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Research on Iris Region Localization Algorithms

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ABSTRACT
Iris recognition is a biometric technique that offers premium performance. Iris localization is critical to the success of an iris recognition system, since data that is falsely represented as iris pattern data will corrupt the biometric templates generated, resulting in poor recognition rates. So far different algorithms for iris localization having been proposed. This paper explored four efficient methods for iris localization, out of these three methods of iris localization in circular form and one methods of unwrapping the iris in to a flat bed. Experimental results are reported to demonstrate performance evaluation of every implemented algorithms. Conclusion based on comparisons can provide most significant information for further research. A CASIA and UPOL iris databases of iris images has been used for implementation of iris localization
General Term
Biometrics,Iris Recognition,Iris Localization
Keywords :- Circular Iris Localization, Flat bed Iris Localization, Timing Analysis, Accuracy Analysis

I. INTRODUCTION

Iris is the coloured annular region of the eye responsible for controlling and directing light to the retina.[1] The average diameter of the iris is 12mm, and the pupil size can vary from 10% to 80% of the iris diameter.[2][10] Its strength lies in the rich unique textural information contained in the underlying tissues, which is complex enough to be used as a biometric signature [1][2]. The first stage of iris recognition is to localize the iris and isolate it from digital eye image. The eye image captured with an iris scanner from CASIA V_1 iris database is as shown in Figure.1. Pupil is exactly at the core of the eye image. Iris portion can be approximated by two circles, one for the iris/sclera boundary and another, which is interior to the first, forms the iris/pupil boundary.

The two circles are usually not concentric.[3][4][5]
The success of segmentation of iris portion depends on the imaging quality of eye images.[6][7][8]

Specular reflections can occur within the iris region corrupting the iris pattern.
Also, persons with darkly pigmented irises will present very low contrast between the pupil and iris region if imaged under natural light, making segmentation more difficult stage.[9] The eyelids and eyelashes generally occlude the upper and lower parts of the iris region, it affects recognition results.[10]
In this paper we have implemented four methods of iris localization. Out of these three methods of iris localization in circular form and one method of unwrapping the iris image in to a flat bed. and above the lower eyelids or eyelashes are included..

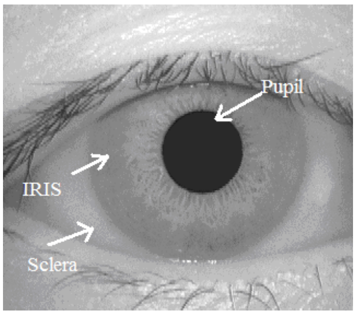


Figure 1**.** An eye image from CASIA V_1 iris database.

II. CIRCULAR IRIS LOCALIZATION

For localization of iris, there are many methods in the literature that finds the iris and pupil regions centre and then radius.[11][12][13] Many researchers have discussed number of methods for localizing the iris image from the available eye images.[14][15][16] These methods are database dependent. Among many such available methods We have implemented three methods for iris localization in circular form named as, Daugman's Grid Method, Random Circle Contour Method and Circular Hough transform method.

2.1. Circular iris localization using Daugman's grid method

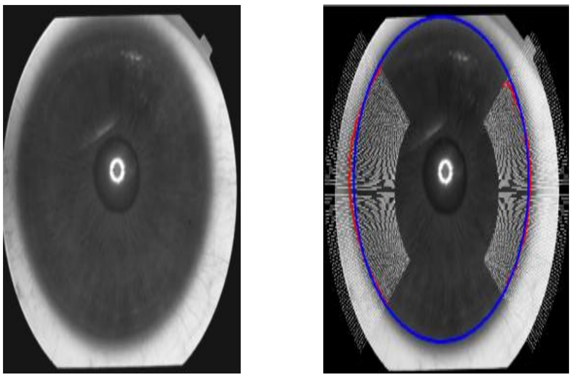
Initially the image of the eye is converted to gray scale and its histogram is linearly stretched, as to be able to take benefit of all range given by the 256 levels of the gray scale. Then, following the ideas proposed by Daugman [7][9], a grid is placed over the image and testing each of the points in the grid, the center of the iris, as well as the outer boundary;

i.e., the border between the iris and the sclera, is detected making use of the circular structure of the latter (see Figure 2).
The detection is performed maximizing *D*, where

$$D = \sum_m \sum_{k=1}^{5} (I_{n,m} - I_{n-k,m}) \quad (1)$$

being,

$$I_{i,j} = I(x_0 + i\Delta_r\ cos(j\Delta_\theta),\ y_0 + i\Delta_r\ sin(j\Delta_\theta)) \quad (2)$$



(a) (b)

Figure 2. Boundary detection using Daugman's grid method (a) an iris image from UPOL database, (b) detected outer boundary.

where,

(x_0, y_0) is a point in the grid which is taken as center,

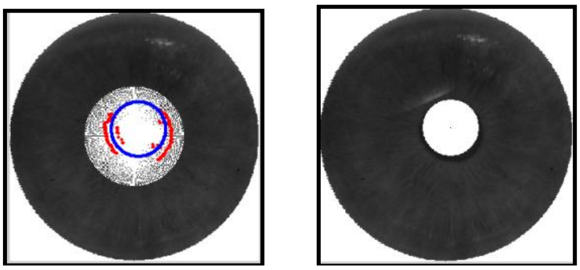
Δ_r and Δ_θ are the increments of radius and angle,

I (*x*, *y*) is the gray level of the image at pixel (*x*, *y*) and

D is the maximum variation in gray level.

In this way the outer bound between the sclera and the limbus is detected, which is the outer bounds of the iris.
Then the biggest square inside this circle of the iris is considered, and the same process is performed in order to find the inner boundary; i.e., the frontier between the iris and the pupil. The points inside this last border are also suppressed, obtaining the image as shown in Figure 3 (a).

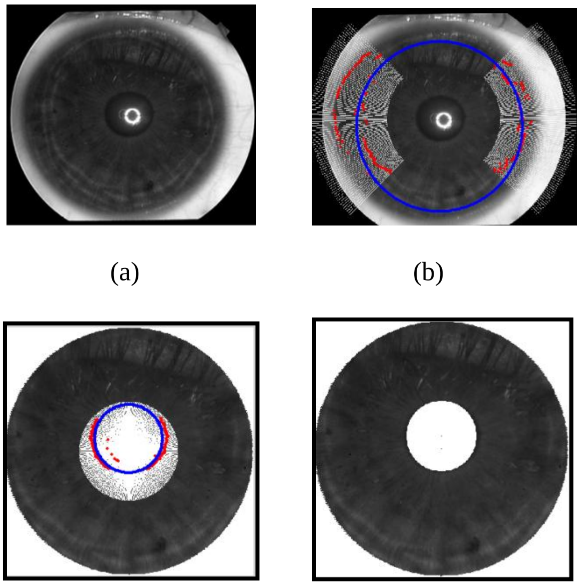
In the last step of the pre-processing block, the image of the isolated iris is scaled to achieve a constant diameter regardless of the size in the original image. This can be easily observed from the Figure 3 (b)
.
In order to test the consistency of the algorithm for the eye images available in the UPOL database, the same algorithm has been executed for the other images available in the database.



(a) (b)

Figure 3. Boundary detection using Daugman's grid method (a) detected inner boundary, (b) isolated iris image.

It was observed that the algorithm successfully localize all the images in the database. For further clarity and observations another eye image from the same database and the obtained results has been illustrated in Figure.4.



(a) (b)

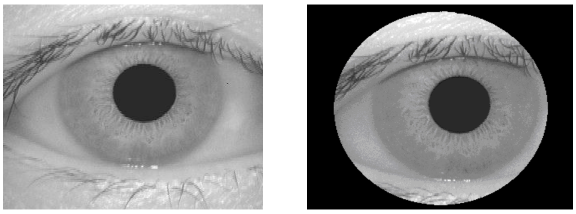
(c) (d)

Figure 4...Boundary detection using Daugman's grid method (a) another iris image from UPOL database, (b) detected outer boundary, (c) detected inner boundary, (d) isolated iris image.

2.2. Circular iris localization using random circular contour method

In this method, initially any random circular contour is marked which contains iris and pupil region to eliminate the remaining portion of the eye.[17] A circular pseudo image is formed of the desired diameter. The inside region of the circle is set at gray level '1'(white) and the outside region to '0'(black). The diameter selected is such that the circular contour will encircle the entire iris. This diameter selection is crucial as it should be common for all iris images. In this method we have set the diameter empirically. This circular pseudo image is then convolved with the eye image from the database.

Thus when the product of the gray levels of the circular pseudo image and the original have been illustrated in Figure.5. iris image has been taken, the resultant image will have the circular contour enclosing the iris patterns and the outside of the circular contour will be at gray level '0'(black). The results for marking random circular contour [21]



(a) (b)

Figure 5.Formation of random circular contour around the iris (a) original eye in CASIA database (01_1_2.bmp), (b) marked random circular contour.

The resultant image Figure 5(b) is the partial localized iris image. Now onwards we have performed two tasks. One task is to find the ratio of the limbus diameter and pupil diameter forms the basis of the first criterion in comparison of any two irises. And the other task is to move this circular contour in such a way that it is concentric with the pupil.[10] This alignment is required since minor shifts often occur due to offsets in the position of the eye along the camera's optical axis. So before pattern-matching, alignment is carried out. The limbus and pupilary boundary of the iris are concentric about the pupilary center. So our aim is to determine the pupilary center. Thus to achieve this, we have used point image processing techniques such as thresholding and gray-level slicing (without the background) on the resultant partially localized image to eliminate the other features of eye except the pupil of the eye. The pupil of the eye is set at gray level '0' (black) and rest of the region is set at '255' (white). The resultant pupil image has been illustrated in Figure.6.

Then the resultant pupil image is scanned row-wise to determine the number of pixels having gray level '0' in each row and the maximum count have been considered as the diameter of the pupil along the row.

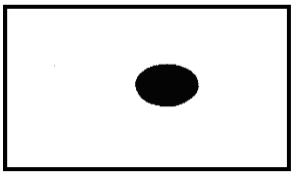


Figure 6. Pupil Image of the random circular contour around the iris in Figure 5.

Now scanning the resultant pupil image column-wise, a counter will count the number of pixels having gray level '0' in each column and the maximum count has been considered as the diameter of the pupil along the column. Taking the average of the two, we have obtained the average of the pupil diameter.

Next step involves determining the center of the pupil. This is done by finding the row and column having the maximum number of pixels of gray level '0' (black), which corresponds to the center of the pupil. Knowing the center of the pupil, we now shift the center of the circular contour to the center of the pupil. The resultant image will have the pupil and the iris regions concentric with the circular contour. The image obtained from the circular contour encircling the pupil and the iris is not at the center of the frame. So the step in the alignment involves shifting the circular contour to the center of the frame. Knowing the center of the frame and the center of the circular contour, the difference in the two centers can be determined. Using this difference, gray level shifting on the image has been carried out appropriately.[18] The resultant image will have the center of the circular contour coinciding with the center of the frame. This has been illustrated in Figure.7.

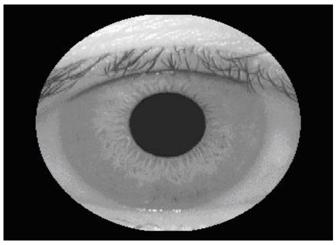


Figure 7. Centrally shifted random circular contour around the iris in Figure 3.5.

The ratio of the limbus diameter and pupil diameter forms the first criterion in comparison of any two irises.[19] Pupil diameter is now known to us. In order to determine the limbus diameter we have used image point processing operators, mainly gray level slicing with and without the background and a digital negative, we obtain only the iris at gray level '0' (black) and the remaining portion of the image is at gray level '255' (white) .
The shape of the limbus in this case can be considered to be semi-circular as shown in Figure 8.

Figure 8 Semi-circular limbus after gray level slicing.

Now scanning row-wise, a counter determines the number of pixels having gray level '0' (black) in each row and the maximum count can be considered as the diameter of the limbus along the row. Now scanning column-wise, a counter determines the number of pixels having gray level '0' (black) in each column and the maximum count can be considered as the radius of the limbus. Doubling gives the diameter of the limbus along the column. Taking the average of the two, we get the average limbus diameter. Then, the ratio of the limbus diameter and the pupil diameter is determined which is the basis of the first criterion in identification / comparison of the iris.
Finally, the result of iris localization of the eye with iris (limbus) and pupil are circled correctly in the aligned iris image has been demonstrated in Figure 9.

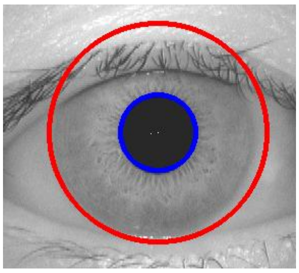


Figure 9.Aligned Iris in eye marked with circles for iris and pupil boundaries.

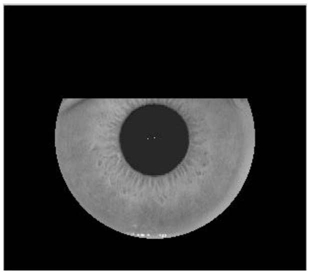
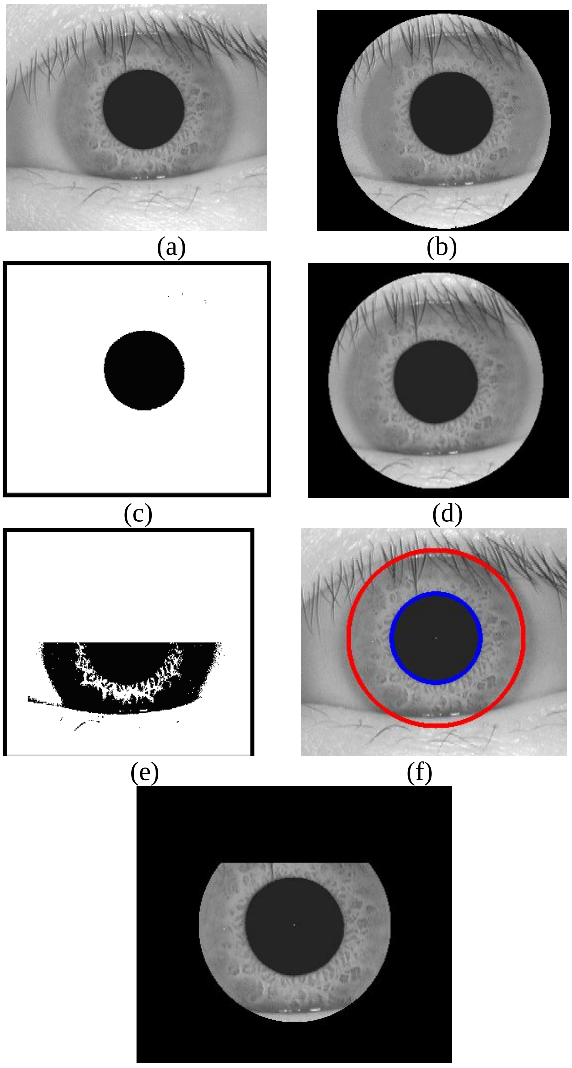


Figure 10. Resultant iris after removal of the eyelids / eyelashes.

Removing the portion of the iris occluded by the eyelids / eyelashes (as can be clearly observed from Figure.9) is very important because it affects the recognition results.[10]
The eyelids / eyelashes are occluding part of the iris, so only the portion of the image below the upper eyelids and above the lower eyelids are included.



(g)

Figure 11. Formation of random circular contour around the iris (a) original eye in CASIA V_1 iris database (08_1_2.bmp), (b) marked random circular contour. (c) Binary Pupil Image, (d) Alignment of iris in the center of the frame, (e) Binary Semi-Iris Image, (f) Localized iris in eye, (g) Iris after removal of the eyelids.

Thus removing the portion of the iris occluded by the eyelids / eyelashes is the next task to perform. This is achieved by changing the gray level above the upper eyelids and below the lower eyelids to '0' (black). Thus the resultant image obtained after localization and alignment can now be analyzed using pattern matching techniques. The resultant iris image after removal of the eyelids / eyelashes has been presented in Figure 10.

The same algorithm has been executed for another eye image CASIA: 08_1_2.bmp from the CASIA V_1 iris database and the obtained results has been shown for further clarity in the Figure 11(a) to Figure 11(g).

2.3. Circular iris localization using Hough transform

The Hough transform is a standard computer vision algorithm that can be used to determine the parameters of simple geometric objects such as lines and circles present in an image.[22] The circular Hough transform have been employed to deduce the radius and centre coordinates of the pupil and iris regions.[5][10][23][24]
Initially, an edge map is generated by calculating the first derivatives of intensity values in an eye image and then thresholding the result. From the edge map, votes are cast in Hough space for the parameters of circles passing through each edge point. These parameters are the centre coordinates x_c and y_c, and the radius r, which are able to define any circle according to the equation given by,

$$x_c^{\,2} + y_c^{\,2} - r^2 = 0 \tag{3}$$

A maximum point in the Hough space will correspond to the radius and centre coordinates of the circle best defined by the edge points as,

$$(-(x-h_j)\sin\theta_j + (y-k_j)\cos\theta_j)^2 =$$

$$a_j((x-h_j)\cos\theta_j + (y-k_j)\sin\theta_j) \tag{4}$$

where,

a_j Controls the curvature,

(h_j, k_j) is the peak of the parabola, and

θ_j is the angle of rotation relative to the x axis.

In performing the preceding edge detection step, we bias the derivatives in the horizontal direction for detecting the eyelids; and in the vertical direction for detecting the outer circular boundary of the iris of the eye images from CASIA V_1 iris database.

For finding Hough transform, we provide range of iris and pupil radius as range of circle radius from CAISA V_1 iris database specification and create edge map of eye for iris co-ordinates detection[24] and we create edge map of extracted iris region for pupil radius and co-ordinates from Hough transform. Brightest point in Hough transformed image is the desired center for Iris.[26]

The motivation for this work is that the eyelids are usually horizontally aligned, and also the eyelid edge map will corrupt the circular iris boundary edge map if using all gradient data. Taking only the vertical gradients for locating the iris boundary will reduce influence of the eyelids when performing circular Hough transform, and not all of the edge pixels defining the circle are required for successful localization.[26] [29][31]

This makes iris localization more accurate and more efficient, since there are less edge points to cast votes in the Hough space.
The intermediate stages to localize the iris using circular Hough transform of two different eye images from the CASIA database have been illustrated in Figure 12 and Figure 13.

III. FLAT BED IRIS LOCALIZATION

Irises from different people may be captured in different size and, even for irises from the same eye, the size may change due to illumination variations and other factors. such elastic deformation in iris texture will affects the results of iris matching.[8] Daugman solved this problem[3][6][28].Flat bed iris localization is nothing but

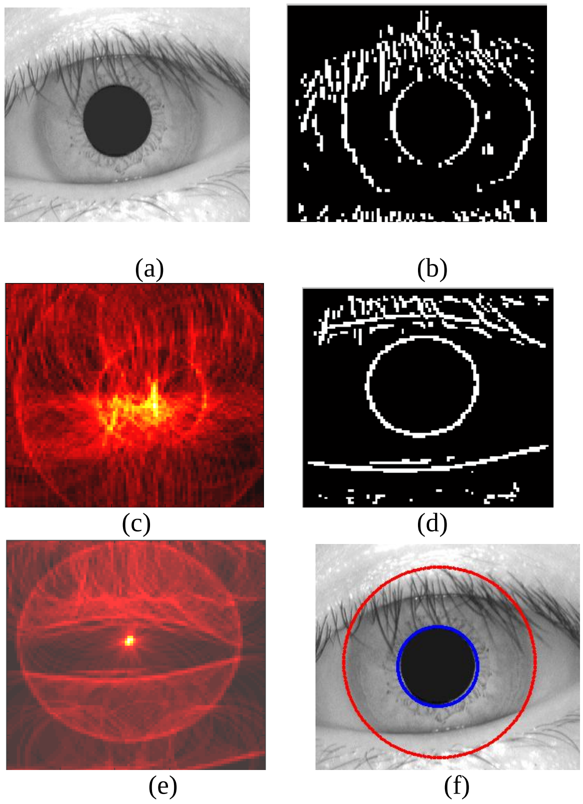


Figure 12.(a) Original eye image (CASIA: 14_1_1.bmp) from CASIA database,
(b) Vertical edge map of eye, (c) Hough transform, (d) Horizontal edge map,
(e) Hough transform image showing center of the iris, (f) Localized iris image.

such elastic deformation in iris texture will affects the results of iris matching.[8] Daugman solved this problem[3][6][28].Flat bed iris localization is nothing but unwrapping the circular localized iris into a rectangular region. Image processing of the iris region is computationally expensive.

In addition the area of interest in the image is a ‘donut’ shape, and grabbing pixels in this region requires repeated rectangular-to-polar conversions.[31][32] To make things easier, the iris region is first unwrapped into a rectangular region using simple trigonometry. This allows the iris decoding algorithm to address pixels in simple (row, column) format.

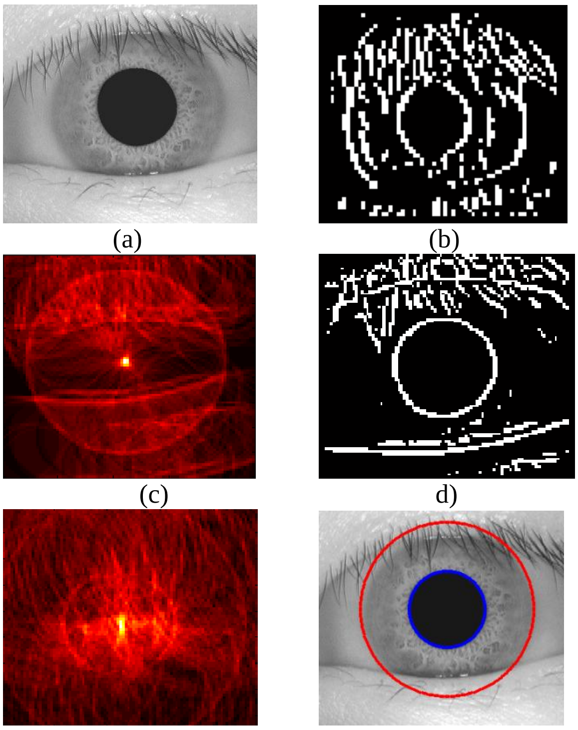


Figure 13. (a) Original eye image (CASIA: 47_1_1.bmp) from CASIA database,
(b) Vertical edge of eye, (c) Hough transform, (d) Horizontal edge map, (e) Hough transform image showing center of the iris, (f) Localized iris image.

Figure.14. shows simple implementation of the iris unwrapping.

Once the iris region is successfully segmented from an eye image, the next stage is to transform the iris region so that it has fixed dimensions in order to allow comparisons. The dimensional inconsistencies between eye images are mainly due to the stretching of the iris caused by pupil dilation from varying levels of illumination. Other sources of inconsistency include, varying imaging distance, rotation of the camera, head tilt, and rotation of the eye within the eye socket.[8] The normalization process will produce iris regions, which have the same constant dimensions, so that two photographs of the same iris under different conditions will have characteristic features at the same spatial location.

Another point of note is that the pupil region is not always concentric within the iris region, and is usually slightly nasal.[3] This must be taken into account if trying to normalize the ‘donut’ shaped iris region to have constant radius.

The homogenous rubber sheet model can be shown in relevant to iris and pupil inside it. We can remap each point within the iris region to a pair of polar coordinates (r, θ) where r is on the interval [0, 1] and θ is the angle between [0, 2π]. The remapping of the iris region from (x, y) Cartesian coordinates to the normalized non-concentric polar representation is modeled as,

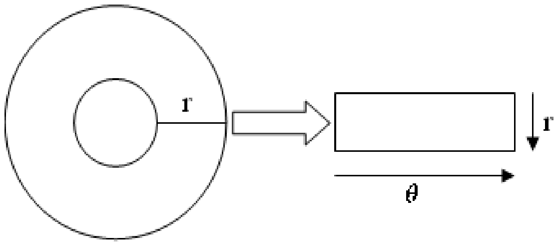


Figure 14. Implementation of iris unwrapping

$$I(x(r,\theta), y(r,\theta)) \rightarrow I(r,\theta) \quad (5)$$

with

$$x(r,\theta) = (1-r)\, x_p(\theta) + r\, x_1(\theta) \quad (6)$$

$$y(r,\theta) = (1-r)\, y_p(\theta) + r\, y_1(\theta) \quad (7)$$

where,

$I(x, y)$ is the iris region image,

(x, y) are the original Cartesian coordinates,

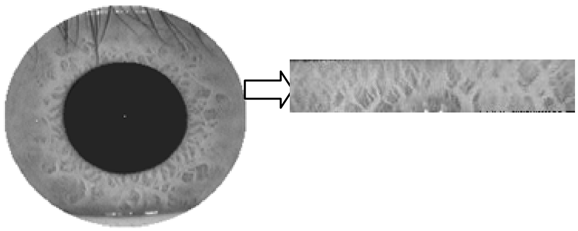
(r, θ) are the corresponding normalized polar coordinates,

x_p, y_p are the coordinates of the pupil, and

x_1, y_1 are the iris boundaries along the θ direction.

The rubber sheet model takes into account pupil dilation and size inconsistencies in order to produce a normalized representation with constant dimensions. In this way the iris region is modeled as a flexible rubber sheet anchored at the iris boundary with the pupil centre as the reference point. Even though the homogenous rubber sheet model accounts for pupil dilation, imaging distance and non-concentric pupil displacement, it does not compensate for rotational inconsistencies.

This procedure of iris unwrapping is applied on iris images from the CASIA V1 iris database and the resultant output has been illustrated in Figure 15.



(a) (b)

Figure 15. Flat bed iris localization (a) circular localized iris (CASIA V_1: 33_1_3.bmp), (b) Unwrapped normalize image.

In our experiments for generating the normalized flat bed iris image, we find that the zigzag Colleratte area is one of the most important parts of complex iris patterns ,which is closer to the pupil and provides the most discriminating information for recognition.[16][21][30] It is usually less sensitive to the pupil dilation and less affected by the eyelids and eyelashes. From the empirical study, it is found collarette region is generally concentric with the pupil and the radius of this area is restricted in a certain range.[30] So we extract the flat bed iris for the region closer to the pupil as illustrated in Figure.16. This region takes up about 80% of the normalized image.

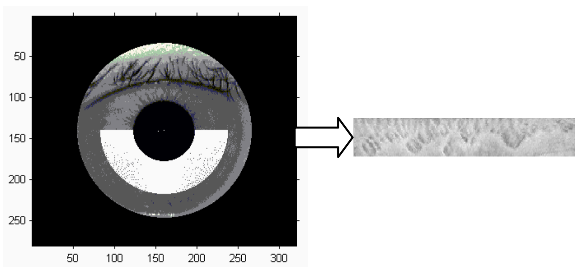


Figure 16. Extraction of flat bed iris for the region closer to the pupil.

The unwrapped normalized iris image still has low contrast and may have non-uniform brightness caused by the position of light sources.[8] All these may affect the subsequent feature extraction and matching. In order to obtain a better distributed texture in the iris, we first approximate intensity variations across the whole iris image. The mean of each small block (we have considered the size of each block as 16×16 empirically) constitutes a coarse estimate of the background illumination. This estimate is further expanded to the same size as that of the normalized image by using bi-cubic interpolation. The resultant estimated background illumination for the same unwrapped normalized iris image has been illustrated in Figure.17.

Figure 17. Estimated background illumination.

This estimated background illumination is subtracted from the unwrapped normalized image to compensate for a variety of lighting conditions. Then we enhance the lighting corrected image by means of histogram equalization in each (32×32) region. Such processing compensates for non-uniform illumination, as well as improving the contrast of the image.[8] Figure.18 shows the preprocessing result of an iris image, from which we can see that finer texture characteristics of the iris become clear.

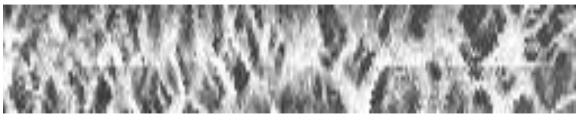


Figure 18. Enhanced unwrapped iris image.

This procedure of iris unwrapping into flat bed iris localization has been applied on all the iris images from the CASIA V_1 iris database along with the estimation of background illumination and compensation for non-uniform illumination, as well as improving the contrast of the unwrapped iris image. The resultant outputs of various intermediate stages for another iris image CASIA: 20_1_3.bmp from CASIA V_1 iris database has been illustrated in Figure.19.

IV. RESULTS AND DISCUSSIONS

The proposed algorithms have been developed using MATLAB 7.1. It is tested on 2.4 GHz CPU with 2 GB ram. The famous iris database CASIA V_1 Iris, which is currently the largest iris database available in the public domain have been selected for experiments. CASIA-IrisV_1 includes three subsets which are labeled as CASIA-IrisV_1-Interval, CASIA-IrisV_1-Lamp, CASIA-IrisV_1-Twins. From the database we have selected 372 iris images from 108 different eyes (under different conditions) of 54 subjects. The images in the database have been acquired during different stages and the time interval between two collections is at least one month, which provides a challenge to the algorithm. All iris images are 8 bit gray-level JPEG files, collected under near infrared illumination.

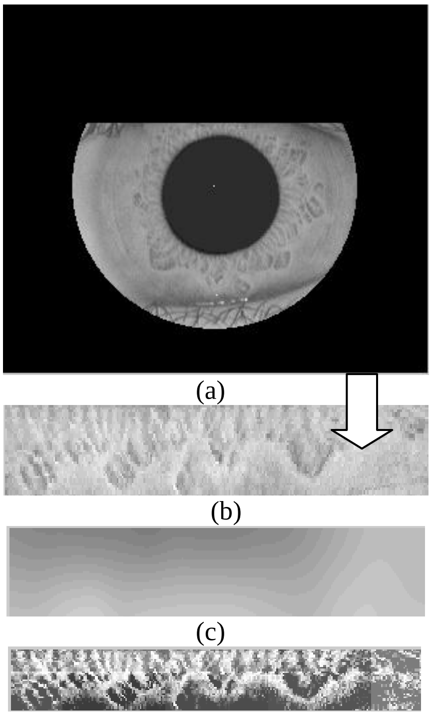


Figure 19. Flat bed iris localization (a) circular localized iris (CASIA: 20_1_3.bmp),
(b) Unwrapped normalize image, (c) Estimated background illumination,
(d) Enhanced unwrapped iris image.

Accuracy of the proposed algorithms of iris localization have been observed Table 1. in three categories as fully localized iris, only pupil detection and the rejected samples for which neither iris nor pupil has been detected

Localization Algorithm	**Fully localized Iris image**	**Only Pupil Detection**	**Rejected samples**
Random Contour Circle	86.29 %	3.76 %	9.85 %
Daugman`s Grid	73.66 %	9.14 %	17.20 %
Haugh Transform	92.47 %	4.84 %	2.69 %

Table 1.Accuracy of various Circular Iris Localization Algorithms

Timing analysis of all the algorithms have been performed to find the computational complexity of all the algorithms with the same database and mentioned in Table 2.

Localization algorithm	**Time of execution (sec)**
Random Contour Circle	1.114
Dougman's grid	2.731
Hough transform	7.468

Table 2.Timing analysis with CASIA V_1 iris database for various circular iris localization algorithms.

V. CONCLUSIONS

For iris localization Hough transform is the best in account of accuracy but it is worst with respect to processing time since it has to perform complex computations, whereas Random Contour Circle method is fairly good with respect to both accuracy and processing time but it can be used only for the images in CASIA V_1 iris database. The Dougman's grid method gives correct results only for iris having less variation in pattern and with darker back ground with respect to sclera.

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