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Towards Fast Iris Segmentation for Real-Time Recognition

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***Abstract*—this research describes a simpler and time efficient scheme for iris segmentation which is the core component of any iris based biometric recognition system. Time efficiency and simplicity is of much importance when the recognition system is to be used for real time applications. Segmentation starts from the pupil which is the darkest part, so lowest intensity pixels in the eye image belong to the pupil region.**

Segmentation starts from pupil using the state of the art circular Hough transform technique and then iris-sclera boundary is estimated using a very thin slab from the original image. The occlusions due to eyelids and eyelashes are avoided by selecting only a portion of segmented iris for biometric feature extraction.

Keywords—, *Pupil, Sclera, Biometric, Circular Hough Transform and Canny Edge map.*

I. INTRODUCTION

Every individual in the world possesses some special physiological and behavioral characteristics that are unique to him and some of them are stable throughout his/her life span. Fingerprint, speech, and iris are well-known examples. These physiological characteristics which are distinct over the whole human race can be used as a unique identifier for each individual, hence termed as biometrics.[1] A good biometric identifier is characterized by use of a feature that is; highly unique so that the chance of any two people having the same characteristic will be minimal, stable so that the feature does not change over time, and can be easily captured in order to provide convenience to the user, and prevent misrepresentation of the feature. Human iris is emerging as one of the most effective biometric identifier, as it is unique to extent that even two identical twins have the different irides [2] and right eye iris differs from left eye iris for same individual, stable throughout the adult life [2, 16, 17, 18] and is very difficult to be stolen or cracked in contrast to traditional identifiers like passwords and access cards. Template size is small and image encoding and matching is relatively fast.

The human iris is a circular diaphragm with a rich texture, which lies between the pupil and the sclera. A front-on view of the human eye with the labeled segments is shown in Fig. 1. The function of the iris is to control the amount of light entering through the pupil. The region at the periphery of iris is called sclera, so circular iris region has two boundaries, pupil boundary and Limbic or Iris-Sclera boundary.

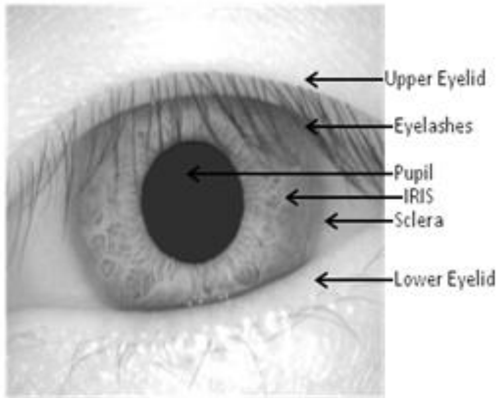

Fig. 1. Segments of Eye Image

There are two major approaches which serve as the basis for the iris segmentation techniques in use today. Integro-differential operator by John Daugman [3] and Circular Hough transform of the edge map of the image [4].Other segmentation approaches [6, 7, 8, 9, 10] have been introduced with each one having some pros and cons. The major concern regarding this research in all these approaches is the number of computations and complexity involved for segmentation.

John Daugman`s Integro-differential operator makes use of the following optimization for iris segmentation.

$$\max_{(r,x_o,y_o)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{C(s;r,x_o,y_o)} \frac{I(x,y)}{2\pi r} ds \right| --- (1)$$

Where; "*" is the convolution operator, $G_\sigma(r)$ is a Gaussian smoothing function given as;

$$G_\sigma(r) = \frac{1}{\sqrt{2\pi r}} e^{\frac{-(r-r_o{}^2)}{2\sigma^2}} ----- (2)$$

(r, x_o, y_o) are the candidates for radius and center of iris respectively. Required parameters are searched iteratively in the three dimensional parametric space to maximize the above given convolution which is costly in terms of computations involved.

The other major approach which serves as the basis for the most of the recent segmentation techniques is Wildes Algorithm [4, 5]. In this approach the edge map of the whole image is first determined and then the circular Hough Transform is used to detect the two circles (pupil and iris).

Circular Hough Transform (CHT) takes each edge point as the center and draws circles of radii from minimum expected radius to maximum expected radius populating an accumulated array, requiring a large number of computations. Most of the segmentation techniques afterwards follow the Wildes algorithm with a common variation of coarse to fine strategy, and different techniques to avoid occlusions and detection in the presence of noises like blurring, improper illumination, non-cooperative user.

II. PROPOSED ALGORITHM

The iris region, shown in Fig.1, can be approximated by two circles, one for the iris-sclera (limbic) boundary and other for the iris-pupil boundary (Pupillary). The eyelids and eyelashes normally cover the upper and lower parts of the iris region. Also, specular reflections can occur within the iris region corrupting the iris pattern. A technique is required to isolate and exclude these effects as well as locating the circular iris region. The success of segmentation depends on the imaging quality of eye images. Images used in this research are taken from CASIA iris database [11, 12], which does not contain specular reflections due to the use of Near Infra-Red (NIR) light for illumination. On the other hand, 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. Algorithm proposed in this article starts from iris-pupil boundary detection using circular Hough Transform and, edge detection for limbic boundary detection. A block diagram of the processing steps is shown in Fig.2 below.

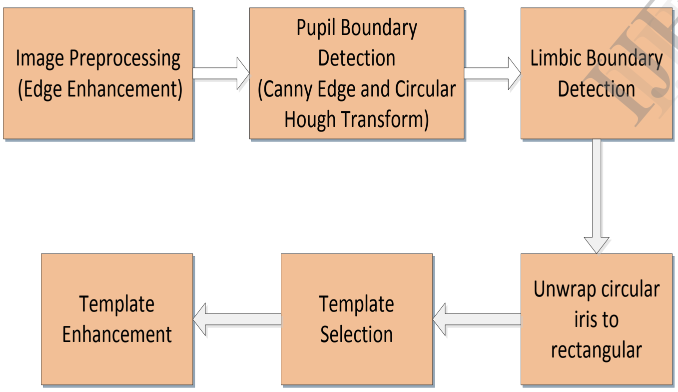

Fig. 2. Iris Segmentation Steps

A. Pupil Detection

The inner boundary of the iris can be detected by finding the pupil, which is approximately circular and the darkest portion of the eye image [12] therefore, it will contain the pixels with lowest intensity values when represented in grayscale. The region at the periphery of pupil which is the area of interest is normally much brighter than the pupil region. This difference at the pupil boundary facilitates the easy detection of this boundary. After edge enhancement using histogram equalization [15]. Canny edge map [13] of the image is taken which is fed to the circular Hough transform .The range of the radius search is set intelligently to 25 to 60 for the selected database. It is important to note here that appropriate selection of this range is crucial for computation efficiency of the Algorithm.

Circular Hough Transform takes each edge point as the candidate center and draw circles of candidate radii. An accumulated (Number of circles passing through that point) score for each center point corresponding to the radius value is maintained. Highest accumulated score identifies the detected center and radius of the circle). Detected pupil radius is incremented by 3 to avoid errors due to imperfect circular boundary. Steps for Pupil localization are shown in Fig. 3 below.

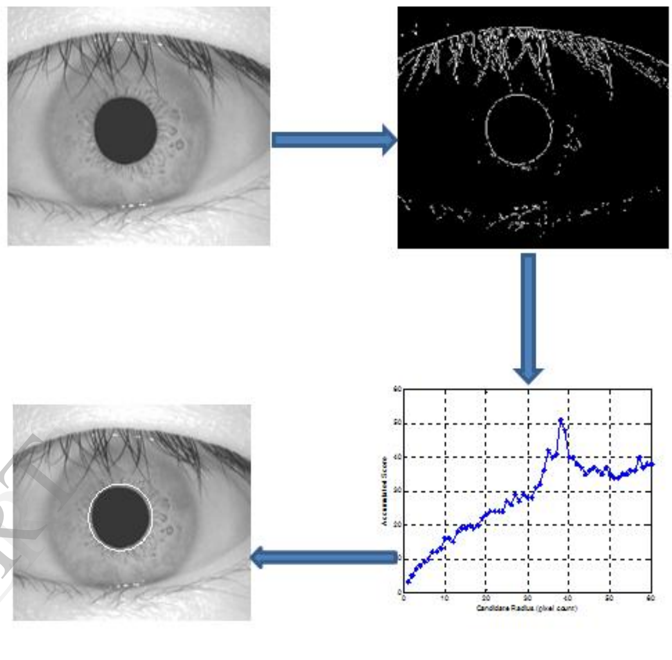

Fig. 3. Pupil Boundary Detection $\begin{bmatrix} a & b \\ c & d \end{bmatrix}$, (a) Original iris image (b) Canny Edge Map (c) Hough Accumulated scores (d) Detected pupil circle

B. Iris-Sclera Boundary Detection

Iris-Sclera boundary is always challenging to detect because the pixel intensity values of the iris and sclera region are approximately the same especially when the image is captured using NIR camera.

The eyelids and eyelashes mostly cover the upper and lower part of the iris and hence it cannot always be completely and correctly segmented. To determine the radius of iris take N rows above the center row (row that contains the previously detected pupil center) and N rows below the center of the pupil so, we will have only 2N+1 rows. Value of N for iris image database after hit and trial is fixed to 11. Here again the boundary is approximated as a circle, Using the definition of radius, Every point which lies on the parameter of the circle will be equidistant from the center. Image is sharpened to enhance the edges in the preprocessing stage , so that edge operator can easily detect the edge points for iris-sclera boundary. Now, the edge points that are equidistant from the center and lie outside the pupil boundary represent the iris-sclera boundary and give us the approximate radius of the iris. Fig.4 below shows the area of interest for limbic boundary detection.

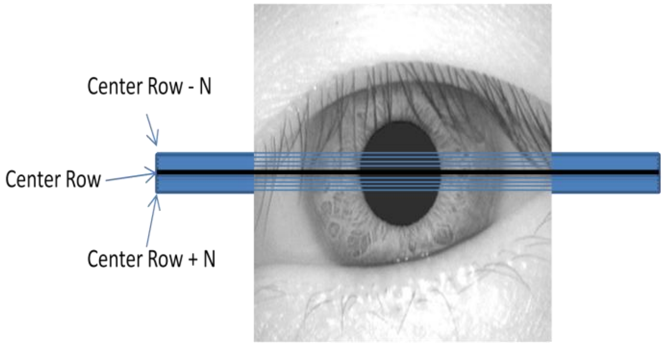

Fig. 4. Rows for Limbic Boundary Detection

The distance of each edge point (outside the pupil boundary) from the center is computed . For a circle these distances must be equal , representing the radius of the circle. Fig.5 below shows the result of Iris boundaries detection.

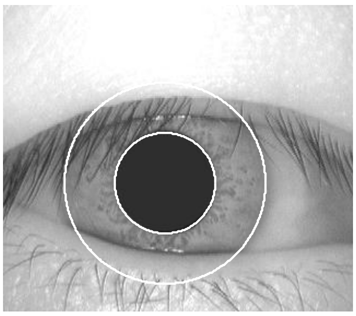

Fig. 5. Inner(iris-pupil) and Outer (iris-sclera) boudary

C. Unwrap and Template Selection

The iris region is extracted from the image using the inner and outer radii. This region is unwrapped to rectangular form using Daugman's Rubber Sheet model [2]. The Rubber Sheet model converts/.maps the coordinates of each Cartesian pixel point from the segmented iris region to polar coordinates (r, θ). The circular iris region is unwrapped in this way to a rectangular block. The center of the pupil is considered as the reference point and a remapping formula is used to convert the points on the Cartesian scale to the polar scale. The segmented iris region can contain occlusions by eyelids and eyelashes. Most of the present iris segmentation algorithms use Hough Transform to detect the lines representing eyelids and eyelashes and are removed from the image after detection.

Fig. 6. Extracted (Up) and Unwrapped (down) Iris region

Fig.6 above shows the extracted iris and result of unwrapping. It is obvious that eyelids and eyelashes are occluding the iris and if used as it is for feature extraction, will produce inaccuracies in the recognition.

For this purpose during unwrap from circular to rectangular, sweep the angle theta from -20 to 10 degrees and from 170 to 200 degrees covering only 60 degrees instead of whole 360 degrees and use these two sections as template for feature extraction. The region is selected based on the fact that in almost 98 percent of iris images the occlusions by eyelids and eyelashes do not cover this region. Selecting this region as template for feature extraction signifies no need for detection or elimination of eyelids and eyelashes.

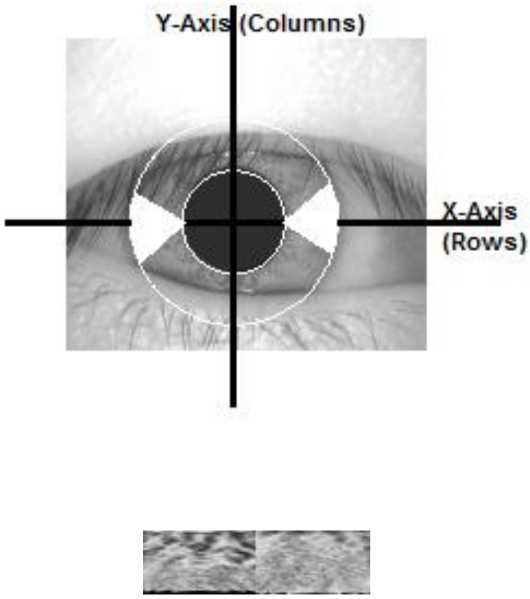

Fig. 7. Region of Interest (up) and extracted template (down after adaptive equalization [15])

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III. RESULTS AND DISCUSSION

Fig. 8 shows the results of iris boundaries localization and segmentation of a small section of iris to be used for feature extraction, it is evident from the results that the algorithm is successfully detecting the papillary and limbic boundaries with these images, but is limited to images where iris-sclera edge can be detected after edge enhancement. The iris-sclera boundary is not very distinct so, preprocessing stage is very important to enhance the edges. If this detection fails the outer boundary cannot be accurately determined using the proposed Algorithm.

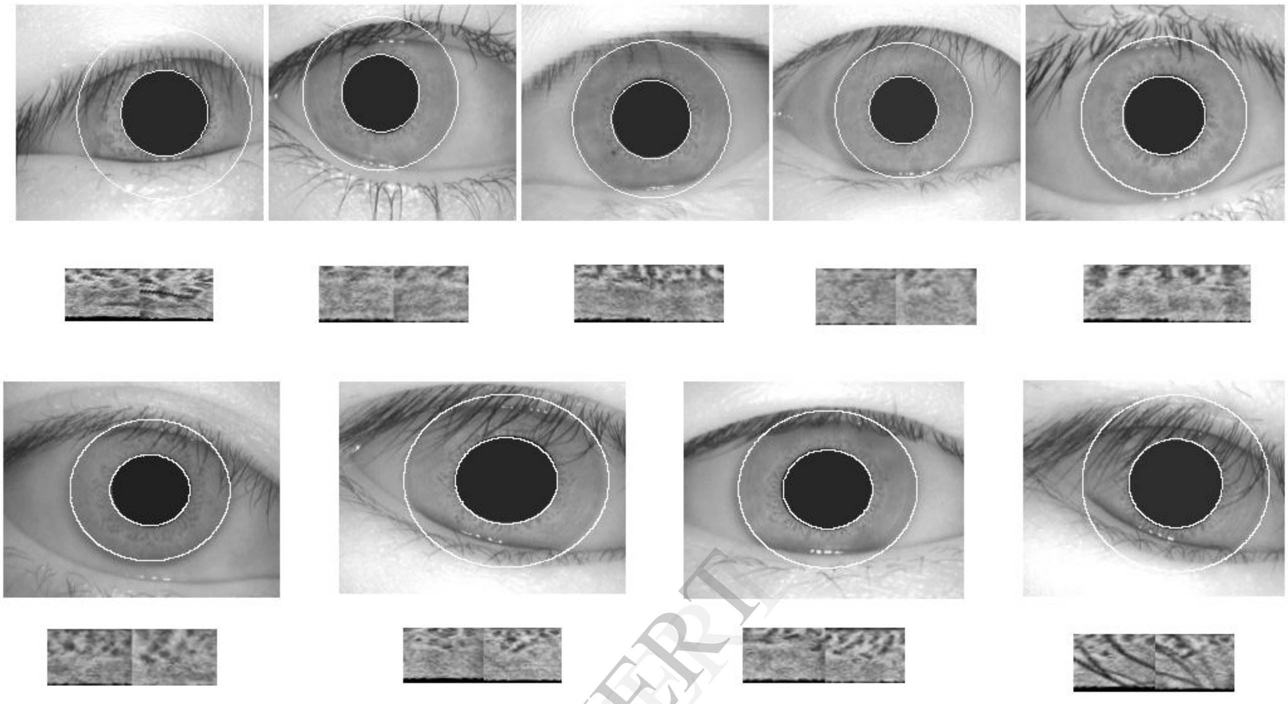

Fig. 8. Results of Segmentation on Images selected from CASIA iris database [12]

Fig. 9 below shows some inaccuracies in the limbic boundary detection due to the fact that the proposed algorithm is fitting a circle but the outer boundary is not purely circular in some cases and cannot be perfectly detected by the proposed algorithm.

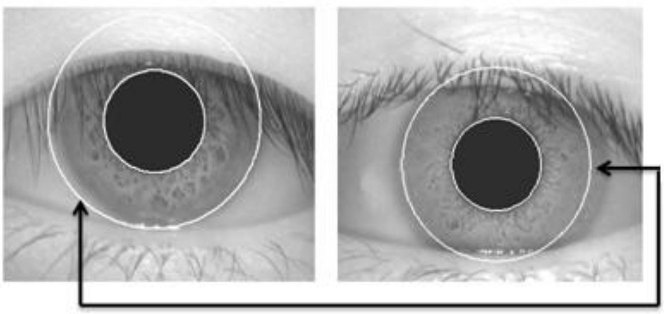

Fig. 9. Inaccuracies in Limbic Boundary

To have a glimpse of the time efficiency of the proposed algorithm, Wildes Algorithm [4] to detect the circular boundaries of iris was also implemented and the platform used for this purpose is Matlab R2012b [14] running on a Lenovo corei3 laptop. A brief comparison of the timing analysis using the CASIA Iris version1 database [11] is shown in Table1 below;

TABLE 1. TIMING ANALYSIS COMPARISON (TIME(S))

Method	Min	Max	Average
Proposed Algorithm	3.031	3.129	3.082
WIldes Algorithm [4]	8.185	9.302	8.743

This study proposed a new and fast approach for iris segmentation. High accuracy is achieved on images from the CASIA Iris version1 database[11].The computation time is very less as compared to the other techniques because of the fact that it involves a parametric search for the candidate radii and centers for the only one circular region i.e. pupil instead of two. From the average times in Table1 above, it can be concluded that the proposed algorithm is almost 3 times more efficient.

This approach is highly dependent on finding an effective edge map of the image using canny edge detector because this serves as the starting point of the segmentation and the search for the limbic boundary is carried out only in a thin slab from the original image. The selection of template for feature extraction is also done in a way that the template size will be much smaller hence requiring less space for backhand database and fast matching and recognition stages.

Time efficient performance of the proposed scheme makes it a good candidate for real time applications.

IV. ACKNOWLEDGMENT

Portions of the research in this paper use the CASIA-IrisV1 collected by the Chinese Academy of Sciences' Institute of Automation (CASIA) available online at http://biometrics.idealtest.org/

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