Improved Iris Segmentation Algorithm without Normalization Phase

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***Abstract*—Earlier state-of-art algorithms of iris recognition system works well for ideal-data, because of the perfect iris localization algorithms. The same ideal-algorithm suffers a lot under non-ideal data. Non-ideal-data refers to eye image captured under unconstrained environments, such as non-uniform illumination, image captured at a distance, eye image with reflections, blurred image, off-axis eye images, majority of occlusions due to eyelashes and eyelids. So there arises a need for perfect iris localization and segmentation algorithm. This proposed method segments the iris region almost perfectly even in the non-ideal data. Further, the fixed and consistent iris strip is obtained without the need for normalization phase. Moreover, this proposed method is tested on publicly available CUHK iris database. Experimental result shows that, this proposed iris segmentation algorithm results in better accuracy when compared to the earlier state-of-art-algorithms with reduced computational complexity.**

Keywords: iris localization, iris segmentation, square wedges, edge detection, region filling

I. Introduction

Out of various biometric traits, iris recognition has the highest degrees of freedom with the higher recognition accuracies [1]. Since the iris is developed at the early childhood and stays stable for the entire lifetime, iris recognition is said to be accurate, reliable against artifice. Further, iris recognition is proved as a phenotypic feature rather than genotypic feature. It is also proved that, the probability of two irises would be exactly the same is estimated at 1 in 10^{72}[2]. The traditional iris recognition comprises of following steps:

Step 1: Image acquisition phase.

Step 2: Preprocessing phase.

Step 3: Pupil and Iris localization and segmentation phase.

Step 4: Normalization phase, and

Step 5: Feature Extraction and matching phase.

To build a robust iris recognition system, iris segmentation plays a vital role. Many earlier state-of-art-algorithms followed different methods for iris segmentation phase. Some of those methods used in the traditional iris recognition system for iris segmentation are discussed in the following section.

According to John Daugman's approach [1], Integro Differential Operator [IDO] is used for localizing the pupil and iris boundaries. Then, the annular iris region is segmented. To make the dissimilar dimensions of segmented iris regions of various images from same subject, normalization phase is considered as mandatory. For this purpose, Daugman uses Rubber Sheet Model (RSM). Thus, the annular iris region is unwrapped and the transformation from Cartesian to polar coordinates (r, θ) takes place. Here, 'r' lies in the range of [0, 1] and 'θ' lies in the range of [0, 2π]. Figure 1 shows the template for Daugman's RSM. After the normalization phase, feature extraction and matching process takes place.

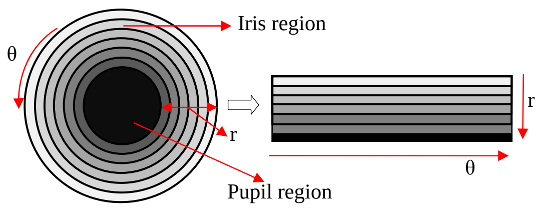

Fig. 1. Daugman's Rubber Sheet Model

In M. Ezhilarasan approach [3], modified Daugman's RSM is implemented to reduce the occlusions due to eyelids and eyelashes. In the standard Daugman's RSM, entire iris strip is considered for feature extraction after unwrapping annular iris region. While considering like this, there is a possibility of slight intervention due to pupil region, eyelids, and eyelashes. To exclude these occluded regions, red-dotted line is drawn over the normalized iris strip such that majority of occlusions are eliminated. Therefore, the iris regions above this red-dotted line alone are considered for feature extraction and rest of the regions with trivial occlusions are rejected. After the normalization process, the normalized iris strip is segmented and identified as Region of Interest (RoI) and occluded regions. Figure 2 shows the template for fixing of red-dotted line over the normalized iris strip. Since this red-dotted line segments the normalized iris region, this method is termed as Segmented Daugman's RSM. After identifying the RoI, the feature extraction, and matching process is carried out.

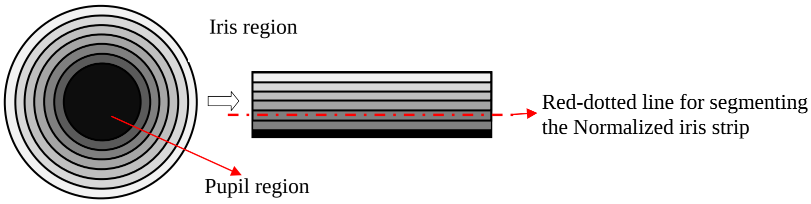

Fig. 2. Segmented Daugman's RSM

J. G. Ko et al [4-6] uses mask templates for identifying the pupil and iris boundaries, respectively. From the annular iris region, the iris regions lying in the 45° to 315° and 135° to 225° alone is considered for iris segmentation. That is, the iris regions lying only within the regions of ±45˚ along the central axis of iris region alone are considered for segmentation. Figure 3 shows the template for fixing of wedges over the iris region for segmentation and the essential iris region to be segmented is shown by dark black color. After fixing the wedges, the normalization process follows. In the unwrapped iris strip, iris regions lying beneath this special wedge alone (shown in the dark black color) are considered for feature extraction process there by the majority of occlusions due to eyelashes and eyelids are reduced significantly.

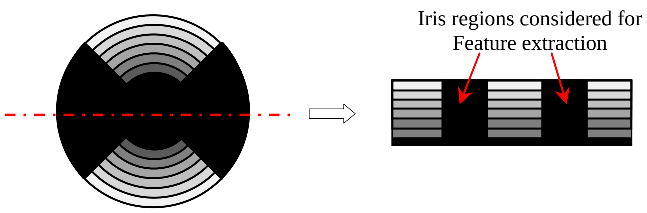

Fig. 3. Fixing of special wedges for segmenting the iris region

L. Birgale et al [7] uses specially designed mask to segment the iris region without the need for normalization phase. Here, the circular and hexagonal shaped masks are used. After identifying the pupil boundary, these masks are superimposed over the eye image such that, the iris regions around the pupil region and beneath the masks alone are considered for iris segmentation. Figure 4(a) and 4(b) shows the template for fixing of circular and hexagonal masks over the eye image.

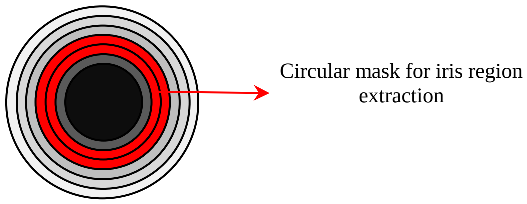

Fig. 4(a). Fixing of Circular Mask for segmenting the iris region

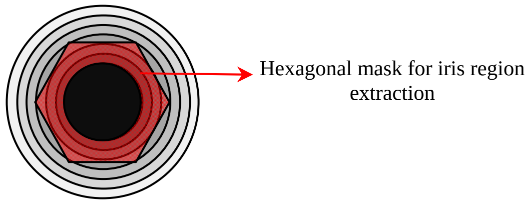

Fig. 4(b). Fixing of Hexagonal Mask for segmenting the iris region

The regions shown in red color in figures 4(a) and 4(b) is the considered iris regions for segmentation. Afterwards, the conventional normalization process is carried out to acquire the rigid, uniform, and consistent iris strip. Then the feature extraction and matching process takes place.

A. *Summary of the earlier iris-recognition algorithms*

Some of the steps are common in the earlier state-of-art-algorithms up to the normalization process and beyond. They are summarized below:

(a) Either pupil localization or iris localization is carried out as the initial step.

(b) During the pupil localization, pupil coordinates (such as, centre and radius) are determined,

(c) During the iris localization process, clear identification of limbic boundary is done, and

(d) Afterwards the segmentation of annular iris region takes place. Then, it is subjected to normalization phase to acquire the rigid, uniform, and consistent iris strip.

(e) Subsequently, feature extraction and matching process takes place.

In order to minimize the complexity in the generating the uniform and rigid iris strip, the proposed iris segmentation algorithm employs a new method for iris segmentation by excluding the normalization phase as in the traditional approach.

Remainder of this paper is organized as follows: Section 2 deals with the proposed iris segmentation algorithm. Section 3 shows the experimental results and discussions. Finally, section 4 draws the conclusion.

II. Proposed Iris Segmentation Method

Various literature reviews show that, the conventional iris segmentation algorithm consists of three phases namely, pupil localization, iris localization, and iris segmentation, respectively. In contrast to this, proposed method directly extracts the iris strip by incorporating a novel technique so that the normalization process is extricated. Therefore, in contrast to the conventional process, the proposed method consists of two stages, namely, Pupil Localization Stage (PLS) and Iris Segmentation Stage (ISS).

PLS deals with identification of pupil region with its boundary and its centre coordinate. ISS deals with fixing of specially designed wedge over the annular iris region for segmenting the rigid, uniform, and consistent iris region without the need for normalization phase. Figure 5 shows the various steps involved in the proposed iris segmentation method.

A. *Pupil Localization Stage (PLS)*

To reduce the False Acceptance Rate (FAR) and False Rejection Rate (FRR), the pupil and iris region should be localized and segmented perfectly. The steps for pupil localization are explained in the following sections.

Step 1: Original image from CUHK Iris Image Dataset is shown in figure 6(a). The contrast of this eye image is increased by using inbuilt Matlab command stretchlim [8]. It is shown in figure 6(b).

Step 2: Edges in the contrast enhanced image are detected by using the 'Canny' method [9]. It is shown in figure 6(c).

Step 3: Filling of all the connected regions takes place using the inbuilt Matlab command [10]. It is shown in figure 6(d).

Step 4: Now, Area Opening process is carried out such that, the connected regions whose pixels size is less than 80 pixels are removed with the help of inbuilt Matlab command [11]. Subsequently, labelling the resulting connected regions takes place. Then, apply the morphological processing (erosion and then dilation) with the disk shaped structuring element of radius 5 pixels. It is shown in figure 6(e).

Step 5: Conversion of greyscale to binary image takes place.

Step 6: The area of all the connected regions are calculated. Then connected region with the largest area is the pupil region. The inbuilt Matlab command regionprops [12] is used to measure the area of the connected regions. Consequently, the identifier of the pupil region (P_{id}), centre coordinates (P_x, P_y), and its boundary is also determined. Superimposing of identified centre coordinates (P_x, P_y) on the original image and marking of pupil boundary is shown in the figure 6(f).

B. *Iris Localization Stage (ILS)*

After detecting the pupil boundary, the traditional approach proceeds with iris localization, iris segmentation, normalization, feature extraction and matching process, respectively. In contrast to the traditional approach, this proposed method results in rigid, uniform, and fixed rectangular iris strip without the need for annular iris localization, annular iris region segmentation and normalization phase. With respect to ideal-data, most of the eye image will be free from occlusions due to eyelids and eyelashes. In contrast to the ideal-data, most of the eye images in non-ideal-data will have majority of occlusions due to eyelids and eyelashes. Due to this reality, the majority of occlusions due to upper eyelids, lower eyelids, and eyelashes accumulate on the upper and lower part of the annular iris region only. Therefore, this proposed method identifies the left and right portions of the annular iris region for segmentation. For segmenting the rigid, uniform, and consistent iris strip from annular iris region, two special square shaped wedges are designed in 30 x 30 pixel sizes each and it is fixed on left and right sides of the annular iris region.

To fix these wedges initially, the left most and right most pixels along the central axis of the pupil region in the pupil boundary is identified. It is done by traversing along the pupil centre coordinates (P_x, P_y) in the left and right direction and find the first dark pixel. Next, fixing of wedges takes place such that, the centre point of the square shaped wedges, identified left and right most first dark pixel on the pupil boundary and pupil centre coordinates (P_x, P_y), all put together lie on the same line. Thus, the wedges are fixed and centre aligned with respect to the pupil's centre coordinates (P_x, P_y).

Iris regions inside the specially designed two wedges alone are considered for iris segmentation. After segmenting the iris regions inside these wedges, they are combined horizontally to form the rectangular iris strip of 60 x 30 pixels size. Figure 6(g) shows the fixing of wedges after the identification of pupil's boundary, and the figure 6(h) shows the segmented and horizontally combined iris regions to form the rigid, consistent, and uniform rectangular iris strip of 60 x 30 pixels size.

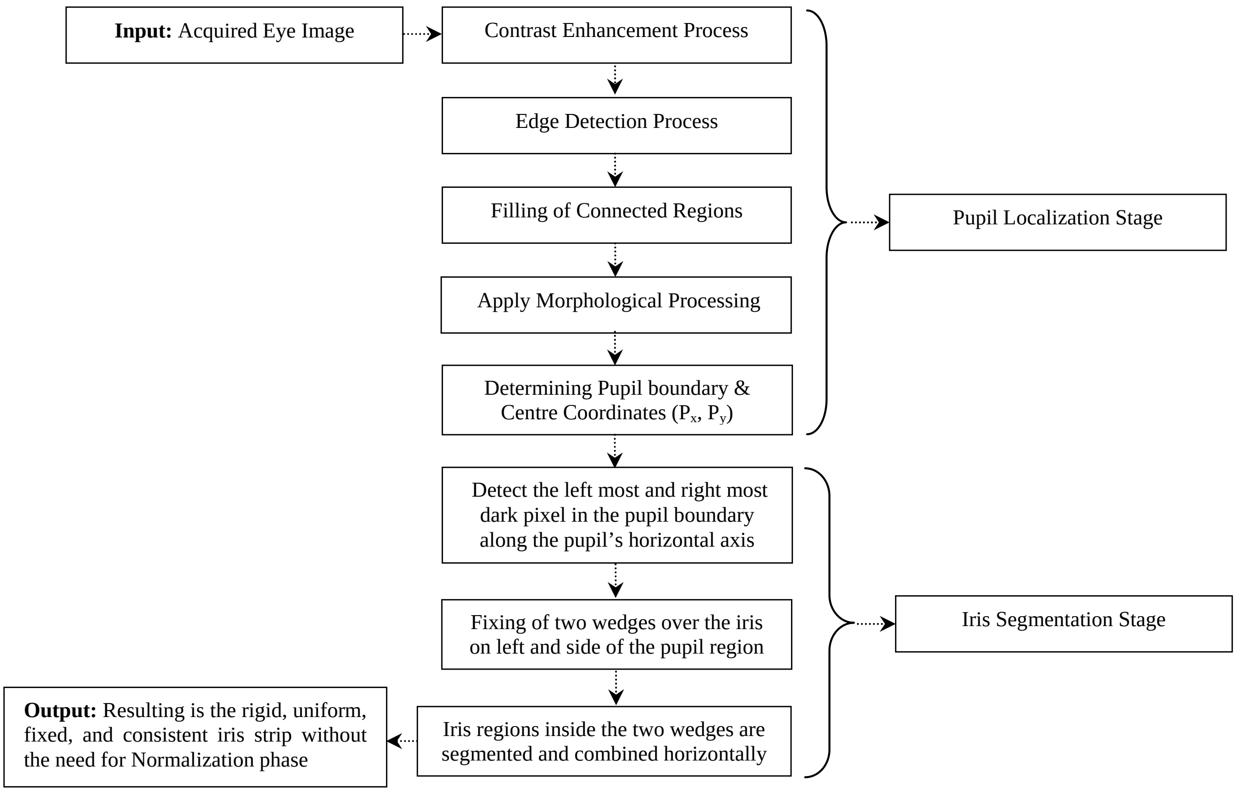

Fig. 5. Steps in the proposed Iris Segmentation method

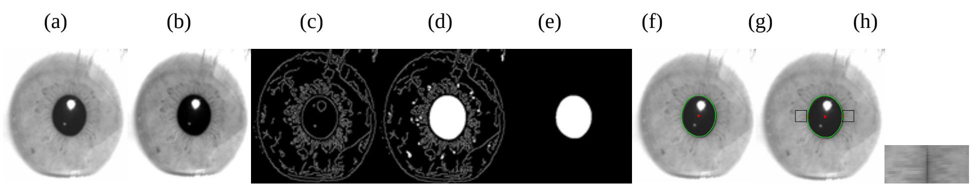

Fig. 6. Randomly selected test images from CUHK Iris Database (a) Original Image, (b) Enhanced image using stretchlim, (c) Edge detected image, (d) Filled connected components, (e) Image after morphological processing, (f) Identified pupil boundary and centre coordinates, (g) Fixing of two wedges on iris region, and (h) Segmented and horizontally combined iris region of 60 x 30 pixels size.

III. EXPERIMENTAL RESULTS

This proposed method is implemented in Matlab version 7.12. Configuration of the machine is Intel I3 3.1 GHz processor with 2GB DDR3 RAM. Table I shows the details of the CUHK Iris Image Dataset details.

TABLE I
CUHK Iris Image Dataset

Sl. No.	Database Name	Total number of images in the database	Number of images used for testing	Image type	Remarks
1	CUHK Iris Image Dataset [13]	252	252	BMP	Images does not have unique dimensions

The accuracy (A) of the proposed iris segmentation algorithm is estimated as the ration of the total number of eye image whose iris region is segmented perfectly (T_s) to the total number of images present in the database (T_d), and it is represented in the equation (1).

$$A = T_s / T_d * 100 \qquad (1)$$

Figure 7 shows the result of this proposed method for some of the randomly selected images from CUHK Iris Image Dataset. The resultant image is the uniform, consistent, and fixed rectangular iris strip without the need for normalization phase. Table II shows the accuracy result of this proposed iris segmentation algorithm and also the average execution time taken to segment the fixed, consistent, and rigid rectangular iris strip from an eye image.

(a) (b) (c) (d) (e) (f) (g) (h)

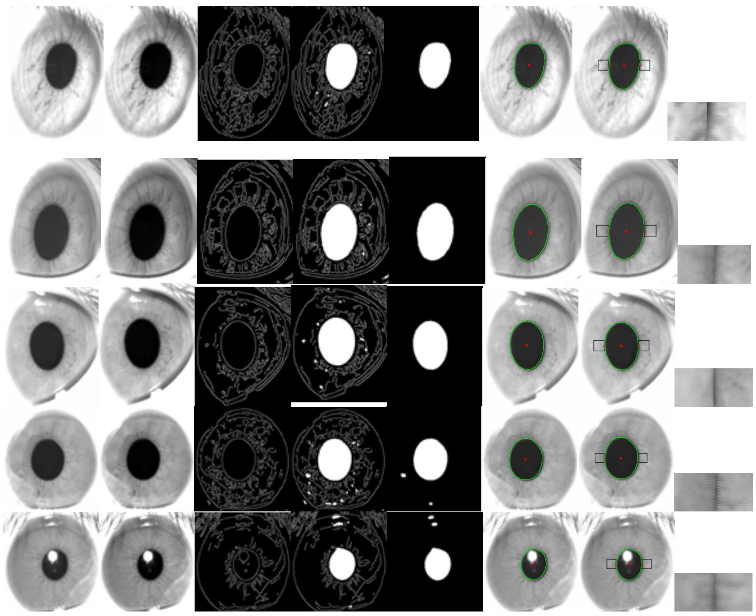

Fig. 7. Randomly selected test images from CUHK Iris Dataset (a) Original Image, (b) Enhanced image using stretchlim, (c) Edge detected image, (d) Filled connected components, (e) Image after morphological processing, (f) Identified pupil boundary and centre coordinates, (g) Fixing of two wedges on iris region, and (h) Segmented and horizontally combined iris region of 60 x 30 pixels size.

TABLE II
Accuracy of the Proposed Iris Segmentation Algorithm

Sl.	Name of the Iris Database	Accuracy (%)	Average Execution Time*
1	CUHK Iris Image Dataset	98 .4126%	0.50968 seconds

*For segmenting the iris strip from the annular iris region

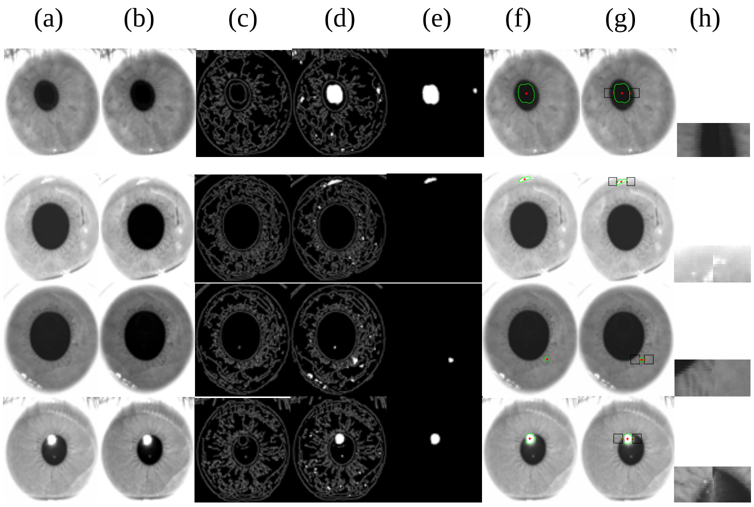

Fig. 8. Some of the incorrect segmentation from CUHK Iris image Dataset (a) Original Image, (b) Enhanced image using stretchlim, (c) Edge detected image, (d) Filled connected components, (e) Image after morphological processing, (f) Misidentified boundary and its centre coordinates, (g) Fixing of two wedges, and (h) Wrongly segmented region of 60 x 30 pixels size.

A. Discussions

This proposed method results in rigid, uniform, and consistent rectangular iris strip even in the absence of normalization phase. Moreover, the need for iris localization is not mandatory and thus its computational complexity is eliminated. Further, the resulting iris strip through this proposed method is almost free from occlusions so that, there is no need for determining the Region of Interest (RoI) from the normalized iris region as in the traditional approach.

In addition to the above, this proposed method detects the pupil region perfectly irrespectively of its shapes, such as, circular shaped pupil, elliptical shaped pupil, and even the improper-circle shaped pupil. Due to the scenario of fixing the wedges takes place in the left and right side of the pupil region, the occlusions due to the intrusion of upper eyelids, lower eyelids, and eyelashes are prohibited to almost 100% in the case of CUHK Iris Image Dataset.

Finally, the proposed method fails rarely in two circumstances. First, in case of very low contrast acquired image, the pupil region itself is not clear so that its boundary detection is not possible. Second, in case of very bright reflections in the acquired image leads to misidentification of pupil region. This is due to the lighting effect during the image acquisition process. Out of 252 images in the CUHK Iris Image Dataset, four images are not segmented properly, and it is shown in the figure 8.

IV. Conclusion

This proposed method exempts the need for normalization phase and results in uniform, consistent, and rigid iris strip. After the pupil localization phase, the iris regions are directly segmented by employing the specially designed two wedges. Further, this proposed algorithm works well for dissimilar pupil shapes too. This method greatly reduces the computational complexity without compromising the iris segmentation accuracy. By using this proposed iris segmentation method, even better and robust iris recognition system for real time applications can be built.

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