Improving Iris Localization Performance Using Image Processing Tools: Multi-Input Databases

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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. Image quality plays a crucial role in any pattern matching system. Three different iris databases have been employed for comparison of performance of proposed iris detection and isolation technique based on morphological features. CASIA, UPOL, and UBIRIS databases were processed as different types of noise like iris obstruction by eyelids, eyelashes, lighting reflections, and poor focused images. 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 image selection, iris preprocessing, iris segmentation, iris localization, and isolation. Experimental results show that our method achieves an accuracy of 100% for select best iris data, and 99% for isolate iris region.
Keywords: *Edge Detection, Gamma Correction, Pupil Detection, Histogram Equalization, and Iris Detection.*

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. 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].

2. System Overview

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 detection and iris image enhancement), (v) feature extraction, and (vi) matching [1-3, 14]. All steps can be divided into preporcessing, feature extraction, and classification; Fig.1 shows the main steps for iris recognition system.

2.1. Properties of The Iris

Iris is composed of elastic connective tissue, the trabecular meshwork, whose prenatal morphogenesis is completed during the 8th month of gestation [4]. 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 [4]. 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.2.

2.2 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 camera that acquired higher resolution images of eyes [1-3].
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.

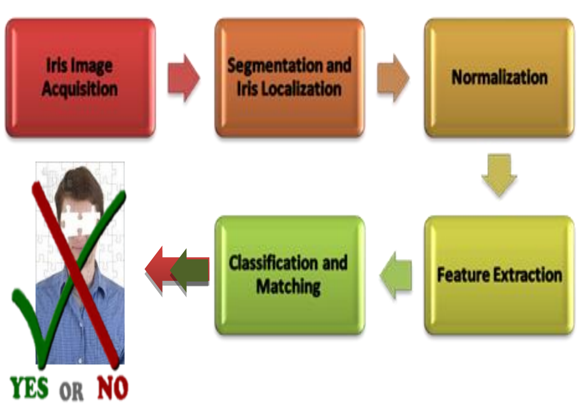

Fig. 1 Iris Recognition System Stages

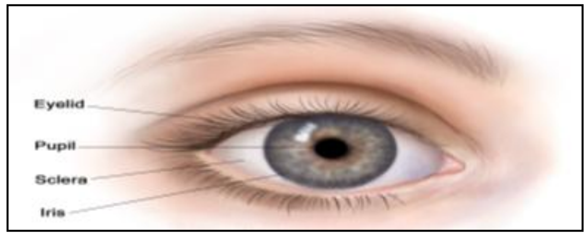

Fig. 2 The structure of the eye

2.3 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].

2.4. 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 [3].

3. Data Collection

The performance of the proposed system was tested using three different iris databases: the Chinese Academy of Sciences Institute of Automation (CASIA) iris database, the University of Palack´eho and Olomouc (UPOL), and UBIRIS database.
CASIA database [6]; 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. 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.3.

UPOL [7] 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.4. UPOL database contains 284× 7683× 576 iris images captured from 128 eyes of 64 subjects (three images per left and right eye). 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 methodology.
UBIRIS [8] database is comprised of 1877 images collected from 241 subjects within the University of Beira Interior 6 in two distinct sessions and constituted Public and freely available iris images was built database with a fundamental characteristic that distinguished it from the remaining ones: it is a “noisy iris image database” and the noise factors are not only avoided but also rather induced as shown in Fig.5. It contains some noise factors but significantly lacks iris specular and lighting reflections, in order to simulate the non-cooperative image capturing.

4. Background and Related work

The iris localization involves the following two steps: data acquisition and iris detection. The data acquisition step obtains iris images. In this step, infrared illumination is widely used for better image quality. The iris detection step localizes an iris region in the image using boundary detection algorithms. Several noises are suppressed or removed in this step. There are many attempts in the area of iris localization and segmentation. The first attempt was made by Daugman et al. [1, 5] and Wildes et al. [13]. Daugman’s method [16] is widely considered as the best iris recognition algorithm.
Eye detection can be divided into two categories, active [9] and passive [10]. Active eye detection uses external source for illumination [11]. 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.

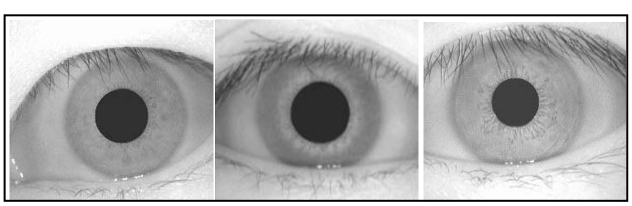

Fig. 4 Samples of CASIA iris database

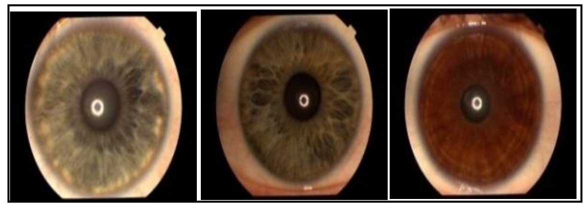

Fig. 5 Samples of UPOL iris database

Fig. 6 Samples of UBIRIS iris database images

5. Proposed Iris Localization Algorithm

Based on morphological features iris region can be detected using sequences of easily and fast 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 of proposed algorithm as in Fig.7 are broadly consists of the following stages (i) image selection, (ii) image enhancement, (iii) reflection removal, (iv) sclera removal, (v) iris segmentation, (vi) iris localization, (vii) eyelids detection, (viii) eyelashes detection, and (ix) iris isolation.

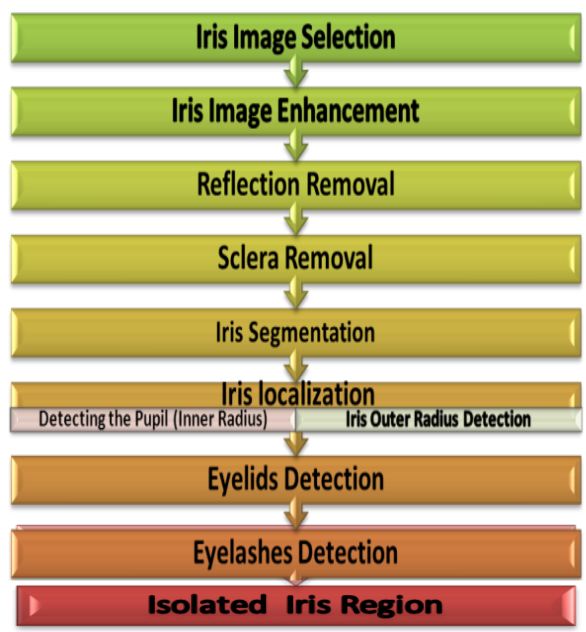

Fig. 7 Block diagram of the proposed system

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5.1. Selection of Good Iris Data

Yet, image acquisition and selection has often been an area of limited activity with most research focusing on better localization and feature extraction techniques to improve recognition performance. Needless to say a transform is only as good as the data that is fed into it and with proper image screening all classifiers can achieve a dramatic improvement in accuracy. In the image acquisition step, left and right eye images of each user are rapidly captured by the CCD camera, 30 frames per second and stored by 320 ×240 size [1]. After that, to detect the counterfeit iris and to evaluate the quality of eye image, we use an easily efficient algorithm of eye image check, which evaluates the coefficient of variation of pupil radius, tests the eyelid and eyelashes movement, compare between available iris images. At the second step, the algorithm which checks eye image quality to find out bad quality images such as occlusion, eyelash interference and the truncation of iris region. After finishing the algorithm of eye image check, we can select the qualified image between both iris images.

Image selection needs to be reliable because it has a major influence on the all subsequent steps, iris image has to meet certain quality requirements; e.g., it should not be too noisy or blurred. The quality of the iris image is checked to see whether it is sufficient for the steps that follow. If the quality is considered too low, the image is rejected if it is allowed. Therefore, image preprocessing is significant part of iris recognition systems. The input images will be converted to grayscale if it RGB. Selecting the good quality iris image, the eye image check algorithm picks out the bad quality image from both iris images. Selecting the good iris image by hand based objective measure firstly, and then after several studies and experiments for choosing suitable automated easily and simple iris selection technique. The proposed technique to check image is based on correlation, Gamma correction, and normalization techniques.
The rank normalization function applies rank normalization to the pixel intensity values of an image. This means that all pixels in an image are ordered from the most negative to the most positive (from the one with the smallest intensity value to the one with the largest intensity value). After the ordering the first pixel is assigned a rank of one, the second the rank of two, and the last is assigned a rank of N, where N is the number of pixels in the image [12]. Gamma correction performs nonlinear operation in brightness adjustment that focuses on the basic information in the iris and normalizes all other parts [19]. Brightness for darker pixels is increased, but it is almost the same for bright pixels. This can lead to test the eyelid, eyelashes movement, iris area against pupil deformation, and compare between available iris images for the same user. Finding the best correlation between the histogram of original image and histogram for rank normalized image and the original and image after applied Gamma correction will be the main base of this technique in easily and fast way. This case study from CASIA V.1 database; after compare the correlation between the different histograms of two different images of the same iris (00.1108, 0.0671), and (0.0498, 0.026020) image (018_2_4) will be accepted and will be used as the iris image for this user followed to subsequent stages and system will auto reject sample (018_2_2) as it more occluded with eyelids and; Fig.8, and Fig.9.
Select the best correlation coefficient for different images that certain the same person in different datasets as shown in Fig.10, Fig.11, and Fig.12 and the comparison between the correlations applied samples as in Table 1 and experimental result of 100 different persons chosen from CASIA, UPOL, and UBIRIS databases are shown in Table 1.

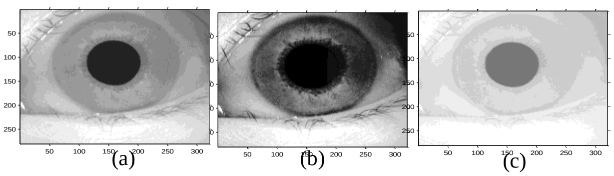


Fig. 8 Sample of CASIA V.1 (case 018_2_4.bmp); (a) original image, (b) rank normalized image, and (c) image after Gamma correlation with (γ=0.4)

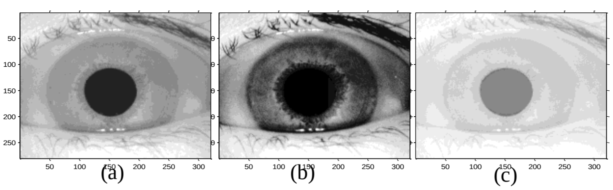


Fig. 9 Another image for the previous selected person (case - 018_2_2.bmp) (a) original image, (b) rank normalized image, and (c) image after Gamma correlation with (γ=0.4)

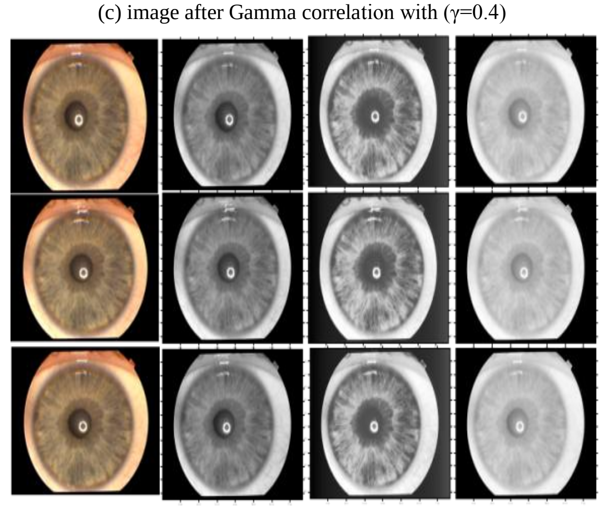


Fig. 10 Samples of different images for UPOL (case- 041L) as case study for image selection stage

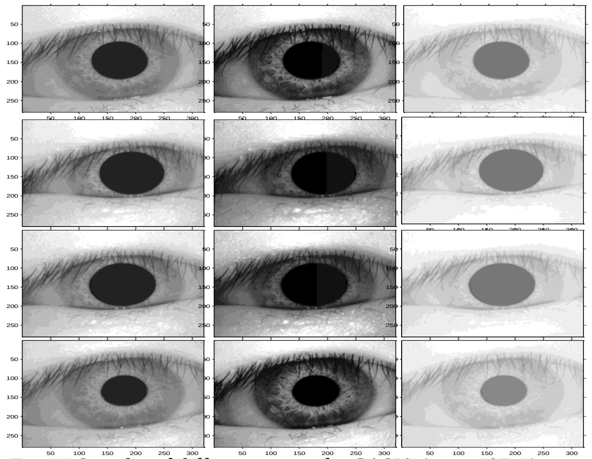


Fig. 11 Samples of different images for CASIA (case- 107_2) as case study for image selection stage

5.2. Iris Image Enhancement

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. 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. We wish to improve its contrast and brightness by using standard techniques such as histogram operations [12, 18]. Histogram equalization (HE) can be used as a simple but very robust way to obtain light correction when applied to small regions such as an eye. The aim of HE is to maximize the contrast of an input image, resulting in a histogram of the output image that is as close to a uniform histogram as possible. It maximizes the entropy of an image, thus reducing the effect of differences in illumination within the same "setup" of light sources.

Adaptive Histogram Equalization (AHE) involves applying equalization based on the local region surrounding each pixel. Each pixel is mapped to intensity proportional to its rank within the surrounding neighbourhood [18]. This type of equalization also tends to reduce the disparity between peaks and valleys within the image's histogram. However,

Table-1 Result of Iris Image Selection Stage

Case Study		***Correlation coefficient between original and rank normalized image***	***Correlation coefficient between rank normalized image and processed image with Gamma correction***	***Sorting the most suitable image for iris detection according to comparison results***	***Best for localization***
CASIA	107_2_1.bmp	0.1143	0.0483	2	107_2_4.bmp Then 107_2_1.bmp
CASIA	107_2_2.bmp	-0.0428	-0.0925	4 (The Worst)	
CASIA	107_2_3.bmp	0.0351	-0.0221	3	
CASIA	107_2_4.bmp	0.1701	0.0927	1 (The Best)	
Experimental Result for 100 cases from CASIA v.1 database compared with subjective measure			***98%***		
UBIRIS	Img_201_1_1.jpg	0.1716	0.1073	1 (The Best)	Img_201_1_1.jpg Then Img_201_1_2.jpg
UBIRIS	Img_201_1_2.jpg	0.1684	0.1056	2	
UBIRIS	Img_201_1_3.jpg	0.1666	0.1047	3	
UBIRIS	Img_201_1_4.jpg	0.1599	0.1019	5	
UBIRIS	Img_201_1_5.jpg	0.1482	0.0950	6 (The Worst)	
UBIRIS	Img_201_1_6.jpg	0.1565	0.0996	4	
Experimental Result for 100 cases from UBIRIS database compared with subjective measure			***97%***		
UPOL	041L_1.png	-0.6498	-0.6142	1 (The Best)	041L_1.png Then 041L_3.png
UPOL	041L_2.png	-0.6514	-0.6231	3 (The Worst)	
UPOL	041L_3.png	-0.6505	-0.6160	2	
Experimental Result for 100 cases from UPOL database compared with subjective measure			***100%***		

the enhancement often leads to noise amplification in “flat” regions, and “ring” artifacts at strong edges as shown in Fig.8.
Histogram Truncation operations allow gray levels to be distributed across the primary part of the histogram [12]. This solves the problem when one has a few very bright values in the image that have the overall effect of darkening the rest of the image after rescaling as shown in Fig.13. After several experiments and based on subjective measure and localization, Histogram equalization will be used as enhancement stage in our proposed system.

Fig. 12 Samples of different images for UBIRIS (case- Img_201_1) as case study for image selection stage

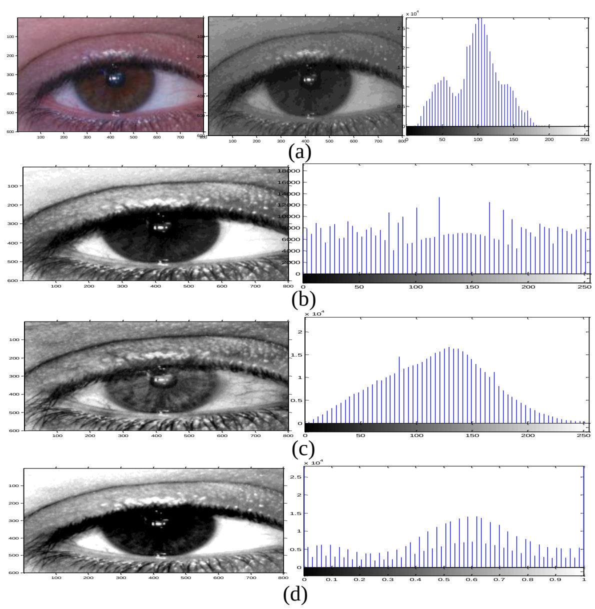


Fig. 13 Enhancement of UBIRIS sample; (a) original image, gray scaled image and its histogram, (b) result Image and its histogram after linear equalization, (c) result after adaptive equalization, and (d) result image and its histogram after truncation

5.3. Reflection Removal

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, and UBIRIS databases. Grayscaled image is checked for intensity gradients to check on reflection evidence and it will be in UPOL and UBIRIS images only and corrective action is initiated to improve it. Gray scaled image is converted into binary image as shown in Fig.14, Fig.15, and Fig.16.

5.4. Sclera Removal

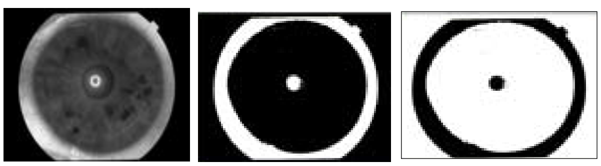
Sclera wrongly considered as belonging to the iris similarly to the above described type of noise, when the segmentation of the scleric iris border is not accurate, portions of the sclera are wrongly considered as belonging to the iris and acts as iris border and appear in the lower part of the segmented and normalized iris images. A variety of filters can be used to enhance image quality such as Gaussian filter, and histogram equalization. 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. Sample of UPOL and UBIRIS image after removing sclera are shown in Fig.17.

5.5. 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 and UBIRIS, 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].

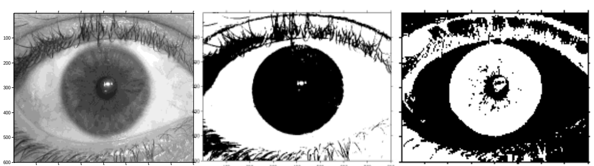
5.6. Iris Localization

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 as in [3] via: (i) pupil detection, (ii) edge detection, (iii) image clean up, (iv) pupil information extraction, and (v) outer iris localization. All steps of the previous proposed method in [3] based on morphological features and applied on CASIA v.1 database which applied on this paper for UPOL and UBIRS data sets also. An example of steps of iris localization tested on sample of CASIA is in Fig.18, and sample of UPOL, and UBIRIS as shown in Fig.19.



(a) (b) (c)

Fig. 14 Reflection detection and removal stage applied on sample of UPOL image; (a) enhanced gray scaled image, (b) binary image, and (c) inverted binary image.



(a) (b) (c)

Fig. 15 Reflection detection and removal stage applied on sample of UBIRIS image; (a) enhanced gray scaled image, (b) binary image, and (c) inverted binary image.

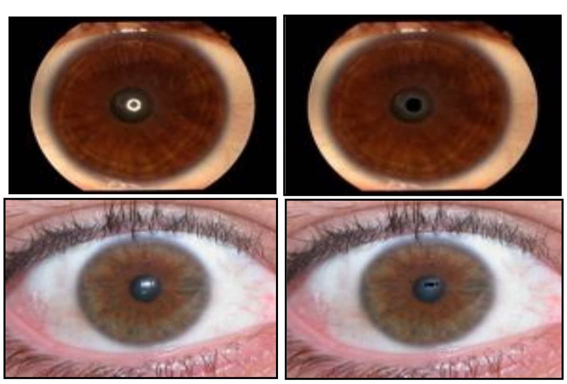


Fig. 16 Result of reflection removal stage applied on sample of UPOL, and UBIRIS databases

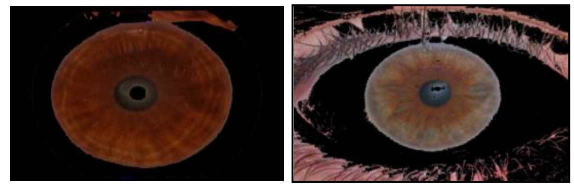


Fig. 17 Sample of UPOL and UBIRIS image after removing sclera

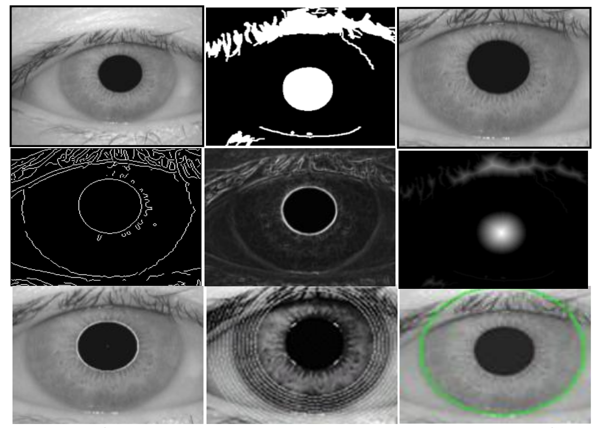


Fig. 18 f Iris segmentation and localization process applied for sample of CASIA database

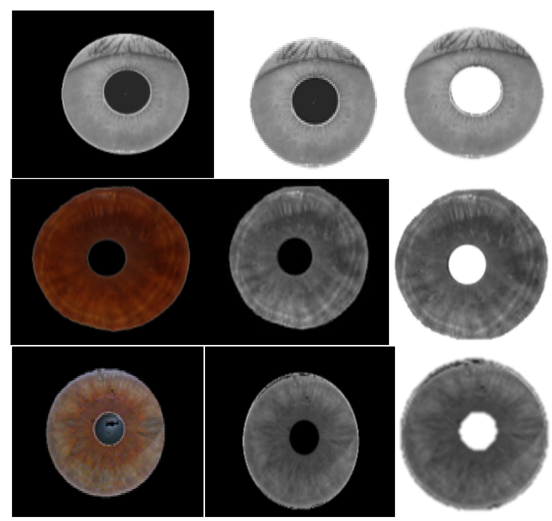


Fig. 19 Samples of iris isolation regions; CASIA, UPOL, and UBIRIS respectively**.**

5.7. 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, 15].

5.8. 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 [17]. 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 [3]. 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. After performing the above steps human iris region iris mask can be extracted, check on artifacts, get isolated iris region, and detect eyelids and eyelashes information if it present and then get (Pixel position + intensity) and isolate iris area as shown in Fig.20, and Fig.21. All previous steps from iris image selection to isolate iris region are also relatively high speed and simple for each applied image see Table.2.

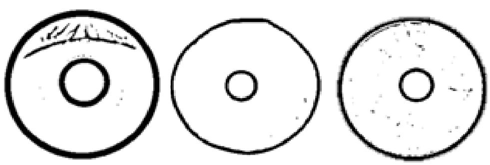


Fig.20 Extracted masks to detect the eyelashes and eyelids from CASIA, UPOL, and UBIRIS iris areas.

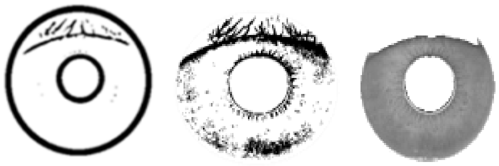


Fig. 21 Sample of detects eyelashes and eyelids from iris region of CASIA sample.

Table-2 Execution Time

Time (seconds)	*Iris localization applied on (CASIA) database*	*Iris localization applied on (UPOL) database*	*Iris localization applied on (UBIRIS) database*
Average	18	35	122.5
Min	16	25	85
Max	20	45	160

6. Conclusions and Future Work

Three iris databases were used to test this work and obtain experimental results. 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 localization method was performed on a set of 100 users randomly selected with and without reflection removal, are shown in Table-3. 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, and the presence of contact lenses, an elliptical iris shape, and changing in illumination which fail most of the previous methods. Selecting the good quality iris image, the eye image check algorithm picks out the bad quality image from both iris images enhance and make isolation process easier, and more accurate. It reaches 100% on UPOL selected cases.

In this paper, we proposed a robust iris image selection, detection and isolation algorithm that localizes the pupillary boundary and the limbic boundary in the presence of noise applied on different databases hoping that they were representative of the respective database images. As expected, through the analysis of databases, we obtained a more objective idea about the degree and type of noise characteristics of each image database. 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, and UBIRIS database are noisier database. In the future, we plan to test our algorithm on more multiple public iris image databases that contains a relatively larger number of noises. A biometric identification system, based on the processing of the human iris by the morphological feature extraction, can be introduced and tested on different databases that represent more types of noise.

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Table-3 Result of Iris Image Selection Stage

Iris Database	***Reflection Elimination***	***Segmentation***	***Eyelid Detection***	***Eyelashes Detection***	***Pupil Detection (without reflection removal)***	***Pupil Detection (with reflection removal techniques)***	***Iris Localization (using Morphological features)***
CASIA V.1	No Reflections	100%	99%	95%	100%	100%	99%
UPOL	100%	Segmented	100%	100%	50%	98%	96%
UBIRIS	100%	99%	98%	96%	63 %	97%	92%