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A NEW OBJECTIVE CRITERION FOR IRIS LOCALIZATION

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Iris localization is the most important step in iris recognition systems. For commonly used databases, exact data is not given which describe the true results of localization. To cope with this problem a new objective criterion for iris localization is proposed in this paper based on our visual system. A specific number of points are selected on pupil boundary, iris boundary, upper eyelid and lower eyelid using the original image and then distance from these points to the result of complete iris localization has been calculated. If the determined distance is below a certain threshold then iris localization is considered correct. Experimental results show that proposed criterion is very effective.

Keywords: Iris localization, Image segmentation, Biometrics, Computer vision

1. Introduction

The term "Biometrics" refers to automatic human identified based on physiological or behavioral characteristics. Physiological characteristics are those which a human physical own such as face, finger, iris, retina, hand and palm etc. whereas behavioral characteristics depends on the action of a human like signature, gait, voice etc. Among these characteristics, iris recognition is the area of most interest for many researchers during the last two decades [1-8]. Iris patterns and its structures is developed by the end of first postnatal year. Iris patterns of identical twins are different. Even left and right iris patterns of the same human are also different. Normally iris is modeled by two circles and two parabolas. Circles are for iris inner and outer boundaries and parabolas are for upper and lower eyelids. Daugman, pioneer of iris recognition system uses an integrodifferential operator to isolate the iris. Wildes system uses border detection based on the gradient and Hough transform to obtain the iris in the image. For automatic iris segmentation if the pupil is considered as a perfect circle then sometimes it is not possible to correctly localize the pupil because pupil is not perfect circle in most of the eye images even when the camera is orthogonal to the iris. To localize the iris correctly pupil is sometimes ellipse or irregular shaped. Most widely used database in iris recognition is of Chinese Academy of Sciences, Institute of Automation (CASIA version 1.0) and many researchers have reported good iris localization results with reference to subjective criteria. Ground truth of iris localization is not provided by CASIA. Therefore, a new objective criteria is proposed in this paper based on the user input to the localization system and the output tells the difference in obtained results and the input by number of pixels.

2. Background

Daugman [9] presented the first approach to computational iris recognition, including iris localization. An integro-differential operator is proposed for locating the inner and outer boundaries of an iris. The operator assumes that pupil and limbus are circular contours and performs as a circular edge detector. Detecting the upper and lower eyelids is also performed using the Integro-differential operator by adjusting the contour search from circular to a designed accurate [4]. Integro-differential operator is defined as

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

where I(x, y) is an image containing an eye. The integro-differential operator searches over the image domain (x, y) for the maximum in the blurred

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partial derivative with respect to increasing radius r of the normalized contour integral of I(x, y) along a circular arc ds of radius r and center coordinates (x_0, y_0). The symbol * denotes convolution and $G_\sigma(r)$ is a smoothing function such as a Gaussian of scale σ and is defined as:

$$G_\sigma(r) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(r-r_0)^2}{2\sigma^2}}$$

The integro-differential operator behaves as a circular edge detector. It searches for the gradient maxima over the 3D parameter space, so there are no threshold parameters required as in the Canny edge detector [10]. Daugman simply excludes the upper and lower most portions of the image, where eyelid occlusion is expected to occur.

Wildes [5] had proposed an iris recognition system in which iris localization is completed by detecting edges in iris images followed by use of a circular Hough transform [11] to localize iris boundaries. In a circular Hough transform, images are analyzed to estimate the three parameters of one circle (x_0, y_0, r) using following equations:

$$H(x_0, y_0, r) = \sum_i h(x_i, y_i, x_0, y_0, r)$$

where (x_i, y_i) is an edge pixel and i is the index of the edge pixel

$$h(x_i, y_i, x_0, y_0, r) = \begin{cases} 1, & \text{if } g(x_i, y_i, x_0, y_0, r) = 0 \\ 0, & \text{otherwise} \end{cases}$$

where

$$g(x_i, y_i, x_0, y_0, r) = (x_i - x_0)^2 + (y_i - y_0)^2 - r^2$$

The location (x_0, y_0, r) with the maximum value of $H(x_0, y_0, r)$ is chosen as the parameter vector for the strongest circular boundary. Wildes' system models the eyelids as parabolic arcs. The upper and lower eyelids are detected by using a Hough transform based approach similar to that described above. The only difference is that it votes for parabolic arcs instead of circles. One weak point of the edge detection and Hough transform approach is the use of thresholds in edge detection. Different settings of threshold values may result in different edges that in turn affect the Hough transform results significantly [12].

Boles et el. [3] proposed an iris recognition method. Iris localization is started by locating the pupil of the eye, which was done by using some edge detection technique. As it was a circular shape, the edges defining it are connected to form a closed contour. The centroid of the detected pupil is chosen as the reference point for extracting the features of the iris. Iris outer boundary is also detected by using the edge-image.

Ma et al. [13] estimated the pupil position using pixel intensity value projections and thresholding. Centroid of the specific region is calculated to obtain the center of pupil. After that a circular Hough transform is applied to detect the iris outer boundary.

Some other methods have been proposed for iris localization but most of them are minor variants of integro-differential operator or combination of edge detection and Hough transform. For example, Cui et al. [6] computed a wavelet transform and then used the Hough transform to locate the iris' inner boundary while using integro-differential operator for the outer boundary. Tain et al. [14] used Hough transform after preprocessing of edge image. Masek et al. [15] implemented an edge detection method slightly different from the Canny operator and then used a circular Hough transform for iris boundary extraction. Rad et al. [16] used gradient vector pairs at various directions to coarsely estimate positions of the circle and then used integro-differential operator to refine the iris boundaries. Kim et al. [2] used mixtures of three Gaussian distributions to coarsely segment eye images into dark, intermediate & bright regions and then used a Hough transform for iris localization. All previous research work on iris localization used only image gradient information and the rate of iris extraction is not high in practice.

Iris localization is generally done by combining edge detectors and curve fitting since iris is the annular part between pupil and sclera. So the boundaries of the iris are modeled by two non-concentric circles and the eyelids are modeled by two parabolic curves.

In this paper, a new objective criteria for iris localization is proposed, based on the user input to the localization system and the results imply the difference in obtained localization curve and the input points by number of pixels.

3. Iris Localization

For detecting the pupil, a point in pupil is determined. Decimation algorithm is used to reduce the image with a factor of 21. Location of minimum intensity value is a point inside the pupil. A specific sized window is cropped from the original image, while this point is used as center of the window. Highest peak in histogram of this window is taken as threshold to make the binary image, which is used to find the centroid to make the pupil of same density for using the following set of equations

$$C_x = \frac{M_x}{A},\ C_y = \frac{M_y}{A}$$

where $M_y = \iint_w xdA$, $M_x = \iint_w ydA$ and $A = \iint_w dxdy$

where "w" is window size. This process is iterated till single pixel accuracy is achieved for pupil center. Now to calculate the radius of the pupil, binary is used in which pupil is white and remaining part is black. From center, pixels are counted till a black pixel is found in left, right and downwards directions and average of these is taken as radius of pupil. To find the exact boundary of the pupil, points on the pupil are forced to change their position towards the exact boundary points. This change is carried out by inspecting maximum gradient in radial direction along a line of length 25 pixels. Mid point of the line is the point on the circle. After repositioning, new points are joined linearly to get the exact boundary of the pupil.

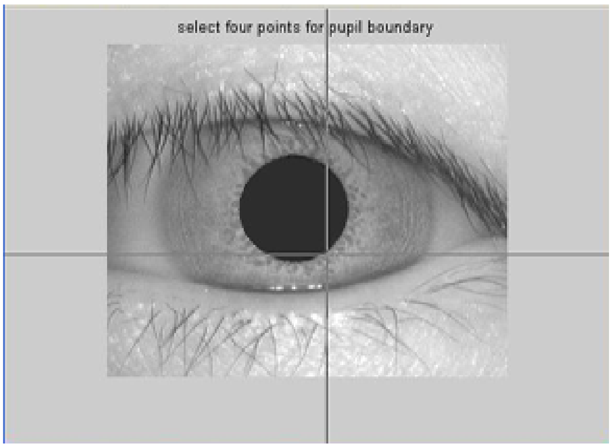
For iris outer boundary, image is blurred by applying Gaussian filter to reduce the effect of sharp changes in the iris and single eyelashes. An estimated band is used in which iris outer boundary lies based on pupil radius and distance of first maximum on the horizontal line passing through the center of the pupil from the x-coordinate of pupil center. Only two sectors of this band are used to find the points on iris boundary. One sector is from right side at angle range -pi/3 to 7pi/12 and the second sector is from left side at angle pi to 6pi/5. These sectors are applied with Gaussian filter in radial direction. A few one dimensional signals are picked in radially outwards direction from the center of pupil within the band and locations of the points with maximum rate of change are obtained. Outliers among these points are deleted using mahalanobis distance in a specific range and statistically least square fit circle is drawn which is the required boundary of the iris. Further details can be seen in our paper [1].

4. Proposed Criterion

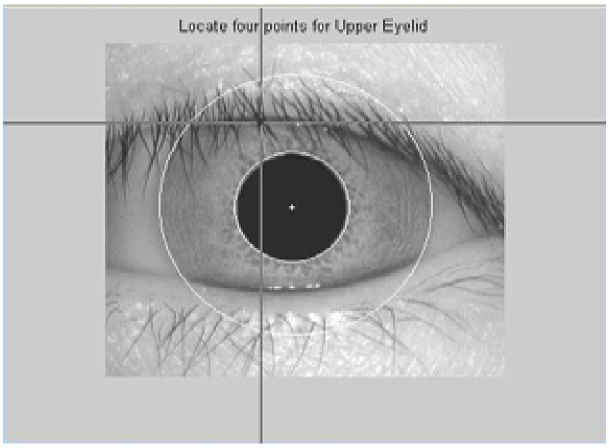
In general, reported results of iris localization are determined by observing the image after drawing localization curves on it, which is subjective criteria. A new objective criterion is proposed in this paper, based on sixteen interactive points on the iris image. After implementing the iris localization method, validity of the algorithm can be checked using this method. Interactively four different points are selected on pupil boundary. Then pupil boundary is obtained using iris localization algorithm. The shortest distance between the interactively selected points and obtained boundary is accumulated. This process is repeated with four different points on each of iris outer boundary, upper eyelid and lower eyelid. Threshold of five is set to classify the correctly localized image. If the accumulated distance of pupil is less than five then it is considered correct. Figure 1 shows the selection of interactive point for pupil boundary, iris boundary, upper eyelid and lower eyelid. When four points for pupil boundary were selected pupil circular boundary was drawn on the image as shown in Figure 1(b). Similarly, as four points are selected on iris boundary, its boundary is drawn and system is ready obtaining next points for upper eyelids (see Figure 1(c)). It is vital to note that these points are used only to verify the localization results. They play no role for localization.

5. Results and Discussion

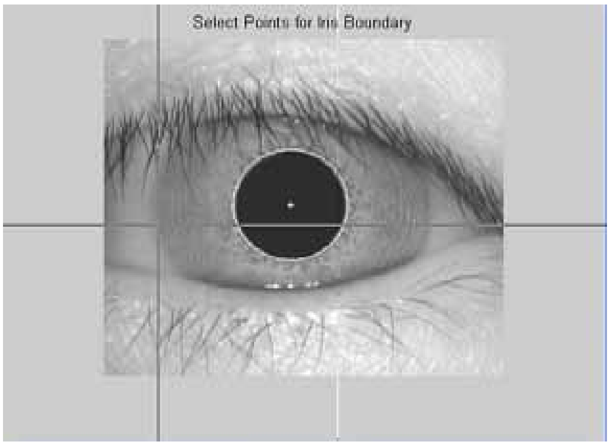
Matlab 7.5 is used as development tool and CASIA Iris Database [17] (the most commonly used iris dataset in literature) is experimented for validation of the proposed objective criterion. It contains 756 iris images of 108 different people and seven images of each person is captured in two different sessions of one month interval. Three images were acquired in first session and four in second session. Dimensions of each image is 280×320 pixels.



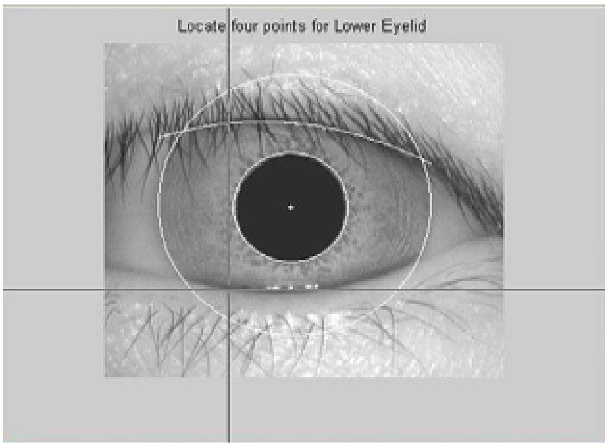
(a) For pupil boundary



(c) For upper eyelid



(b) For iris boundary



(d) For lower eyelid

Figure 1. Interactively selection of points.

The results of iris localization for three different observers have been given in Table 1 to 3 respectively. In these tables, numbers represent the accumulated distance between interactively selected (four) points and localized boundaries of pupil, iris, upper eyelid and lower eyelid. Shortest distance between the points and corresponding curves is calculated and then accumulated to find one reading of the given tables. The three observers experiments on the implemented localization system and based on their interactive selection of points, the average accuracies of pupil, iris, upper and lower eyelid localization are 99.95%, 99.86%, 99.73% and 99.64% respectively. The average distances between the four selected points by the observers on pupil, iris, upper & lower eyelids and the localized boundaries are 2.96, 3.03, 3.17 and 3.67 pixels respectively. Total number of observations in all the experiments (60 of three observers) with distance more than a specific threshold are considered as error in localization which are as follows: one in pupil, three in iris, five in upper eyelid and eight in lower eyelid localization which means that the errors in number of experiments for pupil, iris, upper eyelid and lower eyelid localization are 1.6%, 5.0%, 8.3% and 13.3% respectively. This error can be reduced by adding more experiments by the observers. Three nonlinear points are required to draw a circle or parabola. Reason for using four interactive points is that, it will decrease the probability of exactly finding the localization curve. The localization result is considered incorrect if the accumulated distance is equal or greater than the threshold. For experiments we have fixed the value of threshold as five pixels.

Table 1. Results of Iris Localization for Observer 1.

S. No.	Accumulated distance between the selected points and localized boundary (in pixels)			
	Pupil	Iris	Upper Eyelid	Lower Eyelid
1.	3.104268	1.739336	4.099020	2.645751
2.	1.348676	1.325102	2.449490	2.449490
3.	2.286910	2.494473	0.000000	1.414214
4.	2.745829	2.426495	5.099020	3.000000
5.	2.991204	1.236048	3.316625	2.236068
6.	4.730627	1.611112	5.000000	7.071068
7.	3.198530	3.654523	1.732051	4.242641
8.	3.586066	0.472185	3.162278	4.242641
9.	2.737602	1.909563	1.414214	3.605551
10.	1.296471	4.391953	1.414214	1.414214
11.	3.578633	1.861891	2.236068	1.414214
12.	2.492652	2.003857	1.732051	9.643651
13.	2.218382	1.407475	3.872983	3.872983
14.	3.681779	3.678309	3.872983	2.236068
15.	3.165565	5.576684	0.000000	2.236068
16.	0.668098	1.667229	2.449490	4.582576
17.	2.415611	3.263996	6.928203	4.243181
18.	4.308528	2.899298	4.480741	1.414214
19.	2.719873	2.195720	3.477226	4.795832
20.	4.877810	2.992269	3.853721	9.219544

Table 2. Results of Iris Localization for Observer 2.

S. No.	Accumulated distance between the selected points and localized boundary (in pixels)			
	Pupil	Iris	Upper Eyelid	Lower Eyelid
1.	3.588612	4.518063	6.403124	2.449490
2.	3.207023	3.277555	2.236068	4.242641
3.	1.534592	4.870797	4.164414	1.000000
4.	3.512950	4.555074	0.000000	3.006361
5.	2.589748	2.774800	0.000000	1.732051
6.	3.768160	4.646162	3.162278	2.449490
7.	0.249212	3.812243	4.141428	3.601471
8.	3.659107	2.218974	0.000000	1.732051
9.	4.386564	2.178294	2.449490	2.449490
10.	2.660343	1.368064	1.414214	4.690416
11.	2.765746	3.030213	0.000000	1.732051
12.	3.022411	1.302695	0.000000	11.023796
13.	0.681665	5.421389	4.088801	2.000000
14.	3.518203	0.431011	4.690416	5.000000
15.	2.955416	4.552374	10.630146	4.196152
16.	2.849581	2.084361	6.633250	3.316625
17.	2.535322	1.994846	4.242641	4.795832
18.	2.945114	4.623281	4.472136	1.186414
19.	2.780537	4.600927	3.872983	5.196152
20.	3.937846	6.215354	2.925824	2.449490

Table 3. Results of Iris Localization for Observer 3.

S. No.	Accumulated distance between the selected points and localized boundary (in pixels)			
	Pupil	Iris	Upper Eyelid	Lower Eyelid
1.	3.719031	3.678354	4.079249	3.741657
2.	3.497450	4.821354	2.549834	4.480741
3.	3.073572	3.089748	2.645751	2.236068
4.	4.826818	6.120449	1.973682	3.082763
5.	0.9005220	3.397782	4.795832	5.567764
6.	3.473052	1.287006	2.727922	2.247449
7.	3.351926	2.759619	1.549834	7.348469
8.	2.448119	3.219624	4.062258	3.872983
9.	3.738195	3.364008	3.557439	4.082763
10.	3.424304	4.578423	4.795832	3.872983
11.	0.089207	2.734676	3.162278	3.744563
12.	4.549443	5.512988	1.124038	7.549834
13.	3.205167	4.456083	4.398238	2.165151
14.	2.395131	1.146670	2.000000	1.588457
15.	2.248467	3.902884	2.124356	4.774964
16.	5.498850	2.668008	1.000000	4.002907
17.	1.970672	1.186189	9.055385	3.480741
18.	3.130747	3.244641	1.672316	4.242641
19.	3.498025	1.813643	5.652476	4.000000
20.	2.995694	1.471147	1.493589	0.000000

According to the observer 1, 2 and 3, accuracy of correct localization of pupil is 100%, 100% and 99.86% respectively whereas iris is 99.86% correct for each observer. Correct localization rate of upper eyelid is 99.73% for each observer and for lower eyelids achieved results are 99.60%, 99.73% and 99.60% accurate with respect to observer 1, 2 and 3.

6. Conclusions

Iris localization is the most difficult step in iris recognition systems because the nature of iris image changes with slight change in illumination conditions. Its accuracy highly affects the complete system. In this paper, a new objective criterion for iris localization is proposed, based on the interactive input of the user to the localization system and the resultant number implies the difference (in pixels) between the actual curve and interactive points. A threshold of five is set to validate the results. Experimental results show that the proposed criterion is very effective and can be implemented for the evaluation of results of other databases.

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