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Research on Iris Localization Algorithm based on the Active Contour Model

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Abstract

An automatic and robust iris segmentation algorithm will be employed when iris recognition is used to identify human efficiently. Many studies have shown that iris localization is one of the most important parts of the iris recognition system. Most current studies are based on the assumption that iris edge is round, and the gray information of eye image is used for iris segmentation, which requires very high quality of image. Based on the active contour model, an algorithm for iris location was proposed. First, a plurality of pupil edge points was located as the initial contour point set. Then, the real contour evolution of pupil was approximated by the approximation of energy function. Finally, the accurate iris edge was located by daugman's circular gradient operator. Based on CASIA (V2.0) iris database, experiment results show that the location effect of the proposed algorithm is more superior than that of the classical calculus method and hough transform method.

Keywords: *active contour, iris localization, circular gradient operator,hough transform*

1. Introduction

Iris recognition is known as a means of identification with the high safety due to the uniqueness and complexity of the iris texture. Iris recognition is composed of iris image acquisition, iris location, iris feature encoding and matching. Iris localization refers to the localization between the inner edge of the iris (the pupil edge) and the outer edge of the iris, and accurate localization is considered as the precondition to realize iris verification and identification. Existing iris localization algorithm is mainly divided into two categories. One is the calculus method based on the iris edge gradient represented by Daugman [1], and the other is hough transform method represented by Wildes [2]. Daugman believes that the gray distribution of the iris image acquisition have some differences. In general, the iris is darker than sclera and the pupil is darker than the iris, which forms obviously dark gradient in the iris edge. According to the prior knowledge of the iris shape being similar to the ring, Daugman uses the circular shape operator in order to localize the inner and outer edges of iris. First, Wildes transformed the gray image into binary edge image, and then the edge points was voted to get the parameters of inner and outer iris edges by Hough transform.

However, the above algorithm requires the good contrast ratio of images, which needs the high quality of the iris image. In fact, the shape of iris edge is not a strict circle. According to the limitations of the above classical iris localization algorithm, the iris localization algorithm is proposed based on the active contours model [3]. The active contours model does not limit in advance the iris edge model, and is not sensitive to the iris image gradient. The experiments show that the localization effect is better than that of the classical calculus method and Hough transform method, which provides a good the foundation for the subsequent iris recognition steps.

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2. Iris Image Preprocessing

Because of the influence of illumination conditions, before the iris image localization, it is necessary to preprocess the iris image in order to enhance the contrast ratio of iris margin, remove the small noise, and improve the robustness of algorithm. The Gauss filter is often used to remove the noise of the original iris image so that target contour information can be protected better in filtering noise [4].

$$G(x,y) = \frac{G_g(x,y)}{\sum_x \sum_y} \quad G_g(x,y) = e^{-(x^2+y^2)/(2\sigma^2)} \tag{1}$$

σ is a standard variance. The smaller the σ value is, the more obvious the filter effect is; the more template, and Gauss smoothing filter template with the common size of 3 x 3 is shown in Figure 1.

$$\frac{1}{16} \times \begin{array}{|c|c|c|} \hline 1 & 2 & 1 \\ \hline 2 & 4 & 2 \\ \hline 1 & 2 & 1 \\ \hline \end{array}$$

Figure 1. Gauss Smoothing Filter

3. Iris localization Algorithm based on the Active Contour Model

3.1 Basic Principle of the Active Contour Model

Active contour model is known as Snake method, because in the process of approaching to the target contour, closed curve like a snake crawling is constantly changing its shape. In the practical application, active contour model is often used in the given target initial profile down approaching to the precise contour [5]. An active contour is a set of sorting collection points in image, which can be expressed as:

$$V = \{v_1, \cdots, v_L\} \tag{2}$$

In which

$$v_i = (x_i, y_i), i = \{1, \cdots, L\} \tag{3}$$

The points on the contour can be obtained by the iterative approximation the boundary of the target via solving a minimum energy problem. For each $v_i^{'}$ in the v_i neighborhood area, the following energy function can be calculated:

$$E(v_i^{'}) = \min[\alpha E_{int}(v_i) + \beta E_{ext}(v_i)] \tag{4}$$

In the above formula, E_{int} represents the energy function depending on the contour shape; E_{ext} represents energy function depending on the nature of images; α and β are the weighted

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coefficients. During the approximation process, each v_i moves to the v_i' of the corresponding minimum E_i. If the energy function is chosen appropriately, the active contour should eventually remain in the target contour. The method is used to localize the iris inner and outer edges mainly considering the iris edge is not true circular. The search template need not be set in advance, but the dynamic boundary search is employed to identify the iris edge.

The Snake algorithm reaches the goal of the boundary through continuously minimizing itself the energy function. The general process of iris localization is shown as follows. First, the gray test method is used to examine a point in the pupil as the pseudo center of circle; then this point is regarded as the center, and a few points around it are taken as the initial contour point set of the Snake algorithm; finally according to the evolution of Snake operation mechanism, the center of profile point after evolution is calculated as the iris edge center and the distance between the profile point and this center is treated as the radius of iris edge. Based on the above procedures, the iris boundary is localized.

3. 2 The Pupil Center and the Initial Contour Set Detection

The active contour model is used to localize the iris. First, a point is searched as the center of the pupil. Based on the analysis histogram of the typical eye image shown in Figure 2. the grayscale value increases with the order of the pupil, iris and sclera, and the grayscale value of pupil is concentrated and its value is lower, which has a great difference from the iris. According to the above properties of the grayscale value distribution, the first peak value in the histogram is regarded as the eye image segmentation threshold *T*. The eye image is set *I* (*x*, *y*), and *T* is used to do binaryzation operation on the human eye image. The binary image of the BW (x, y) is shown in Figure 3.

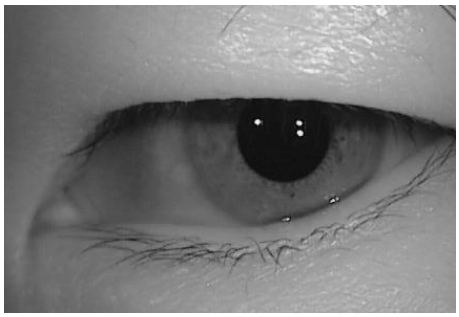

Figure 2. The Eye Image

Figure 3. The Eye Image by Binaryzation Operation

It can be seen that the pupil is successfully separated in Figure 3. The boundary points of the white area in the binary image BW can be used as the initial boundary points in the active vontour model, from which the boundary points *N* are selected, and here *N*=100. A boundary point is set as (x_i,y_i), $3 \le i \le N$. The general equation of the circle is expressed:

$$x^2 + y^2 + Ax + By + C = 0 \tag{6}$$

The formula (7) is used to determine (x_p,y_p) and r_p.

$$\begin{cases} x_p = -\dfrac{A}{2} \\ y_{p=} -\dfrac{B}{2} \end{cases} \tag{7}$$

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$$r_p = \frac{\sqrt{A^2 + B^2 - 4C}}{2}$$

The formula (6) is transformed as:

$$Ax + By + C = -x^2 - y^2 \tag{8}$$

The matrix form of formula (8) is shown as follows:

$$\begin{bmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ \vdots & \vdots & \vdots \\ x_i & y_i & 1 \\ \vdots & \vdots & \vdots \\ x_n & y_n & 1 \end{bmatrix} \begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} -(x_1^2 + y_1^2) \\ -(x_2^2 + y_2^2) \\ \vdots \\ -(x_i^2 + y_i^2) \\ \vdots \\ -(x_n^2 + y_n^2) \end{bmatrix} \tag{9}$$

Suppose $P = \begin{bmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ \vdots & \vdots & \vdots \\ x_i & y_i & 1 \\ \vdots & \vdots & \vdots \\ x_n & y_n & 1 \end{bmatrix}$, $Q = \begin{bmatrix} A \\ B \\ C \end{bmatrix}$, $N = \begin{bmatrix} -(x_1^2 + y_1^2) \\ -(x_2^2 + y_2^2) \\ \vdots \\ -(x_i^2 + y_i^2) \\ \vdots \\ -(x_n^2 + y_n^2) \end{bmatrix}$

The least square method [6] is used for fitting the pupil edge, and the least squares solution of the formula (9) is as follows:

$$Q = (P^H P)^{-1} P^H N \tag{10}$$

Based on the solutions of *Q*, the pupil parameters are determined to obtain the pupil initial center and contour set, which is shown by the white point in Figure 4.

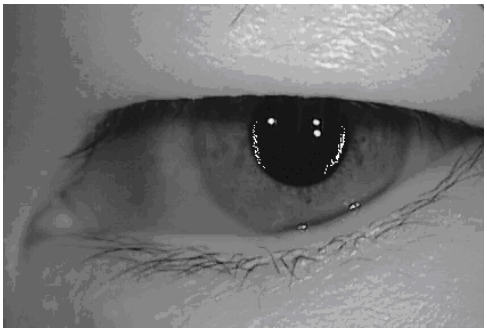

Figure 4. The Initial Contour of the Pupil

3. 3 The Localization of the Iris Inner Boundary

3.3.1 The Rough Localization of the Iris Inner Boundary

First, the initial center in Section 3.2 is regarded as the starting center, and the white point is the initial point set of the iris contour. The active contour model is discretized into:

$$E(v_i') = \min_{0 \le j \le 16} [\alpha E_{int}(v_{i,j}) + \beta E_{ext}(v_{i,j})] \tag{11}$$

In the above formula, i=0,1,.....,N-1,v_i is the control point on the contour; N is the total number of control points, where N=100. $v_{i,j}$ is the control points of v_i (v_i=$v_{i,0}$) and $v_{i,j}(j \neq 0)$ in 16 neighborhood field.

The internal energy uses the following function:

$$E_{int}(v_{i,j}) = \frac{\left| \bar{d} - \left| v_{i,j} - v_i \right| \right|}{\max\limits_{0 \le j \le 16} \{ \bar{d} - \left| v_{i,j} - v_i \right| \}} \tag{12}$$

$\bar{d}$ is the distance between the control points on the contour.

$$\bar{d} = \frac{1}{N} \sum_{i=0}^{N-1} \left| v_{i+1} - v_i \right| \tag{13}$$

This method is widely applied, which was originally designed by Williams[7]. Its advantage is that the point close to the average distance has smaller energy value so that the contour point is evenly distributed.

According to the value of the gray image itself, the external energy function is designed:

$$E_{ext}(v_{i,j}) = \frac{I(v_{i,j}) - \min Gray}{\max Gray - \min Gray} \tag{14}$$

$I(v_{i,j})$ is the grayscale value of $v_{i,j}$, and $\min Gray$ and $\max Gray$ are minimum grayscale value and maximum grayscale value in 16 neighborhood field respectively. According to the above method, the final point set of the contour is attained to complete rough localization to the inner edge of the iris, which is shown in Figure 5.

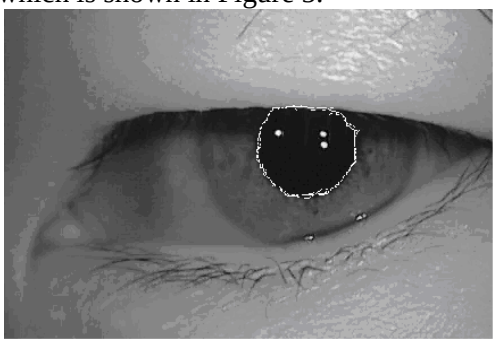

Figure 5. The Final Contour Point Set of Pupil

3.3.2 The Precise Localization of the Inner Boundary

After the rough localization of the inner boundary, the center of the final contour point set can be regarded as the center of the pupil.

$$C = v_c = \frac{1}{N} \sum_{n=0}^{N-1} v_t \tag{15}$$

v_t is the final points set of the contour, and the average value of the distance from v_t to the center is regarded as the radius of pupil.

$$R = \frac{1}{N} \sum_{i=0}^{N-1} \left| v_t - v_c \right| \tag{16}$$

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C and *R* have a certain distance to the accurate inner boundary, and the circular gradient operator proposed by daugman is used to localize the precise inner boundary. The physical meaning of circular gradient operator is to search for the precise positioning results of which the biggest change value of the average value of the corresponding pixel grayscale value corresponding to (r, x_0, y_0) is regarded as the inner edge with r change of the circular radius detection operator. (x_p ,y_p, r_p) is the rough location result as the pupil edge parameters, namely (x_p ,y_p) for the *C* coordinates, r_p=*R*. In order to improve the speed of iris inner edge localization, the search scope of the pupil edge parameters is limited in the neighborhood area of (x_p ,y_p) as the center, and the size of 20*20. The variation range of radius is limited in the interval [r_p-20, r_p+20], and finally the accurate parameters for the inner edge is (X_P,Y_P,R_P).

4. The Localization of Iris Outer Boundary

The transition area of iris outer boundary is generally wide and the grayscale value is not higher than that of the inner boundary. In addition, the rich texture information of iris (such as nerve ring) will affect the iris outer edge localization. If the circular gradient operator of Daugman is used, sometimes, the iris outer boundary will not be localized precisely. Therefore, the surface integral [8] is employed for external boundary location.

The surface integral is similar to the circular gradient operator of daugman, but only one difference is that with the *R* change of the circle radius, the calculation of the surface integral is the difference of the mean grayscale value between the two adjacent circles containing pixels. Because the center distance of iris inner and outer edges is in a certain range [9], the distance is less than d_o.

$$\sqrt{(x_0 - x_p)^2 + (y_0 - y_p)^2} \le d_o \tag{17}$$

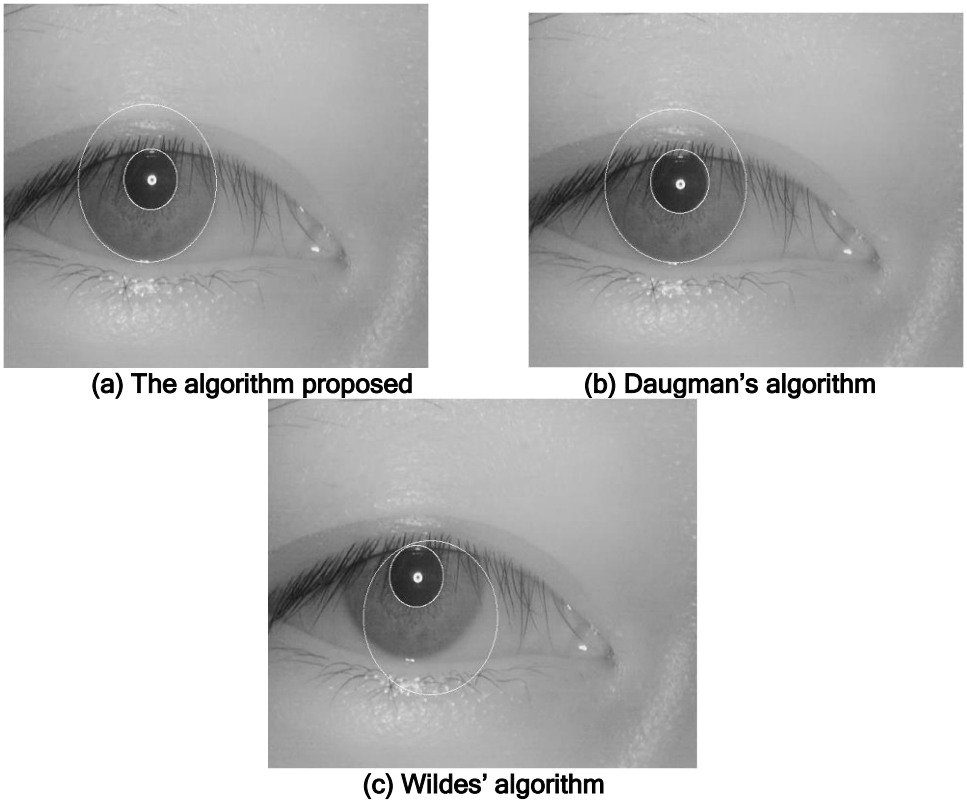
Where d_o=15, the surface integral is adopted to localize the iris outer edge, and the search interval of outer edge parameter: $x_0 \in [x_p\text{-}15, x_p\text{+}15]$, $y_0 \in [y_p\text{-}15, y_p\text{+}15]$, $r \in [80, 130]$. In the normal condition, the eyelids will cover a portion of the iris, so that the integral region is generally limited in the fan-shaped region between $[-\pi/4, \pi/4]$ and $[3\pi/4, 5\pi/4]$. Finally, the outer edge parameters are (X_I, Y_I,R_I).

5. The Results and Analysis of Experiments

Before localizing the iris, the template size is 3*3, and standard deviation σ=1 of Gauss low pass filter s is used to remove smoothly the noise of the iris image.Experimental iris samples from CISIA (V 2.0) iris database, there are a total of 60 different eyes, and each eye has 2 images and a total of 120 eye images. Compared with the classical daugman and wildes algorithms, the localizing performance is shown in Table 1. An localization results example of the same iris image by using the three algorithms are shown in Figure 6, The localization results shows that the results of daugman's algorithm and the algorithm proposed is accurate,but the results of wildes' algorithm is unsatisfactory.

Table 1. The Performance of Iris Localization

Algorithm	Accuracy rate /%	Average time /s
Daugman's algorithm	94.2	11.7
Wildes' algorithm	91.1	14.7
The algorithm proposed	97.2	4.28



(a) The algorithm proposed (b) Daugman's algorithm

(c) Wildes' algorithm

Figure 4. The Results of Iris Location

6. Conclusion

An algorithm of iris localization based on the active contour model is proposed. First, the thresholding image is used to localize roughly some pupil edge points as the initial contour point set. Then, the continuous evolution of the energy function approaches the real pupil contour. Finally, the circular gradient operator is employed to localize precisely the iris edge. Algorithm experiments are based on CASIA (V 2.0) iris database. The experiment results show that the localization effect of the proposed algorithm method is better than that of the classic daugman's algorithm and wildes' algorithm.

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