2014

ISSN : 0974 - 7435 Volume 10 Issue 23

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(23), 2014 [14469-14474]

A Robust and accurate iris localization method

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ABSTRACT

In this paper we present a robust and accurate iris localization method. Firstly, it ensures an automatic threshold by OTSU method and gets binary image, then in the binary image it finds a point in the pupil by gray summing operator. Thirdly it finds three non-collinear points of the pupil boundary by designed template in the binary image that can avoid the influence of other parts of the eye image, especially eyelash. Finally in the original image it uses a crafty method by certain theory of Hough transform, but it need not binary image and can use a few points and former designed template to locate the iris boundary. It can decrease the complexity and amount of calculation and it has good noise immunity and robustness.

KEYWORDS

Template; Gay summing operator; OTSU method; Robust.

INTRODUCTION

Iris as an important personal identification characteristic, it has many advantages such as uniqueness, stability, gathering, non-invasive characteristics etc. Non-invasive biometrics which investigate, develop, and apply identity are inevitable trends. Compared with other non-invasive biometrics such as face and sound, iris recognition has higher accuracy. According to the statistics, iris recognition has the lowest error rate among all biometric identification [1]. Iris location is the previous work of an iris recognition system, it spends nearly half of the time in the whole recognition system, therefore improving the speed of iris location has important value of investigation. The first main method of iris location is using the circle detection operator [2-6]. Among them the method which is put forward in reference [2] is the earliest, references [3-6] make certain improvement on the basis of reference [2], firstly, through the standard deviation or the projection or the grey peak they make a coarse location, secondly, some have made certain improvement to the circle detection operator. The second main method of iris location is using the edge detection operators and Hough transform [7-12]. There are some primary differences in edge detection operators and forms of Hough transform。 The other methods include integro-differential constellation method[13] and rapid and accurate iris location method[14,15]. The existing problems of above-mentioned methods are as following: (1) some require stricter to set parameters; (2) some need long time to locate; (3)others are easily affected by eyelash, eyelid, ray and other noise.

Aiming at the above problems, we present a robust and accurate iris localization method. Firstly, it ensures an automatic threshold by OTSU method and gets binary image, then in the binary image it finds a point in the pupil by gray summing operator. Thirdly it finds three non-collinear points of the pupil boundary by designed template in the binary image that can avoid the influence of other parts of the eye image, especially eyelash. Finally in the original image it uses a crafty method by certain theory of Hough transform, but it need not binary image and can use a few points and former designed template to locate the iris boundary. It can decrease the complexity and amount of calculation and it has good noise immunity and robustness. Many experiments indicate that this algorithm has good functions in precision and robustness.

MATERIALS AND METHODS

Find a pint in pupil

Because the points locating in the pupil area are nearly black in the CASIA iris image database, we find the minimum gray value Min in an image. For reducing the searching scope and getting threshold more accurately when we get threshold by OTSU method, the searching gray scope is in [Min, Min+50].

We apply the OTSU method to make binary. This method as proposed in [10] is based on discriminant analysis. The threshold operation is regarded as the partitioning of the pixels of an image into two classes C_0 and C_1 (e.g., objects and background) at grey-level t, i.e., $C_0=\{0, 1, \ldots, t\}$ and $C_1=\{t+1, t+2, \ldots, l-1\}$. As stated in [16], let $\sigma_B{}^2$ be the between-class variance. An optimal threshold can be determined by maxing the following (equivalent) criterion function with respect to t:

$$\sigma_B{}^2 = \omega_0\omega_1(\mu_1\mu_0)^2 \qquad (1)$$

Where

$$\mu_T = \sum_{i=0}^{l-1} iP_i \qquad (2)$$

$$\omega_0 = \sum_{i=0}^{t} P_i\ ,\ \omega_1 = 1-\omega_0 \qquad (3)$$

$$\mu_1 = \frac{\mu_T - \mu_t}{1-\mu_0} \qquad (4)$$

$$\mu_0 = \frac{\mu_t}{\omega_0}\ ,\quad \mu_t = \sum_{i=0}^{t} iP_i \qquad (5)$$

$$P_i = \frac{n_i}{n} \qquad (6)$$

Where n_i is the number of pixels with grey-level i and n is the total number of pixels in a given image defined as

$$n = \sum\nolimits_{i=0}^{l-1} n_i \qquad (7)$$

Moreover, P_i is the probability of occurrence of grey-level i defined as

$$P_i = \frac{n_i}{n} \qquad (8)$$

When the value of $\sigma_B{}^2$ reaches the max, the corresponding t is the automatic threshold t^* that we want to find.

Otsu’s method as proposed affords further means to analyze further aspects other than the selection of the optimal threshold for a given image.

By t^* we get the binary image of source image. The results of four random images from database are shown in Figure 1. The series numbers under images are the labels of the image in the database.

a 007_1_1 b 070_2_4 c 091_2_1 d 101_2_2

Figure1: The binary results of the images of Figure 1

Then we can find a random point in the pupil. The detail method is: we search the point in the whole image beginning from the first point of the image, then compute the gray summing operator[15] value of each point. The size of the operator is n*n. The gray summing operator value of random point is written as

$$S(x_o,y_o)=\sum_{i=x_o-\frac{n-1}{2}}^{x_o+\frac{n-1}{2}}\sum_{j=y_o-\frac{n-1}{2}}^{y_o+\frac{n-1}{2}} f(i,j) \qquad (9)$$

Here (x_o,y_o) is the current point, i and j denote horizontal and vertical coordinates of each point in the n*n adjacent area of the current point. $f(i,j)$ denotes the gray value. We search the whole image, when S is equal “0”, the corresponding center of the gray summing operator is the point (A (x_0, y_0)) inside the pupil. The results of four random images from database are shown in Figure 2. The center of white rectangle is the point A.

a 007_1_1 b 070_2_4 c 091_2_1 d 101_2_2

Figure2: The sketch map of the one point in the pupil.

Locate the pupil

Because in the binary image, almost all the black pixels locate in the pupil area, the other area is almost white, the boundary between pupil and iris has greater edge intensity (the changes of grey values). So we can design a template to detect the boundary, the size of the template is M*N. The width of the template is M, the height of the template is N, what is more, M and N are odd numbers. The direction of template is always holding the line with the direction of detection, when we search two horizontal boundary points, the direction of template is horizontal. When we search horizontal points we require M>N because that can ensure the importance of corresponding direction. The template of searching horizontal edge point is shown in Figure 3.

$$\left[\;N\left\{\begin{array}{ccccc} -1 & \cdots & 0 & \cdots & 1\\ \vdots & \ddots & \vdots & \iddots & \vdots\\ -1 & \cdots & 0 & \cdots & 1\\ \vdots & \iddots & \vdots & \ddots & \vdots\\ -1 & \cdots & 0 & \cdots & 1\\ \multicolumn{2}{c}{\underbrace{\hphantom{-1\ \cdots}}_{(M-1)/2}} & & \multicolumn{2}{c}{\underbrace{\hphantom{\cdots\ 1}}_{(M-1)/2}}\end{array}\right.\;\right]$$

Figure3:Template H

Beginning from A, we move the template along horizontal direction to left and right and we calculate the output of the template, so we can get the corresponding edge intensity of each pixel. When we search the left and right boundary points, the output of random point(x,y) is written as

$$\mathrm{E}(x,y)=\left|\sum_{j=0}^{j=N-1}\sum_{i=0}^{i=M-1} g(i+x-(M-1)/2,\ j+y-(N-1)/2) * H(i,j)\right| \qquad (10)$$

$g(i,j)$ denotes the gray value of the binary image, $H(i,j)$ denotes the corresponding coordinate of the designed template. When $E(x,y)$ reaches the maximum along left and right directions respectively, we can find left edge point $C(x2,y2)$ and right edge point $D(x3,y3)$ respectively.

When we search the lower edge point E beginning from point A along vertical direction, when we search lower boundary point, the direction of template is vertical, it requires N>M. The template of searching vertical edge point is shown in Figure 4.

$$\left[\;\underbrace{\begin{matrix} -1 & \cdots & -1 & \cdots & -1 \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ 0 & \cdots & 0 & \cdots & 0 \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ 1 & \cdots & 1 & \cdots & 1 \end{matrix}}_{M}\begin{matrix}\left.\vphantom{\begin{matrix}-1\\ \vdots\end{matrix}}\right\}(N\text{-}1)/2\\ \\ \left.\vphantom{\begin{matrix}\vdots\\ 1\end{matrix}}\right\}(N\text{-}1)/2\end{matrix}\;\right]$$

Figure4: Template H1

We calculate the output of the template, so we can get the corresponding edge intensity of each pixel. When we search the lower boundary point, the output of random point(x,y) is written as

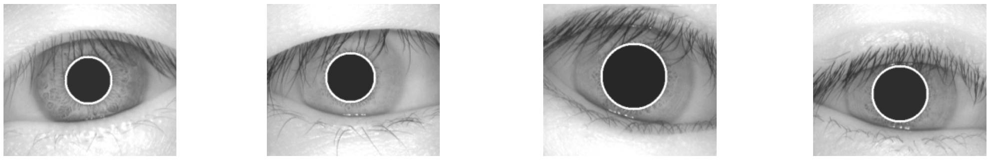
$$\mathrm{L(x,y)} = \left|\sum_{\mathrm{j}=0}^{\mathrm{j}=N-1}\sum_{\mathrm{i}=0}^{\mathrm{i}=M-1}\mathrm{g(i+x-(M-1)/2,\, j+y-(N-1)/2)} * H1(i,j)\right| \qquad (11)$$

$H1(i,j)$ denotes the corresponding coordinate of the designed template. When $L(x,y)$ reaches the maximum, we can find lower edge point.

Then the radius of the inner boundary circle can be calculated as

$$r = (((x3 - x2)/2)^2 + (y6 - y2)^2)/(2 \times (y6 - y2)) \qquad (12)$$

The center of the inner circle is P ((x2＋x3)/2, y6－r)). The pupil location results of Figure 1 are shown in Figure 5.



a 007_1_1 b 070_2_4 c 091_2_1 d 101_2_2

Figure5:The location results of anterior four images

Locate the iris

It is quite hard that we search two points that locate at the upper and lower boundaries between iris and sclera crossing the center of a circle along vertical direction because of the coverage of the upper and lower eyelids and eyelash. So we want to search edge points that locate at the left and right boundaries between iris and sclera crossing the center of a circle in horizontal direction because there is not much coverage. Here we use certain theory of Hough transform, but we need not make edge detection before Hough transform, that say our method are not based on the binary image as former common Hough transform. What is more, our method can decrease the complexity and amount of calculation and it has good noise immunity and robustness. The detail of our method is: firstly, we ensure three parameters xi, yi and ri, the searching scopes of the three parameters are [(x2＋x3)/2－10, (x2＋x3)/2+10], [y6－r－10, y6－r +10] and [r+30, r+80]. The centers of inner boundary circle and outer boundary circle are always not the same point, the pupil always leans to bridge of a nose a certain extent along horizontal direction, this instance may happen along vertical direction too, but this deviation is small. Secondly we set a three-dimensional array TJ[xi][yi][ri] , thirdly we choose forty horizontal lines along vertical direction, the vertical ordinates of these forty lines are [yi－19, yi+20] respectively. On the each line we should find two points they locate at the right side and left side of the middle point of each line respectively. So we can find eighty points totally. The sketch map is shown in Figure 6.

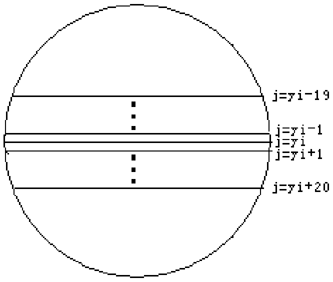


Figure6: The sketch map of the chosen 40 horizontal lines.

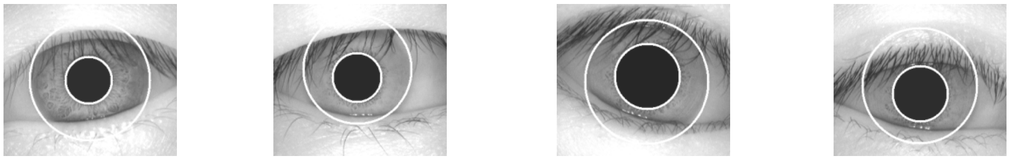
Here j is the vertical ordinates of all the points on one line, the corresponding horizontal ordinates of the two points on each line are calculated by following formula respectively

$$\begin{aligned} xr &= xi + \sqrt{ri * ri - (j - yi) * (j - yi)} \\ xl &= xi - \sqrt{ri * ri - (j - yi) * (j - yi)} \end{aligned} \qquad (13)$$

Here xr and xl indicate the horizontal ordinates of right and left point of each line respectively. Then we calculate the array TJ[xi][yi][ri]. We adopt the former template in Fig in the original image. The calculating formula is as following

$$TJ[xi][yi][ri] = \sum_{j=yi-19}^{j=yi+20} \left(\sum_{a=0}^{a=N-1} \sum_{b=0}^{b=M-1} \begin{matrix} f(xr + b - (M-1)/2,\ j + a - (N-1)/2) * H(b,a) - \\ f(xl + b - (M-1)/2,\ j + a - (N-1)/2) * H(b,a) \end{matrix} \right) \qquad (14)$$

Here f indicates the original image. In the searching scopes of the three parameters xi,yi and ri, we calculate each value of TJ[xi][yi][ri]. At last we choose the maximum value from all the values of TJ, its corresponding three parameter values are the parameters(x4,y4,r4) of the iris outer boundary. The center ordinates of outer boundary are (x4,y4), its radius is r4. The iris localization results of Figure 1 are shown in Figure 7.



a 007_1_1 b 070_2_4 c 091_2_1 d 101_2_2

Figure7:The location results of Figure 1.

RESULT AND DISSCUSS

The images used in our experiments come from the image database[17]. In our experiments, the proposed pupil location algorithm has been used for each image in the database.

When we use gray summing operator to find a point inside the pupil, n(the size of the operator) is chosen 60. Because in the binary image almost all the black points locate in the pupil, some eyelash points are black, but they are not dense, the size of n is not important, we can not only find the point exactly, but also avoid the affection of the eyelash.

The sizes of templates H and H1 are chosen 11×7 and 7×11respectively.When we locate the pupil, the size of the templates are not important because of the binary image. When we locate the iris, this size of the template H is chosen 22×13 for better noise immunity. We examine eighty points when we ascertain one group of the three parameters, so if we find several wrong points that can not affect the location result.

The number of the chosen horizontal lines is 40. Although if we choose more lines that may have better noise immunity, we also should consider that near upper eyelid and lower eyelid it has less effective iris information, and that can take certain trouble on the contrary. When we choose less lines the location result can be affected by eyelid and eyelash.

Adopting above values of the parameters, we have done a lot of experiments on the present image database (756 images), it can reach the accuracy 98.148%. The main reason of the wrong location results is the somewhat dense eyelashes.

CONCLUSIONS

In this paper we present a robust and accurate iris localization method. Firstly, it ensures an automatic threshold by OTSU method and gets binary image, then in the binary image it finds a point in the pupil by gray summing operator. Thirdly it finds three non-collinear points of the pupil boundary by designed template in the binary image that can avoid the influence of other parts of the eye image, especially eyelash. Finally in the original image it uses a crafty method by certain theory of Hough transform, but it need not binary image and can use a few points and former designed template to locate the iris boundary. It can decrease the complexity and amount of calculation and it has good noise immunity and robustness.In our future works, we want to make more experiments on the more database and make more research on the all parameters in our method.

ACKNOWLEDGEMENT

Thanks the Supporting by the National Natural Science Foundation of Education Department of Henan under grant No. 2010A510005.

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