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An effective iris location method with high robustness

RONGNIAN TANG[*], JIUQIANG HAN, XINMAN ZHANG

Xi'an Jiaotong University, School of Electronics and Information Engineering,
28 Xianning West Rd, Xi'an 710049, P.R. China

[*]Corresponding author: rongnian.tang@gmail.com

Now, iris recognition is a topiocal issue. This paper focuses on iris location, which is an important stage in iris recognition, and develops a new method for that purpose. Use has been made of dilation operator in order to suppress the interference of eyelash, and support vector machines (SVM) classifier has been employed to identify the iris boundary. The results of experiment carried out on iris image database showed the method proposed to have an encouraging performance. Compared with the traditional methods, those of Daugman and Wildes, this method offers a higher correct location ratio and is more computationally efficient.

Keywords: iris location, boundary recognition, support vector machines (SVM).

1. Introduction

In recent years, iris recognition has become a hot area of the biometrics technology due to its high reliability, uniqueness, noninvasiveness and stability for personal identification [1–7]. The human iris is an annular part between the pupil (the black central area in the eye) and sclera (the white area in the eye). In general, the iris recognition includes iris location, feature extraction and iris matching. The literature published shows that iris location is one of the key steps in iris recognition system because it not only consumes about 20%–40% of the entire time needed for iris recognition, but directly affects the result of the latter [2, 4, 6].

This paper develops a new method for iris location aimed to save location time and improve correct location ratio. The remainder of this paper is organized as follows. Section 2 briefly reviews some existing location methods. Section 3 provides detailed descriptions of theory and steps of our method. Experimental results and discussion are provided in Section 4. Finally, Section 5 concludes the paper.

2. Related work

The iris is an annular portion between the pupil (inner boundary) and the sclera (outer boundary). Both of the boundaries can be taken as circles which are usually not concentric [1]. So, the task of iris location is to find these two circles and compute their exact parameters. Now, much work has been done on iris location, the methods of Daugman [1] and Wildes [4] being the most well-rounded ones. Daugman's method used integrodifferential operator as circle search operator to search over the image domain for the maximum with respect to increasing radius, of the normalized contour integral along a circular arc of radius and center coordinates. Wildes' method converted the eye image into a binary edge-map via gradient-based edge detection, then voted to get the parameters of iris boundaries by Hough transforms. However, both of them have two disadvantages:

– computationally, they are tedious. Especially, Wilde's method [4] is very computationally demanding because it introduces lots of edge points of other objects, such as eyelashes and eyelids, in Hough transform;

– they are lacking in robustness. The correct ratio of location of them seriously drops followed the increasing eyelash or eyelid.

In order to overcome the limitation mentioned above, a new location method is developed as below. The method uses the dilation operator of morphological to locate the iris inner boundary, and the support vector machines (SVM) to gain the iris outer boundary.

3. Introduction of our approach

3.1. Iris inner boundary location

Although the iris inner boundary is easily distinguishable and can be located correctly by Daugman's and Wildes' methods, both of them are computationally tedious. The proposed method can reduce the expenditure of time without inducing any negative effect to location result. Considering the shape of eyelash as the fine nondirectional slit in the background of eye image, the elimination of the eyelash interference can be seen as a process filling up these fine slits by mathematical method. So, the dilation operator, is introduced into our method for inner boundary location,

$$(f \oplus b)(s, t) = \max\left\{ f(s-x, t-y) + b(x, y) \,\middle|\, (s-x), (t-y) \in f;\ (x, y) \in b \right\} \tag{1}$$

where $\oplus$ denotes the dilation operation, f is the eye image, b is the structuring element.

As mentioned above, the detail stage for iris inner boundary location using morphological can be listed as below, and the part of result of the stage are shown as in Fig. 1.

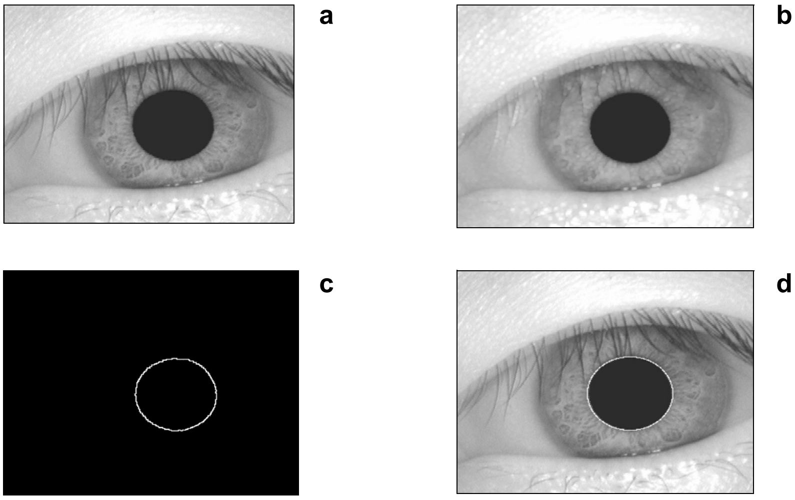

Fig. 1. Iris inner boundary location: the original image (**a**), operated by dilation operator (**b**), edge detection (**c**), location result (**d**).

1. Suppressing eyelash interference by dilation operator:

$$I_1(x, y) = I_0(x, y) \oplus B \tag{2}$$

where $\oplus$ and $I_0(x, y)$ denote the dilation operation and original eye image, respectively, B is a 3×3 square structuring element.

From Figure 1**b**, the most of eyelash melt into image background. Obviously, the dilation operator suppresses the eyelash interference effectively.

2. Binarization and edge detection. Because the gray-level value of eyelash becomes whiter, the iris inner boundary can be get easily and quickly by the binarization operation and edge detection operator in morphological. The result of edge detection is shown in Fig. 1**c**;

$$I_2(x, y) = \mathrm{Bin_r}(I_1(x, y)) - \left[\mathrm{Bin_r}(I_1(x, y)) \odot B\right] \tag{3}$$

where $\mathrm{Bin_r}$ is the binarization of image with threshold r, $\odot$ denotes the eroding operator of morphological, $I_2(x, y)$ is the edge detection image.

3. Obtaining the circle centre and radius of inner boundary by Hough transform:

$$(x_i, y_i, r) = H\left[I_2(x, y)\right] \tag{4}$$

where H is the Hough transform, (x_i, y_i, r) is the circle center and radius of the iris inner boundary.

As the number of pixel which votes to iris parameters through Hough transform is reduced largely, it makes Hough transform more computationally efficient. Otherwise, because Hough transform is hardly affected by local information, the robustness of the proposed method does also enhance. Figure 1**d** shows the result of location.

3.2. Iris outer boundary location

From Figure 1**a**, we can see that the iris outer boundary is not as sharp clear as inner boundary, and can be interfered easily by eyelash, *etc*. The experiment shows that the location correct ratio of Daugman's and Wildes' methods drops down seriously following the increasing eyelash interference. In order to resolve this problem, the proposed method treats the boundary location as classification of pixels.

Support vector machine (SVM) provides an efficient approach to the problem of classification by the kernel mapping technique. The SVM can always find the global and unique minimum, and shows excellent performance in nonlinear and higher dimensional applications. Let $S = ((x_1, y_1), \ldots, (x_i, y_i))$ be a linear non-separable set. Using the Karush–Kuhn–Tucker (KKT) condition, the classification function can easily gain by the SVM [8]:

$$f(x) = \operatorname{sgn}\left[\sum y_i \alpha_i K(s_i, x) + b\right] \tag{5}$$

where $K(s_i, x) = \psi(s_i) \bullet \psi(x)$ is the kernel function which is the dot product of $\psi(s_i)$ and $\psi(x)$, α_i is the Langrange multiplier, s_i is the support vector, b is constant.

Because gray-level changes or gradient of eyelash, and iris boundary are different in different directions, the iris outer boundary can be found by classification. The detail stage is shown as below and in Fig. 2.

1. Let $T\{t_1, t_2, \ldots, t_N\}$ be the training set, $t_i = (x_i, y_i)$ the training data composed of feature vector x_i, including the gradient in a 3×3 region of an pixel $p(m, n)$ from an sample eye image which chosen prior, and scalar y_i, which is

$$\begin{cases} y_i = +1 & p(m, n) \text{ is boundary pixel} \\ y_i = -1 & \text{otherwise} \end{cases}$$

The proposed method chooses polynomials, $K(x_i, x_j) = (x_i \bullet x_j + 1)^d$, as kernel function. Then, the SVM classifier is

$$f(x) = \operatorname{sgn}\left[\sum_{i=1}^{N_s} y_i \alpha_i K(s_i, x) + b\right] \tag{6}$$

2. For location, the gradient information of every pixel of eye image $P_0(m, n)$ constructs as same as the feature vector which be used in training process. Then, the vector x is identified by the SVM classifier expressed by Eq. (6). The result of classification is the iris outer boundary image $P_1(m, n)$.

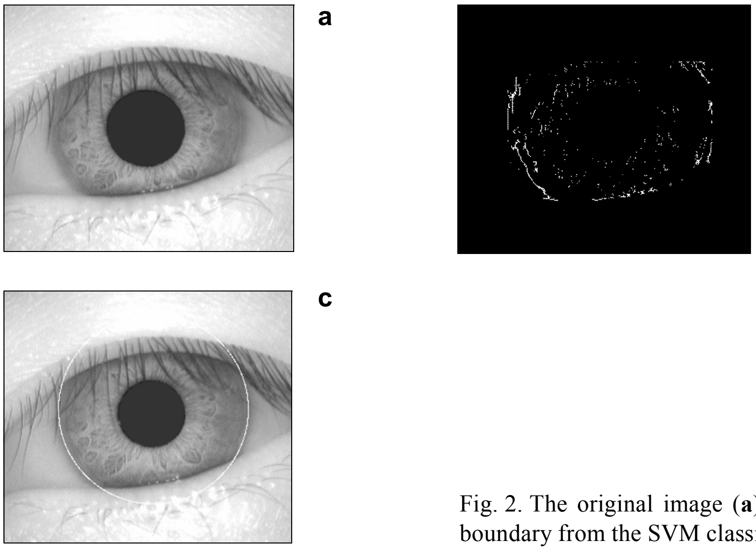

Fig. 2. The original image (**a**), the contour of iris outer boundary from the SVM classifier (**b**), location result (**c**).

Note that the image $P_0(m, n)$, is obtained as a result of dilation operation of the origin eye image, because the dilation operation can suppress the majority of eyelash interference and make classification more accurate.

The experiments show that the proposed SVM classifier can remove the majority of other objects, and preserve a perfect outline of iris boundary. The result is shown in Fig. 2**b**.

3. For obtaining the parameters of iris outer boundary, the proposed method adopts the Hough transform to calculate

$$(x_0, y_0, r) = H\left[P_1(m, n)\right] \tag{7}$$

where H is the Hough transform, (x_0, y_0, r) is the circle center and radius. Figure 2**c** shows the location result.

Mostly, the contour of iris outer boundary which is obtained by SVM classifier is not intact, but applying the Hough transform we can calculate the parameters of circles by that information. Of course, the Hough transform is time-saving in this case because the most of the unrelated pixel is removed.

Note that if the iris region is roughly determined at first by the gray-level value, the SVM classifier will become more computationally efficient.

4. Experiments and results

To evaluate the performance of the proposed method, we apply it to the CASIA ver1.0 [9] database, and present a detailed comparison with the methods of Daugman and Wildes, implemented according to the published papers [2, 3] and the open codes

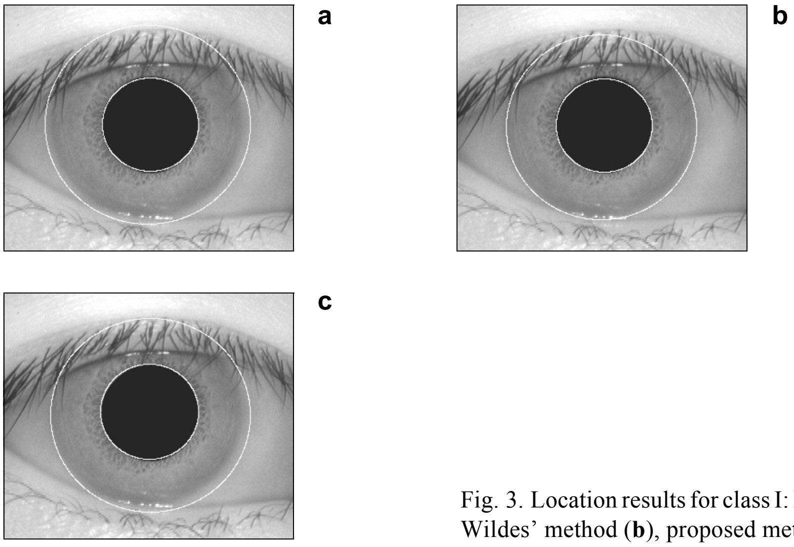

Fig. 3. Location results for class I: Daugman's method (**a**), Wildes' method (**b**), proposed method (**c**).

of MASEK [7]. All of the algorithms are implemented in MATLAB 7.0 and executed on the same computer (Celeron 2.6 GHz, CPU 192M RAM). Note that the original eye images are classified into class I (lighter interfered) and class II (seriously interfered), according to the extent to which iris boundaries are overlapped by eyelash and eyelid. All of the experiments were completed in same environment.

4.1. Qualitative comparison

This experiment is designed to compare the location performance of the three methods. Figures 3 and 4 show the location result for class I and class II, respectively.

Obviously, Fig. 3 shows that all three methods can locate the iris boundaries correctly, and there are hardly any differences between the results. Certainly, it suggests that the proposed method can locate the iris, and the new idea of the proposed method is right.

From Fig. 4, one can see that Daugman's and Wildes' methods give incorrect results, but the result of the proposed method is satisfactory. The robustness of the proposed method is due to the dilation operator and SVM classifier, which have a powerful suppressing ability to the eyelash and eyelid. Thus, the proposed method is an iris location method which offers satisfactory performance.

This experiment shows that the proposed method can complete iris location even for a seriously interfered image. It is more robust than Daugman's and Wildes' methods.

4.2. Quantitative comparison

In the experiment a comparison was made of the correct location ratio and the expenditute of time of the three methods. Table 1 shows the results obtaining using

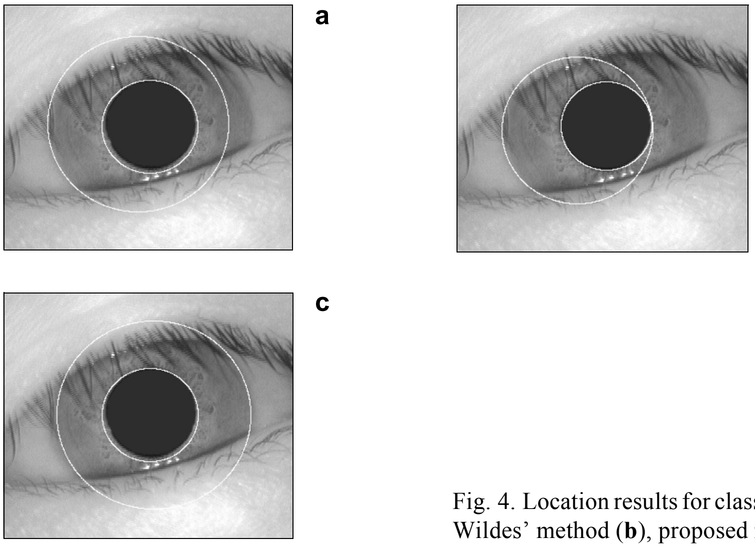

Fig. 4. Location results for class II: Daugman's method (**a**), Wildes' method (**b**), proposed method (**c**).

the three methods with reference to particular class, and Table 2 lists the results for both classes.

Table 1 is designed to test whether the proposed method can give perfect performance or not. By quantitative data, the different of these methods can be illustrated clearly. From Table 1 it follows that, the proposed method has better performance than the other methods for both classes. Whether it is class I or class II, the proposed method not only reduces the location errors, but makes it more computationally efficient.

Especially, we can also see from Tab. 1 that the performance of proposed method is better than that of Daugman's method and Wildes' method when eye image is

T a b l e 1. Results obtained using the three methods for different classes (CLR: correct location ratio).

	Time [s]		CLR [%]	
Method	I	II	I	II
Daugman	6.82	8.26	94.6	93.1
Wildes	13.75	16.6 8	94.8	92.4
Proposed	2.85	3.01	97.26	97.08

T a b l e 2. Results obtained with the use of three methods for all images (CLR: correct location ratio).

Method	CLR [%]	Time [s]
Daugman	93.85	7.52
Wildes	93.6	15.24
Proposed	97.17	2.94

interfered seriously. So, it can be concluded that the proposed method is more robust than the other methods so far as the interference of eyelash is concerned.

Table 2 is designed to compare the performance form whole view, and can give a global impression about all of the three methods. The data from Tab. 2 illustrate the satisfactory performance of the proposed method. Compared with Daugman's and Wildes' methods, the proposed method can make the correct location ratio increase by 3.28% and 3.57%, respectively. Similarly, the expenditure of time in the location process is reduced to 60.9% and 80.7%, respectively.

5. Conclusions

Based on the above comparison and data analysis, we can draw a number of conclusions:

1. Unlike Daugman's and Wildes' methods, the proposed method accomplishes the iris location task according the different characteristics of iris for different location stages. In other words, the proposed method cannot only make the computations more efficient, but also improve the correct location ratio at the same time. The experiments prove that the idea of the proposed method is quite feasible.

2. This paper develops an iris location method combining the morphological operator and SVM classifier. A series of experiments show that the proposed method has satisfactory performance. The method can suppress most interference coming from the eyelash and so on, and has higher stability characteristic.

3. Compared with Daugman's and Wildes' methods, the proposed method can make the correct location ratio increase by 3.28% and 3.57%, respectively, and reduce the location time expense to 60.9% and 80.7%, respectively.

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