Analysis of Iris Image Segmentation in a Color Space Model

S. B. Kulkarni, Kirthishree C. Katti, Arun A. Kumbi, R. B. Kulkarni, Vinita K. Tapaskar

Abstract*—*The paper presents the iris localization using circular Hough transform. Circular Hough transform localized the inner and outer boundaries of the iris.The software of the application is based on detecting the circles surrounding the exterior iris pattern from a set of images in different spaces. The iris segmentation system is based on the combination of the canny edge detection method, adaptive histogram Equalization method, circular Hough Transform and Euclidean Distance formula methods. The main part of Iris recognition is the segmentation of iris part of the eye. The performance of the segmentation is analyzed using UBIRIS, IITD, PALACKY, MMU database with adaptive parameters.

Keywords*— *Segmentation, Canny Edge Detection, Adaptive Histogram Equalization, Circular Hough Transform and Euclidean Distance Formula.

I. INTRODUCTION

Applications such as immigration control, aviation security and financial security require reliable identification of people. Identification of people is getting more and more importance in the increasing network society [1]. Biometrics is the branch of science in which human beings are identified with their behavioral or physical characteristics. Physical characteristics include face, finger, iris, retina, hand geometry; palm print etc. whereas behavioral characteristics include signature, gait, voice etc. [2] Currently, major state of the art identification systems are using fingerprint, face and iris. Recognition systems which use iris biometric are believed to be very accurate [3], and hence efforts are being put to improve their accuracy and reliability. Iris is found to be a well-protected and age invariant biometric. The iris, considered as an internal organ yet externally visible, has unique, complex and stable features that do not change over time since 8 months after the birth [4]. Generalized iris recognition consists of image acquisition, iris segmentation and localization (preprocessing), feature extraction and feature comparison (matching). Biometric based personal identification using iris requires accurate iris segmentation from an eye image [5]. Several researchers have implemented various methods for segmentation of the iris. John Daugman [6] has proposed one of the most practical and robust methodologies, constituting the basis of many functioning systems. This method uses integro-differential operator to find both the iris inner and outer boundaries for iris segmentation. Wildes [7] proposed a gradient based binary edge map construction followed by circular Hough transform for iris segmentation [2].

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II. LITERATURE REVIEW

Iris is a disk bounded by the pupil from inside and by the sclera and the eyelids from the outside. In most commercial systems and advanced researches, the iris is modeled by two non-concentric circles [8], [9]. The algorithm scans the eye image to detect these two circles; then extracts the eyelids by some model approximation and remove eyelashes and specular reflections using intensity threshold. Daugman was the first to present a complete iris recognition system [8]. To segment the iris he defined the so-called Daugman Integro-differential operator shown in equation 1:

$$max_{r,x_0,y_0}\left|G_\sigma(r) * \frac{\partial}{\partial r}\oint_{r,x_0,y_0}\frac{I(x,y)}{2\pi r}ds\right| \dots \textbf{(1)}$$

Where *I(x, y)* represents the image intensity at location *(x,y)*,*Gσ(r)* is a radial σ scale Gaussian smoothing filter, *s* is the contour of the circle *(x ,y ,r)* and * denotes for convolution. The operator searches for the circle where there is maximum change in pixel values, by varying the radius *r* and center *(x, y)* position of the circular contour *s*.Two maximum values are obtained corresponding to the two circles defining the iris. Daugman doesn't use any thresholds on the gradient image, what makes all image information usable. But from the other side, the operator becomes more sensitive to noisy values which may lead to wrong iris detection. As for eyelids, Daugman uses parabolic operator. The operator searches and detect sparabolic curve that models the eyelids. Finally eyelashes and specular reflections are isolated by intensity threshold. Wildes introduced the circular Hough transform to detect the iris [10]. The algorithm calculates the image gradient creating an edge map to be transformed into Hough space. Votes are then calculated to define two circles given array of possible radius. Outer iris boundary is detected before inner boundary. The results are sensible to the defined gradient image and to the predefined range of possible circle radius. Wildes also used parabolic Hough transform to detect the eyelids and intensity threshold to isolate the eyelashes. Masek implemented Wildes segmentation method [11]. He used canny edge detection to detect iris edge points. Vertical edges are used to detect the outer iris boundary at first after it horizontal edges detect inner iris boundary. To separate eyelids from the iris, a horizontal line obtained after a linear Hough transform application on the image isolates each eyelid from the iris. Eyelashes and specular reflections are segmented by intensity threshold. Iris segmentation is based on Hough transform [12]-[17]. Mahlouji et al. utilized circular Hough transform to segment the iris [12]. Using Circular Hough transform applied to an edge map created by a canny filter, the inner iris

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boundary is first detected then the outer boundary is detected after it. After it, linear Hough transform is used to exclude eyelids. Results reported in a recognition accuracy of 97.50%. Iris segmentation is based on Masek's implementation of Wildes‟ segmentation [15]. Compared to Wildes method, the iris detection order is reversed; the pupil is first detected then the outer iris boundary. A second modification is in eliminating very high intensity edge points as they are possibly originated from specular reflections. Upper and lower eyelids are also detected using Wildes‟ method, but they are divided into two equal parts. And instead of modeling each eyelid by a horizontal line, the eyelid is now modeled by two connected lines. Some researchers [18]-[22] used ellipse fitting to segment the iris especially in the case of off angle images. Anon-cooperative iris segmentation algorithm is introduced [18].The method is based on numerically stable direct least squares fitting of ellipses model and modified Chan-Vese model. The iris boundaries are fitted with an ellipse in a first stage, next they are accurately segmented using a modified Chan-Vese model. Better segmentation efficiency with lower processing time is reported using CASIA V3 images. Ryan et al. [22] used Starburst algorithm [23], to detect limbic and pupil boundary. Eyelids are detected using snake algorithm. Better results in iris segmentation are reported but the number of parameters to adjust and search increased (major and minor axis length, center coordinates and rotation angle). Iris is localized by use of Morphologic operators like intensity threshold, opening and closing [24]-[25].More specifically intensity information is used to find a square region that completely surrounds the pupil. The square region is then binarized to extract an edge map from it. An iterative morphological operator's algorithm is then applied to detect the iris inner boundary. Outer boundary is divided into right and left sides in which they are detected by arched Hough transform and finally merged together. Obtained results claim to show an improvement in the precision of the iris localization. But It must be taken into account that the database used to test the methodology (CASIA - Version 1) is considered as an easy non challenging database. Other methods based on circular iris boundaries approximation also have been implemented such as least square method proposed by Zhu et al. [26] and gray-scale distribution feature method proposed by Yuan et al. [27],[28]. Other methods as well are based on ellipse fitting such as Zuo and Natalia [22]. Active contours are also used to detect irises [9], [30]-[36].Many approaches are used to apply parametric models to segment the iris boundaries, [30]-[32]. A semantic iris contour map combining spatial information on iris location (obtained by a circular Hough transform) and gradient map as edge indicator is used for level set active contour segmentation [33]. The semantic iris contour map is claimed to reduce the local extremes in iris region misleading the evolution of the iris contour. Tests were performed on ICE (2005) database and CASIA V3 database, reporting efficient and effective results. Gradient vector flow is used to implement the active contour segmentation [9]. Pupil is first segmented with an initial circle containing the pupil. Then an ellipse containing the iris is used as initial contour to segment the outer iris boundary. Chen et al. used probabilistic active contour [34], Daugman used Fourier coefficients based active contour [30] and Shah and Ross [35] made use of geodesic active contours for iris segmentation. Vatsa et al. [36] used a modified energy function to detect the exact iris boundaries by evolving the initial contour in narrow bands

III. RELATED WORK

The Segmentation works in following steps are canny edge detection method application, adaptive histogram Equalization method, circular Hough Transform, Euclidean Distance formula. But For segmenting the R, G and B planes of the eye image will consider only the respective plane by making other planes to zero.

A. Canny Edge Detection

Canny edge detector is the optimal and most widely used algorithm for edge detection. Compared to other edge detection methods like Sobel,etc. Canny edge detector provides robust edge detection, localization and linking. It is a multi-stage algorithm and the stages involved are illustrated in Figure 1. Thus, instead of providing the whole algorithm as a single API, kernels are provided for each stage. This way, the user can have more flexibility and better buffer management. Optimized kernels and wrappers required for the implementation of canny algorithm are provided to reduce the efforts of the integrator [41].

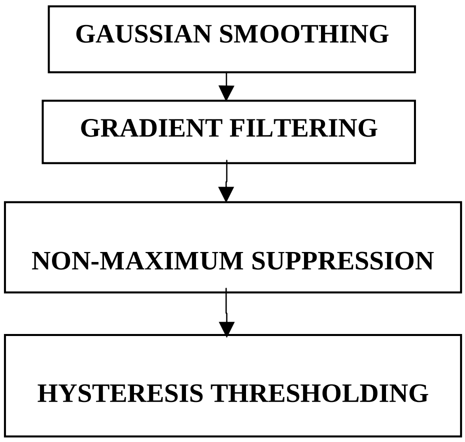

Figure 1: Flow Diagram of Canny Edge Detector

The purpose of edge detection in general is to significantly reduce the amount of data in an image, while preserving the structural properties to be used for further image processing. The main aim of this method is to optimize regarding to the following criteria [37]:

1. **Detection:** The probability of detecting real edge points should be maximized while the probability of falsely detecting non-edge points should be minimized. This corresponds to maximizing the signal-to-noise ratio.

2. **Localization:** The detected edges should be as close as possible to the real edges.

3. **Number of responses:** One real edge should not result in more than one detected edge (one can argue that this is implicitly included in the first requirement).

B. Adaptive Histogram Equalization

Contrast enhancement techniques are used widely in image processing. One of the most popular automatic procedures is histogram equalization (HE). Out of the five senses sight,

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hearing, touch, smell and taste which humans use to perceive their environment, sight is the most powerful. Receiving and analyzing images forms a large part of the routine cerebral activity of human beings throughout their waking lives. In fact, more than 99% of the activity of the human brain is involved in processing images from the visual cortex. This is less effective when the contrast characteristics vary across the image. Adaptive Histogram Equalization (AHE) overcomes this drawback by generating the mapping for each pixel from the histogram in a surrounding window. In future will take different type of images in different time period and use Adaptive Histogram Equalization (AHE) and compare histogram equalization of images [40]. It operates on small data regions (tiles) rather than the entire image. Each tile's contrast is enhanced so that the histogram of each output region approximately matches the specified histogram (uniform distribution by default). The contrast enhancement can be limited in order to avoid amplifying the noise which might be present in the image.

C. Circular Hough Transform

Unlike the linear HT, the CHT relies on equations for circles. The equation of the a circle is the equation (2), which is given below

$$r^2 = (x - a)^2 + (y - b)^2 \quad \ldots (2)$$

Here a and b represent the coordinates for the center, and r is the radius of the circle.
The parametric representation of this circle is the equation (3), which is given below.

$$x = a + r*\cos(\theta)$$

$$y = b + r*\sin(\theta) \quad \ldots (3)$$

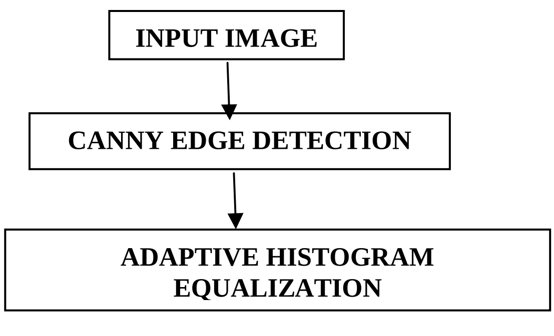
In contrast to a linear HT, a CHT relies on 3 parameters, which requires a larger computation time and memory for storage, increasing the complexity of extracting information from our image. The values in the accumulator (array) are increased every time a circle is drawn with the desired radii over every edge point. The accumulator, which kept counts of how many circles pass through coordinates of each edge point, proceeds to a vote to find the highest count. The coordinates of the center of the circles in the images are the coordinates with the highest count.

IV. PROPOSED IRIS SEGMENTATION

The Segmentation works in following steps:

1. Canny edge detection method application.
2. Adaptive histogram Equalization method.
3. Circular Hough Transform.
4. Euclidean Distance formula.

The flow of these methods is shown in figure 2 Flow Graph of Segmentation below:



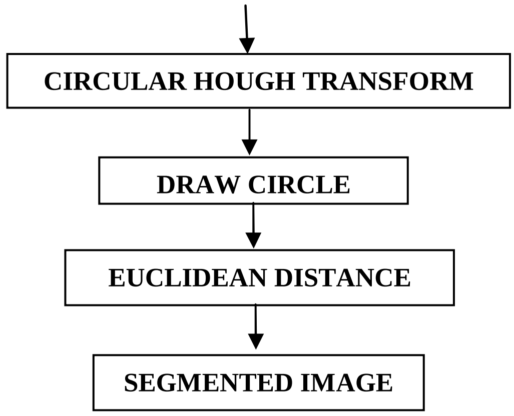


Figure 2: Flow Graph of Segmentation

Figure 2 above shows the flow of the segmentation process of the iris image. Initially the image is selected form the database which becomes the input image of the segmentation process, then Canny Edge Detection method is applied for the detection of the edges in the iris image. The Adaptive Histogram Equalization for contrast enhancement i.e. to make the iris and pupil detection of the eye image more accurate, then Circular Hough Transform is applied to detect pupil and iris centers and radius. From the centers and radius of the eye image Euclidean Distance is used for the segmentation of the iris part from the eye image.

DATABASE	DIMENSIONS	ADAPTIVE PARAMETERS
UBIRIS	800*600	lr=40, ur=50
IITD	320*240	lr=20, ur=30
MMU1	320*240	lr=20, ur=30
MMU2	320*238	lr=10, ur=20
PALACKY	768*576	lr=70, ur=80

Table 1: Adaptive Parameters of Different Databases

The below Table 1 shows the parameters for the different databases. The first column specifies name of the database, the second specifies the dimension of the images in the databases and the last column specifies the adaptive parameters i.e. lower radius (lr) and upper radius (Ur).

A. Canny Edge Detection

The canny Edge detection works as per the below algorithm. The working of the algorithm is shown in below figures (Figure 1, Figure 2). The Figure 1 is the input image which is taken from the UBIRIS Database. The output of the canny edge algorithm is shown in the Figure 2 [38].

Algorithm 1: Canny Edge Detection

Input: An eye image from the database I(x,y).

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Output: An image containing highlighted edges.

1: Compute $f\,x$ and $f\,y$

$$f\,x = \frac{\partial}{\partial x}(f * G) = \left(f * \frac{\partial}{\partial x}G\right) = f * Gx$$

$$f\,y = \frac{\partial}{\partial y}(f * G) = \left(f * \frac{\partial}{\partial y}G\right) = f * Gy$$

$G(x, y)$ is the Gaussian function

$Gx(x, y)$ is the derivate of $G(x, y)$ with respect to x:

$Gx(x, y) = \frac{-x}{\sigma^2}G(x, y)$

$Gy(x, y)$ is the derivate of $G(x, y)$ with respect to y:

$Gy(x, y) = \frac{-y}{\sigma^2}G(x, y)$

2: Compute the gradient magnitude

$Magn\ (i, j) = \sqrt{fx^2 + fy^2}$

3: Apply non-maxima suppression.

For each pixel (x,y) do:

Ifmagn (i, j) <magn (i_1, j_1) or magn (i, j) <magn (i_2, $_{j2}$)

thenI_N(i, j) = 0

elseI_N(i, j) = magn (i, j)

4: Apply hysteresis thresholding/edge linking.

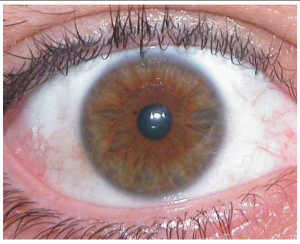
a. Produce two thresholded images I_1 (i, j) and I_2 (i, j).

b. Link the edges in I_2 (i, j) into contours.

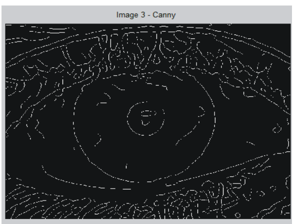
c. Look in I_1 (i, j) when a gap is found.

d. By examining the 8 neighbors in I_1 (i, j), gather edge points from I_1 (i, j)until the gap has been bridged to an edge in I_2 (i, j).

The algorithm runs in steps as shown above. In first step Smoothing and Gradients for the image is found, the image will be blurred to remove noise then the edges should be marked where the gradients of the image has large magnitudes. In the next step Non-maximum suppression takes place where only local maxima should be marked as edges. In third step Double Thresholding is done to determine Potential edges through thresholding. In the final step Edge tracking by hysteresis is done so that final edges are determined by suppressing all edges that are not connected to a very certain (strong) edge. The below figure 3 shows the resultant image of the canny edge detection.



Input image



Output image

Figure 3: Canny Edge Image

B. Adaptive Histogram Equalization

The adaptive histogram equalization works as per the algorithm below. The main function of this function is to highlight the pupil and the iris of the eye image. The step of the algorithm explains the working of the adaptive histogram equalization [39].

Algorithm 2: Adaptive Histogram Equalization

Input: An image containing highlighted edges (x, y).

Output: Contrast enhancement (pupil and iris) image.

1: for each (x, y) in image do

2: rank= 0

3: for each (i, j) in contextual region of (x, y) do

4: if image[x, y] > image [i,j] then

5: rank = rank + 1

6: output[x, y] = rank * max_intensity I

The Algorithm steps performed by this function are that it [40] calculates a grid size based on the maximum dimension of the image. If a window size is not specified chose the grid size as the default window size. Identify grid points on the image, starting from top-left corner. Each grid point is separated by grid size pixels. Calculate the distribution function (df) of the region for each grid point, having area equal to window size and centered at the grid point. Find the four closest neighboring grid points that surround that pixel. Using the intensity value of the pixel as an index, find its mapping at the four grid points based on their dfs. Interpolate among these values to get the mapping at the current pixel location. Map this intensity to the range [min: max) and put it in the output image.

C. Circular Hough Transform

The main function of this algorithm is that to find the radius of the pupil and iris of the given image. The working of the algorithm is shown in Figures. The Algorithm works in the following steps.

Algorithm 3: Circular Hough Transform

Input: *Contrast enhancement (pupil and iris) image(x, y).*
Output: Radius and center of the pupil and iris.

1: for x from 0 to width of Image store in a 2D array: x * cosine(theta from 0 to pi in steps of Angular Resolution).

2: for y from 0 to height of Image store in a 2D array: y * sine(theta from 0 to pi in steps of Angular Resolution).

3: for x from 0 to width of Image for y from 0 to height of Image if Image[x,y] == True store in a 2D array called accumulator:
rho[j] = x*cosine(theta[j]) + y*sine(theta[j]) for all j

4: for each value of theta histogram the rho values in accumulator where the bin size is equivalent to 1 pixel starting at 0 until all rhos are bins and store in a 2D array called hough Space then the histogram where each histogram is indexed by theta and the contents of each bin are the amount of "votes" for each rho value.

5: Plot hough Space where the x axis is Theta from 0 to pi in degrees and y axis in rho –sqrt (width^2+height^2) in pixels.

Adjust the lower and/or upper thresholds to balance between

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the performance and detection quality. Increment the corresponding elements in the Hough array. The coordinates of centers and radius (Cy Cx R) of the corresponding circles. Collect candidate circles. Consider the circles whose centers are near to center of the image. The circle is drawn with the resultant radius and center. The below figure 4 show the resultant image.

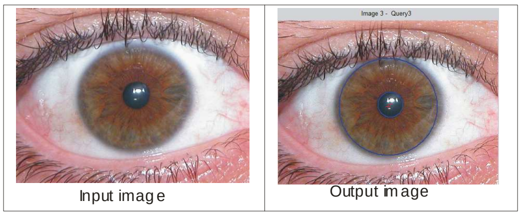


Figure 4: Circular Hough Transform

D. Euclidean Distance Formula

The formula to find distance between points in 2d image is

$$\sqrt{(x1-x2)^2+(y1-y2)^2} \ldots \textbf{(4)}$$

The above equation (4) is used for the segmentation of the image by using the circle and radius of circular Hough transform. The Euclidean distance formula is applied to the image to find whether a pixel in the image falls inside of the iris or outside of the pupil circle, if it is then the value of the pixel is retained otherwise the value is kept equal to color white. The resulting image is shown in below Figure 5.

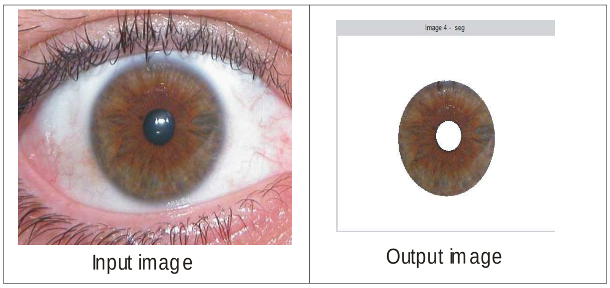


Figure 5: Segmented Image

V. IRIS SEGMENTATION OF DIFFERENT DATA DATABASES

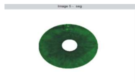
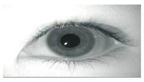
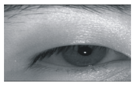
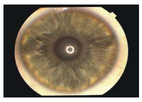
DATABASE	INPUT IMAGE	SEGMENTED IMAGE
UBIRIS		
UBIRIS		
UBIRIS		
UBIRIS		
IITD		
MMU1		
MMU2		
PALACKY		

Table 2: Segmentation in RGB Plane and Other Database Images

If segmentation need to be performed on any one of a single component i.e., R, G or B component of the image, then only respective single component value is retained while the values of the other components are made zero then the segmentation process is applied the resulting figure are shown below and also when the proposed segmentation is applied on other database the results are shown in Table 2.

VI. EXPERIMENTAL RESULTS

In this paper, the segmentation process is applied on all the databases the below table shows the results of the partial or correct iris and pupil detection. From the table 3 it is clear that the segmentation process works well with the UBIRIS database. It works fine with the other databases i.e. MMU, IITD and PALACKY. The segmentation process is formulated for the color eye images. But for gray scale image the segmentation process works fine. The main reason is the use of adaptive histogram equalization function in the segmentation process. This function is used on the color images for the contrast enhancement process of the color image. If this function is applied on the gray scale eye images the results will not be distinctive or ineffective. Hence the proposed segmentation process works well with the color eye images.

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DATABASE NAME	IMAGE SIZE	TOTAL IMAGES	SEGMENTED	
			Complete	Partial
UBIRIS SESSION 1	600*800	1215	624	591
UBIRIS SESSION 2	600*800	663	317	346
IITD	240*320	2318	511	1807
PALACKY	576*768	529	106	423
MMU1	240*320	448	271	177
MMU2	238*320	996	266	730

Table 3: Segmented Images

VII. CONCLUSION

The Adaptive Histogram Equalization is proposed for iris segmentation methodology for the purpose of iris recognition. The proposed method segments accurately the inner iris boundary in its real shape. The effect of the segmentation on iris recognition results is measured using two performance parameters: perfect segmentation and time taken. Compared to other segmentation methods this method segments the eye image faster on UBIRIS (50.2), MMU (37.1), IITD (22.04) and PALACKY (20.03) database. The proposed segmentation process is dependent on the resolution of the image i.e., if the image is smaller the segmentation works quicker compared to bigger eye images. For the UBIRIS Database image the time taken is more compared to the images of the other Databases. Results obtained encourage the use of the proposed segmentation methodology for an improved performance iris recognition system.

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