Novel and Fast Approach for Locating Iris Area

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ABSTRACT

Iris recognition is regarded as the most reliable and accurate biometric identification system. Speed and accuracy of iris location are required to achieve the success of iris recognition. This paper presents a new iris location algorithm to improve speed and accuracy. The first step is to detect a point inside the pupil using the method of minimum local block mean. Then the specialized boundary detection mask (SBDM) is employed to locate three points along the inner and outer iris boundaries. Finally, Thales' theorem is applied to find the hypotenuse that is a diameter of their circumcircle and then the circle parameters can be calculated. Based on the CASIA iris image database, experiment results show that the proposed method is superior to the existing approaches on the speed and precision of iris location.

Keywords: iris recognition, biometric, iris location.

一種新穎及快速的虹膜區域定位方法

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摘 要

虹膜識別是目前最可靠與正確的生物認證系統。然而，虹膜定位的速度及準確率更是虹膜識別不可缺少的一環。這篇論文提出了一種新的虹膜定位演算法改善了定位速度及準確率。首先，我們運用最小局部區域平均值的方法偵測出瞳孔中的一點。然後運用特殊邊界偵測遮罩(Specialized Boundary Detection Mask，SBDM)分別找出虹膜內外邊界的三個點。最後，我們依據Thales' 理論，也就是圓的直徑所對應的圓周角是直角進而找出虹膜內外徑圓的參數。運用中國科學院的虹膜資料庫進行實驗，證明所提出之方法在速度及準確度上均優於現行虹膜定位方法。

關鍵詞：虹膜識別，生物認證，虹膜定位

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I. INTRODUCTION

Biometrics is inherently a more reliable and capable technique to identity human's authentication by his or her own physiological or behavioral characteristics. The features used for personnel identification by current biometric applications include facial features, fingerprints, iris, palm-prints, retina, handwriting signature, DNA, gait, etc. [1,2] and the lowest error recognition rate is achieved by iris recognition [3]. With the increasing interests, more and more researchers gave their attention into the field of iris recognition [3-9].

In an iris recognition system, iris location is an essential step that spends nearly more than half of the entire processing time [4]. The correctness of iris location is required for the latter processes such as normalization, feature extraction and pattern matching. For those reasons, to improve the speed and accuracy of iris location becomes nontrivial. The algorithms proposed by Daugman [5-7] and Wildes [8] are most popularly used for iris location. Daugman’s method is developed first using the integrodifferential operator [5] for localizing iris regions along with removing possible eyelid noises. In the past few years, some methods made certain improvement based on the Daugman’s method [6,7]. The approach presented by Wildes [8] combines the method of edge detection with Hough transform for iris location. However, the parameters need to be precisely set and lengthy location time is required. A novel method proposed by Yuan et al. [9] is a rapid iris location algorithm based on the gray distribution features of eye images. The iris image can be successfully located by following the principle that three points which are not on the same line can define a circle. Although the iris image can be accurately located, the time spent in finding a point inside the pupil can not be disregarded.

Motivated by the above algorithms, in this article, we propose a new algorithm to increase the efficiency of iris location base on structure characteristics of human eyes. Firstly, a point inside the pupil is found using the method of minimum local block mean. Secondly, we employ the specialized boundary detection mask (SBDM) to locate three points along the inner and outer iris boundaries. Finally, we apply Thales' theorem that the diameter of a circle always subtends a right angle to any point on the circle’s circumference to calculate the circle parameters such as the circle center and its radius. Our proposed method doesn’t need to find all the points on inner and outer iris boundaries; therefore the location speed is very fast. Meanwhile, since the circle parameters of iris boundaries are computed using the classical geometry, our algorithm is unaffected by the unwanted features and the iris location accuracy is very high.

II. LOCATING A POINT INSIDE THE PUPIL

The human iris is nearly an annular portion between the block pupil (inner boundary) and the white sclera (outer boundary). The collected eye images provide certain gray distribution characteristics; generally speaking, the intensity of sclera should be whiter than the intensity of iris and the intensity of iris should be whiter than the intensity of pupil. Inside the eye image, the pupil area gives the minimum average gray value.

The first step of our algorithm is to correctly locate a point $P_0(x_0, y_0)$ inside the pupil. At first, we select a block with the size of $k \times l$ that is close to the size of the pupil area. The block has $k \times l$ pixels with k columns and l rows. The width and height of the eye image is a multiple of the block area. Suppose that the eye image is divided into d non-overlap blocks and then the next step is to find the block with the minimum local mean value. Therefore, the center point of the block is the target point and its coordinate can be computed. Figure 1 illustrates the eye image divided by the method of minimum local block mean.

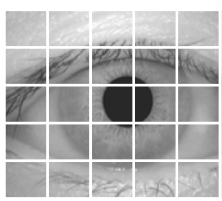

Fig. 1. The eye image divided by the method of minimum local block mean

III. FINDING THE IRIS BOUNDARIES

In this section, the classical geometry is applied to find two iris boundaries using the target point found in Section 2.

3.1 The Design of Specialized Boundary Detection Mask

According to the features of gray distribution, in the eye image, the average gray value of pupil is the minimum and that of sclera is the maximum, and the average gray value of iris is between them. The edge points of two iris boundaries must appear at the points of maximum intensity value changes. Therefore, it is required to locate the points with maximum intensity value changes before finding the iris boundaries. However, since there are some unwanted features in the iris area such as eyelid, eyelashes etc., the requirement can not be fulfilled by using the classical edge detection operators. Also, the correct boundary points can not be found by considering only a small area (e.g. 3x3). As such, here, a specialized boundary detection mask (SBDM) is designed to find the accurate boundary points and calculate the exact boundary circle parameters.

There are two SBDMs in the horizontal and vertical directions, respectively. Let n and m are both odd numbers. The horizontal SBDM (an example is shown in Fig. 2) is constructed by a $n \times m$ matrix and $(m-1)/2 > n$. To set $(m-1)/2 > n$ is to avoid the boundary detection errors resulted from the unwanted features. The mask moving direction is leftward or rightward along the long axis based on the desired boundary. The vertical SBDM is rotated by 90^0 from the horizontal SBDM and the moving direction is upward or downward along the long axis based on the desired boundary. Note that the mask moving directions are associated with the directions of boundary detection. The edge points of inner and outer boundaries can be decided from the processing results achieved by the horizontal and vertical SBDMs.

1	1	1	1	1	0	-1	-1	-1	-1	-1
1	1	1	1	1	0	-1	-1	-1	-1	-1
1	1	1	1	1	0	-1	-1	-1	-1	-1

Fig. 2. An example of the horizontal SBDM

3.2 Location of Iris Inner Boundary

At first, starting from the point $P_0(x_0, y_0)$ found in Section 2, we search the inner boundary of the iris using the horizontal SBDM leftwards and rightwards along the horizontal direction. Then two edge points can be found on the iris inner boundary (P_1 and P_2). Secondly, the third point P_3 can be located by considering the position of point P_2 relative to the pupil. Suppose that point P_2 is at the center of the vertical SBDM, the average pixel value of the upper half mask is V_{upper} and the average pixel value of the lower half mask is V_{lower}. If $V_{upper} > V_{lower}$, the position of point P_2 is on the upper half circumcircle of pupil. Then point P_2 is used as the starting point to search the lower boundary point P_3 of the pupil using the vertical SBDM moving downwards on the vertical direction. If $V_{lower} > V_{upper}$, the position of point P_2 is on the lower half circumcircle of pupil. Then point P_2 is used as the starting point to find the upper boundary point P_3 of pupil using the vertical SBDM moving upwards on the vertical direction. After that, three points on the iris inner boundary can be finally found. Let the three boundary points be $P_1(x_1, y_1)$, $P_2(x_2, y_2)$ and $P_3(x_3, y_3)$. Using those three points, we can calculate the parameters of inner circle precisely according to Thales' theorem that the diameter of a circle always subtends a right angle to any point on the circle's circumference. Fig. 3(a) shows the relationship of those three points.

The detailed steps of finding the inner boundary of iris are described as follows:

(1)Determine the search range. The pupil boundary points (P_1 and P_2) are detected along the horizontal line $y = y_0$. The leftward searching range is $\left[(n-1)/2, x_0 - 1\right]$ and the rightward searching range is $\left[x_0 + 1, imagewidth\text{-}(n\text{-}1)/2\right]$. After P_1 and P_2 are found, then the upper (or lower) boundary point of pupil can be detected via point P_2 along the vertical line $x = x_2$ moving upwards (or downwards) and the searching range is $\left[(n-1)/2, y_2 - 1\right]$ (or $\left[y_2 + 1, imageheight - (n-1)/2\right]$), where n is the length of the long axis of SBDM.

(2)Using SBDM to search the first iris inner boundary point P_1 in the leftward searching range. During the processing, each pixel (x, y) is considered as the center of SBDM and the corresponding edge intensity is calculated using formula (1) given by

$$e = \left| \sum_{i=x-\frac{m-1}{2}}^{x+\frac{m-1}{2}} \sum_{j=y-\frac{n-1}{2}}^{y+\frac{n-1}{2}} f(i, j) * w(i, j) \right| \qquad (1)$$

where $f(i, j)$ represents the pixel value of image, $w(i, j)$ is a weighting of the SBDM. This will generate a set $E = \{e_1, e_2, e_3, ...\}$ from all pixels. Note that set E is sorted from maximum to minimum before further processing. Also, during the processing, for each pixel, the average gray value of the half SBDM close to the pupil center is calculated. The reason is that while the inner boundary point becomes the center of SBDM, all pixels in the half mask close to the pupil center are inside the pupil. The average value of this half mask must be very close to the gray value of the pupil. The reference gray value v of pupil is computed by applying Yuan *et al.* algorithm [9] represented by

$$v = v_0 + (v_0)^{1/2} \qquad (2)$$

In this work, v_0 is the minimum pixel value of the 9×9 square regions that the center coordinate is point P_0. Therefore, starting the search in E from the maximum, simultaneously, the pixel corresponding to a average gray value less than the reference gray value of pupil must be the left boundary point P_1.

The same procedures of step (2) can be easily modified and used for the rightward and downward (or upward) searching ranges, respectively. Then other two points of P_2 and P_3 can be obtained.

(3)By using Thales' theorem as shown in Fig. 3(a) and three points of P_1, P_2 and P_3, the center coordinate of the circle $P_p(x_p, y_p)$ and the radius R_p can be obtained, where $x_p = (x_1 + x_3)/2$, $y_p = (y_1 + y_3)/2$, and $R_p = ((x_p - x_1)^2 + (y_p - y_1)^2)^{1/2}$.

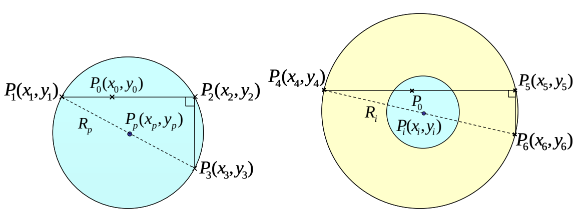

Fig. 3. Thales' theorem is applied to find (a) the inner and (b) the outer boundary of iris.

3.3 Location of Iris Outer Boundary

In the eye image, the inner and outer boundaries of iris are not concentric circles. We treat the iris outer boundary as another circle. Due to that the iris area is different from the pupil; the method of locating the inner boundary in Section 3.2 and the reference gray value of iris need to be modified.

Same as Section 3.2, starting from point P_0 inside the pupil, the outer boundary of the iris can be found using the SBDM along the horizontal direction. Since the moving direction of SBDM is horizontal, the upper and lower points along the outer iris boundary will not be detected. That is, this method is unaffected by the eyelid and eyelashes. Therefore, the left and the right points along the iris outer boundary can be accurately found (as shown in Fig. 3(b)).

The modified method to find the iris outer boundary is described in the following steps:

(1)Determine the search range. The pupil boundary points (P_4 and P_5) are detected along the horizontal line $y = y_0$. The leftward searching range is $\left[(n-1)/2, x_1 - 1\right]$ and the rightward searching range is $\left[x_2 + 1, \textit{imagewidth}\text{-}(n\text{-}1)/2\right]$. After P_4 and P_5 are found, then the upper (or lower) outer boundary point of iris can be detected via point P_5 along the vertical line $x = x_5$ moving upwards (or downwards) and the searching range is $\left[(n-1)/2, y_5 - 1\right]$ (or $\left[y_5 + 1, \textit{imageheight} - (n-1)/2\right]$), where n is the length of the long axis of SBDM.

(2)The reference gray value of iris is computed by directly applying Yuan *et al.* algorithm [9]. The difference here is that they chose two 9×9 square regions locating 5 pixels away corresponding to two outside points of the inner boundary. Then the reference gray value

$\tilde{v}_i$ can be given by

$$\tilde{v}_i = v_i + (v_i)^{1/3} \quad (3)$$

where the average gray value v_i is calculated from all pixels in those two 9×9 regions. This is the most reasonable reference value of iris [9].

(3)Using SBDM, the boundary points can be detected on the iris outer boundary along the horizontal leftward range, horizontal rightward range and vertical upward (or downward) range, respectively. Similar to Section 3.2, we choose the points from the maximum edge intensity in order. By setting each point in the center of the SBDM, while the average gray value of all pixels in the half mask close to the pupil center is less than the reference gray value of iris, then those points are just located on the iris outer boundary.

(4)Finally, the iris center coordinate of the circle $P_i(x_i, y_i)$ and the radius R_i can be obtained as shown in Fig. 3(b), where $x_i = (x_4 + x_6)/2$, $y_i = (y_4 + y_6)/2$, and $R_i = ((x_i - x_4)^2 + (y_i - y_4)^2)^{1/2}$.

3.4 The Special Case of Iris Location

The two points of $P_3(x_3, y_3)$ and $P_6(x_6, y_6)$ can not be correctly found if the point P_0 locates on the horizontal line passing through the center of pupil. As such, although the inner and outer boundary points are on the horizontal line, the upper (or lower) boundary points can not be found. Since boundary points are the leftmost (or rightmost) edge point, only vertical tangent lines can be found. Thus, in this case, point P_0 is moved downwards 15 pixels along the vertical direction. Then, another point $P_0^{'}$ can be found inside the pupil. The new starting point $P_0^{'}$ can be used to search the iris inner and outer boundary using the method described in Sections 3.2 and 3.3 again.

IV. EXPERIMENTAL RESULTS

This section describes the results obtained from the experiments performed by using the proposed approach. In our experiments, the database is from the generally used iris image database, *CASIA Iris Database* [10], authorized from the Institute of Automation, Chinese Academy of Science. Each image has the resolution of 320×280 in 256 gray levels. This database includes 756 iris images from 108 different eyes with 7 each. The experiments conducted below are running on the computing environment of 1.6GHz PC with 512MB RAM using Matlab 7.0. The proposed algorithm is applied at each image in the database. Fig. 4 are four iris example images from *CASIA Iris Database*, the upper row shows the original iris image and the lower row are corresponding results located by our propose method.

A complete experiment has been conducted on all iris images (756 images). This totally spends 30.56 seconds and the average time is 0.04s for each eye image. Only one eye image (054_1_3) can not be accurately located for the iris image part is out of the image boundary. For comparison purposes, traditional methods are also implemented. Final results are shown in Table 1. It shows that our method is better than the two methods [5,8] and can compete with the approach of Yuan *et al.* [9]. Five images can not be accurately located by Yuan *et al.* All of them are affected by the occluded eyelashes and eyelids iris images. In our experiments, we assured the segmentation precision of the iris boundaries obtained by the proposed method with using those iris-located images for iris recognition. The final experimental results have demonstrated promising performance [11].

Table 1. Comparison of our approach to traditional methods

Method	Accuracy (%)	Average time(s)
Daugman [5]	98.4	6.49
Wildes [8]	95.3	8.57
Yuan [9]	99.34	0.38
Proposed	99.87	0.04

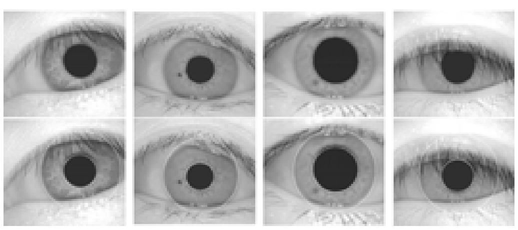

Fig. 4. The upper row shows the original iris images and the lower row are corresponding results located by our propose method.

V. CONCLUSIONS

In this paper, a new iris location algorithm has been proposed to rapidly and correctly locate the iris inner and outer boundaries. The method of minimum local block mean is used to detect a point inside the pupil. The specialized boundary detection mask (SBDM) is employed to locate three points along the inner and outer iris boundaries. Thales' theorem is applied to find the hypotenuse that is a diameter of their circumcircle and then the circle parameters can be calculated. Compared with traditional methods, the execution time of our method is the fastest. Accuracy and robustness have also been achieved. In the future, it is necessary to conduct experiments on a large number of data in various environments to make the iris recognition system to be more stable and reliable.

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