterns. In iris recognition compass, this requires a representation of the iris data invariant to the dimension of the captured image. This is influenced by the distance between the eye and the capturing device, by the camera optical magnification factor and by the iris orientation, caused by torsional eye rotation and camera angles [15]. Therefore, the coordinate system is changed by unwrapping iris and mapping all the points within the boundary of iris into their polar equivalent as shown in Fig.17. The mapped image has 80×360 pixels; i.e., the step size is same at every angle. Therefore, if the pupil dilates the same points are picked up and mapped again, which makes the mapping process stretch invariant [16]. The invariance to all factors can be achieved through the translation of captured data into a double dimensionless polar coordinate system. The rubber sheet model assigns to each point on the iris, regardless of its size and pupillary dilation, a pair of real values (r, θ), where $r \in [0,1]$ and $\theta \in [0,2\pi]$. Remapping of iris image $I(x,y)$ from Cartesian coordinates to polar coordinates can be:

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

where $x(r,\theta)$ and $y(r,\theta)$ are defined as linear combinations of both the set of pupillary boundary points ($x_p(\theta)$, $y_p(\theta)$) and the set of limbus boundary points along the outer perimeter of the iris ($x_s(\theta)$, $y_s(\theta)$) bordering the sclera, which are detected in the iris segmentation stage:

$$\begin{cases} x(r,\theta) = (1-r)\times x_p(\theta) + r \times x_s(\theta) \\ y(r,\theta) = (1-r)\times y_p(\theta) + r \times y_s(\theta) \end{cases} \quad (2)$$

The inner boundary can be detected using threshold based on edge detection algorithms. However, the outer boundary, detection is more difficult due to low contrast; the outer boundary is detected by maximizing changes of perimeter-normalized sum of gray-level values along the cycle, the normalized iris images as shown in Fig.18 and Fig.19 [19].

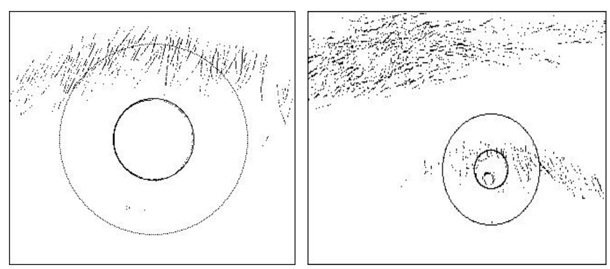


Fig.14: Examples of modified unsharp masking results to detect the eyelashes.

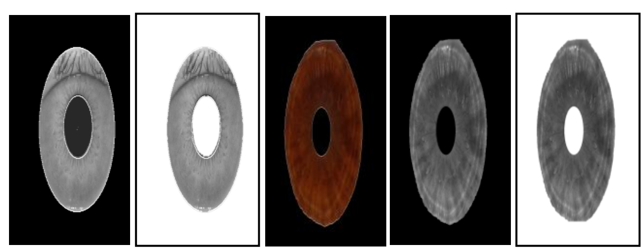


Fig.15 Sample of isolated iris region for CASIA and UPOL database.

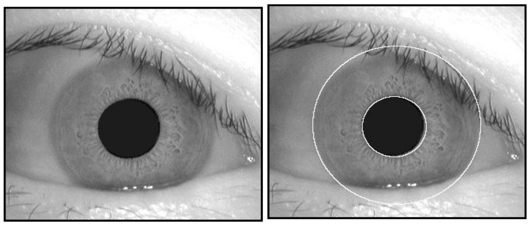


Fig. 16: Localization using CHT algorithm applied on sample of CASIA V.1 iris database.

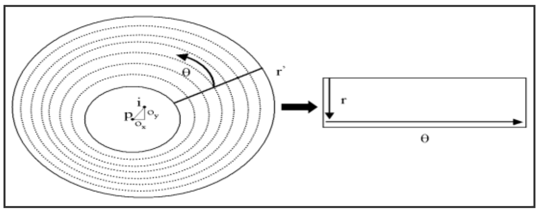
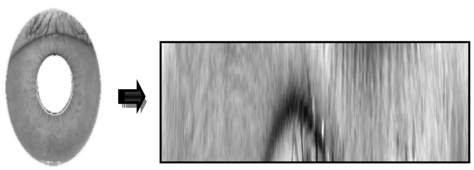
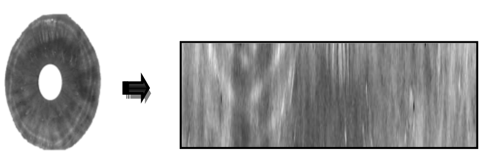


Fig.17 Normalization using Daugman rubber sheet model.



(a) (b)

Fig.18 Normalized iris image for CASIA iris image sample (a) isolated iris region, and (b) normalized iris image.



(a) (b)

Fig.19 Normalized iris image for UPOL iris image sample (a) isolated iris region, and (b) normalized iris image.

8. Feature Extraction

We performed several tests to select the best feature set by evaluating the capacity of simultaneously localize the iris regions and minimize the noise, related essentially with obstructions and reflections. We concluded that three discrete components *x, y, I(x,y)*; where (x, y) the coordinates of the pixel position and I(*x*, *y*) the corresponding pixel intensity, can characterize each pixel and propitiate a correct segmentation. This set, named " Pixel position + intensity" preserves information about spatial relations in the image (pixel position), as well as about the individual properties of each pixel (intensity).

9. Discussions and Results

Two iris databases were used to test this work and obtain experimental results; UPOL, and CASIA iris databases. All experiments of this work are implemented using MATLAB R2012b on a computer with 2.20 GHz Intel Core 2 Duo processor and 2 GB RAM. A subjective evaluation of the proposed iris segmentation method was performed on a set of 150 images from CASIA V1.0 (without reflections) and a set of 150 images from UPOL iris (with specular reflection) databases. The results for iris localization and pupillary and/or limbic boundaries detection, with and without reflection removal, are shown in Table 1.

From experimental results analysis, we found that the proposed approach is able to handle many problems such as invariance to noisy instances, occlusion, specular highlights, the presence of contact lenses, and changing in illumination which fail most of the previous methods. It also reduce the localization accuracy of the proposed approach is compared against Wildes approach (using circular Hough transform) [18, 19] and the localization accuracy of the proposed approach is relatively high especially in an elliptical iris shape see Fig.20. On the other hand, the localization time of the proposed approach is relatively low compared to CHT see Table.2.

10. Conclusions and Future Work

In this paper, we proposed a robust iris segmentation algorithm that localizes the pupillary boundary and the limbic boundary in the presence of noise. For finding edges of the iris, a region-based active contour model along with a Canny edge detector is used.

We randomly selected 150 images from each of the above described iris databases, hoping that they were representative of the respective database images. As expected, through the analysis of different databases, we obtained a more objective idea about the degree and type of noise characteristics of each image database. After the identification of the types of noise that each available database contains, it is concluded that the CASIA Database can become the sample database to test the iris localization methods for the non-cooperative environment against occlusions while UPOL will be perfect against illumination and reflection effects.

To process the iris patterns in an efficient and effective way against existing methods, many simple and effective image processing methods have been presented in iris preprocessing, iris segmentation, iris localization, normalization feature extraction. Experimental results show that our method achieves an accuracy of 99%.

Compared to CHT method achieving 80%, it also runs about faster. In the future, we plan to test our algorithm on multiple public iris image databases that contains a relatively larger number of noises within the captured iris regions. In addition, segmentation results will be compared against other algorithms. A biometric identification system, based on the processing of the human iris by the morphological feature extraction and circular Hough transform, can be introduced to get iris code.

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Table-1 Subjective Evaluation Results

Iris Database	Reflection Elimination	Segmentation	Eyelid Detection	Eyelashes Detection	Pupil Detection (without reflection removal)	Pupil Detection (with reflection removal techniques)	Iris Localization (using CHT)	Iris Localization (using Morphological features)
CASIA V.1	No Reflections	100%	96.67%	86.67%	100%	100%	80%	98.67%
UPOL	100%	Segmented	100%	100%	63.33%	98.667%	92%	99.33%

Table-2 Execution Time

Time(seconds)	Iris localization using Morphological features	Iris localization using CHT
Average	8.5	16.75
Min	7	13.5
Max	10	20

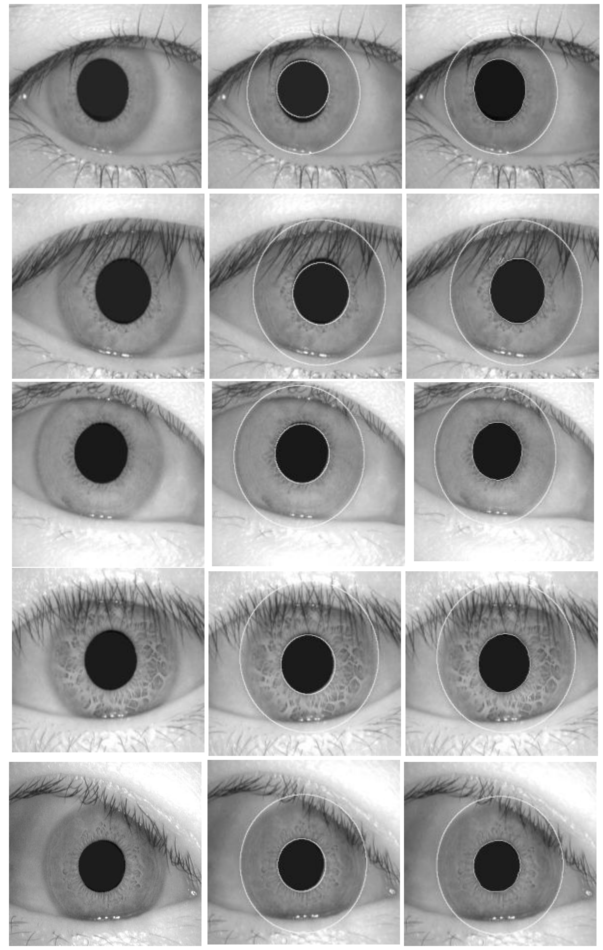

Figure 20: Examples of fail and success of CHT and proposed morphological iris localization applied on CASIA V.1 database.

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