A robust iris segmentation using circular and linear filters

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Abstract

In iris recognition, iris segmentation plays a very important role because its accuracy affects directly to the performance of the whole system. This paper proposes a new approach for segmenting iris that is fast, accurate and especially robust to occlusion and illumination. In this method, a circular filter is used for detecting the center of the inner circle. Then, a technique to linearize the limbus is applied and the limbus is detected using a linear filter. Experimental results show that the proposed method has promising performance for improving the iris recognition accuracy.

1. Introduction

Personal identification based on biometrics is becoming a potential technology in the future once the traditional secure tools have disclosed some disadvantages. Iris recognition is relatively new compared to other biometric technologies. However, it has been receiving extensive attention from scientists and researchers because of its reliability [1]. There have been many approaches to the problem and considerable results have been achieved.

Iris is a donut region between pupil and sclera in which there are many freckles, coronas, stripes, etc. These features make iris unique to each individual [2, 7]. This paper proposes a fast and robust iris segmentation algorithm by using a circular filter to detect the boundary of the pupil and a linear filter to detect the limbus of the iris.

1.1 Related works

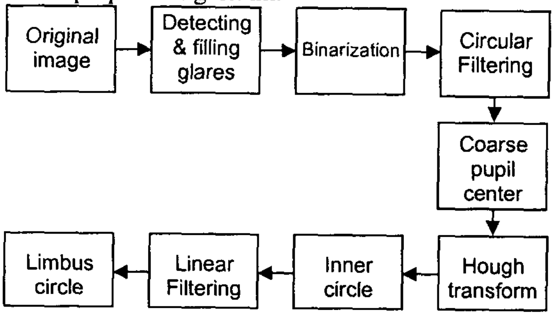
In the iris recognition domain, many methods have been proposed, essential to list here are the phase-based method by Daugman [3-5, 19], the zero-crossing representation method by Boles and Boashash [6], and the texture analysis based method by Ma, et al [8].

As for iris segmentation, many approaches have been proposed also. Daugman uses integro-differental operators that behave like circle edge detectors to detect the inner and outer boundaries. A similar process is used to detect the upper and lower eyelids. Wildes, et al [2, 9] use Canny edge detector and circular Hough transform to detect and locate two boundaries and two eyelids. In order to speed up the Canny edge detector and the circular Hough transform, Ma, et al [8, 10, 11] use some pre-processing calculations to detect the coarse pupil center before applying the tools. Lili and Mei [12] try to use the sudden change of intensity derivative when passing horizontally over the boundaries. They also propose in the paper an approach to evaluate the quality of iris images. Bonney, et al [13] use morphological operations such as erosion and dilation to find out a collection of cardinal edge points, and then an elliptical curve is fitted to the collection. Also, Zhang, et al [14] propose an algorithm based on the AdaBoost algorithm and neural networks, and Morimoto, et al [15] introduce an iris segmentation technique based on active lighting. Some other approaches can be found in [16-17].

Iris recognition usually includes four steps: iris segmentation (detection and localization), iris normalization, feature extraction and matching. Although each step has its importance, iris segmentation is the key step in the entire process because the failure in this step leads to failures in subsequent steps.

1.2 Proposed method

This paper introduces a new method for segmenting iris from an iris image. At first, the input image is detected and filled in glares, if present. Next, the image is binarized by dynamically choosing a suitable threshold. The binary image is then processed by a circular filter for detecting the coarse center of pupil. Next, an approximate radius of pupil is evaluated and a small region containing the iris is extracted from the original image. The circular Hough transform is applied to this extracted image to detect the inner circle more accurately. Finally, two small arc regions centered at the pupil center are extracted and converted to the rectangular coordinate. In these converted images, the limbus now becomes lines. The detection of limbus is performed by detecting these lines. The following is the diagram of the proposed algorithm.



2. Segmentation of iris

Segmentation of an iris image means to detect the inner boundary (between pupil and iris) and the limbus (between iris and sclera). In this approach, the inner boundary is detected at first, and the limbus is then located depending on this circle.

2.1 Circular filter

A circular filter is a square matrix (figure 1) that has values of 1 within the white circular region and -1 in the rest. Also, the area of the white circular region equals to that of the black region. In other words, the number of 1 equals to the number of -1.

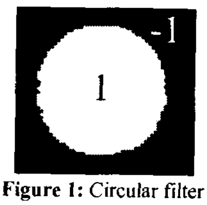


Figure 1: Circular filter

This filter is designed to detect centers of circular shapes in images such as glares and pupils. When an image is processed by this filter, the intensity values at the centers of circular shapes will stand out. Figure 2 illustrates an example.

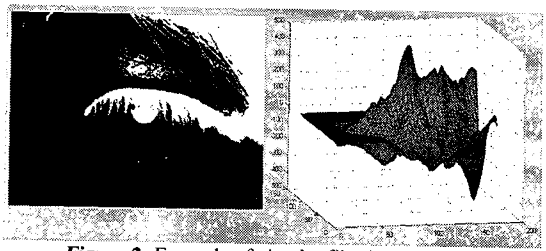


Figure 2: Example of circular filtering to detect pupil

In figure 2, the left image is the binary image (the white is +1 and the black is -1) to be filtered and the right is the filtered image. The area of white regions are larger than that of the circular region, but the value after filtering of the circular-shape region still stands out. That is because when the filtering point is the center of the circular shape, values are small in the black region of the filter, therefore the sum of intensity values is the largest. On the contrary, when the filtering point is in the big white regions, values in the black region of the filter are high, so the sum of intensity values is small.

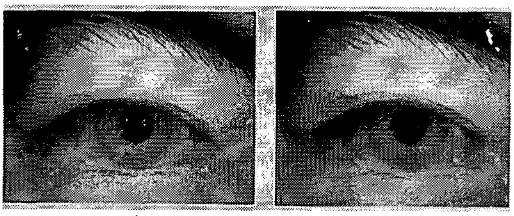
By changing the radius of the white circular region (hereafter referred as the radius of the filter), we are able to detect many circular shapes in different sizes. This radius should approximate the radius of the circular shapes whose centers need to be detected.

2.2 Pupil detection

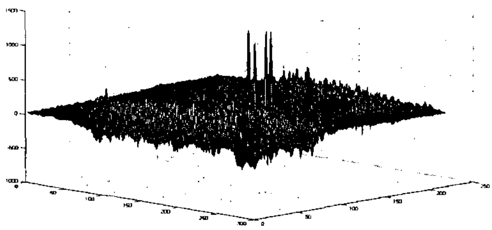
2.2.1 Detecting glares and binarizing image

At first, an instance of the circular filter is used to detect and fill in glares. Commonly, glares in iris images have circular shapes, thus we can apply the filter with a suitable radius. By thresholding the filtered image, we obtain a set of pixels of high values in the image. The size of this set should be smaller than another threshold to make sure that they are really glares. Figure 3 shows an experimental result.

After detecting and filling in glares, the image is binarized by dynamically choosing a threshold which depends on the image. In this approach, 10% of pixels of lowest intensity values are chosen and set to 1. The remaining pixels are set to -1 instead of 0. This will later make the performance of the filter better. Figure 4 illustrates an example.



a) b)



c)

Figure 3: An application of the filter to detect glares: a) the image to be filtered, b) glares detected, c) surface of filtered image

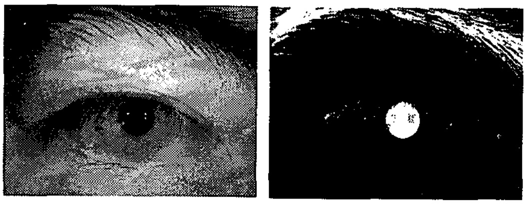


Figure 4: An example of binarization

2.2.2 Pupil detection

Once again, the circular filter is applied to detect the coarse center of the pupil in the binary image. The binary image is processed with a circular filter whose radius is close to the real radius of the pupil in the iris image. For example, in CASIA [18] iris database, the radii of the pupils are in the range (28, 75) in pixels, so we can choose the filter's radius of 50. However, since the shape of the pupil is important here, we can resample the input image to a smaller size in order to reduce the running time. The maximum value of the filtered image is referred as the coarse center of the pupil. Then, a small region of the input image centered at this coarse center is extracted, and the circular Hough transform is applied to this small extracted image to accurately find out the inner circle.

Because of the small size of the extracted image the circular Hough transform is less time-consuming. Furthermore, we can apply a small step to evaluate the coarse radius of the pupil before applying circular Hough transform, and we can therefore decrease the range of searching radii in the circular Hough transform method. This step will be described in details in the next section. An illustration of this process is given in figure 5.

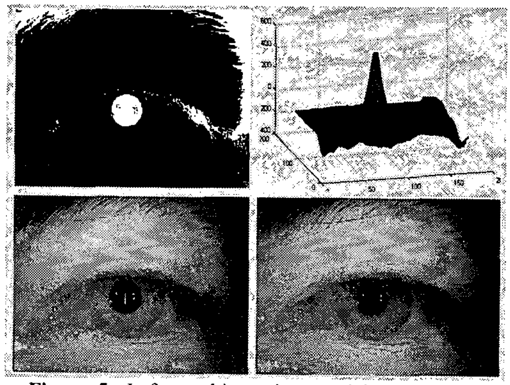


Figure 5: Left-top: binary image, right-top: plot of the image filtered with the circular filter, left-bottom: coarse pupil center, right-bottom: the inner boundary after applying circular Hough transform.

2.3 Limbus detection

After the detection of the inner boundary, the remaining work is to detect the limbus. To do this, two small regions whose inner edges are parts of the inner boundary; outer edges are parts of a circle centered at the pupil center which is big enough to ensure that it will include the limbus; top edges are the horizontal line going through the pupil center; bottom edges are the lines which create with the horizontal line angles of 225° and 315° respectively, are extracted (figure 6).

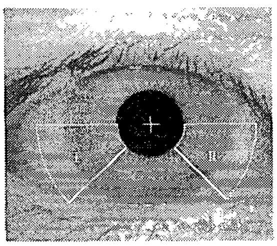


Figure 6: Two arc regions that are good for limbus detection

These regions are then converted to the rectangular coordinate using the homogeneous rubber sheet model by Daugman [19]. In the converted images, parts of limbus circle become lines, and thus instead of detection of circle, it is now easier to detect lines. A linear filter for searching horizontal lines is applied here. The filtered images are then binarized: 15 percent of pixels of the highest values are set to 1, the rest to 0. Next, these images are projected horizontally:

$$v_k(i) = \sum_j J_k(i,j), \qquad k = I, II \qquad (1)$$

where J_k are the filtered images. The maximum values of these vectors, after smoothed, are referred as the distances d_I, d_{II} from the inner boundary to the limbus respectively. The radius of iris is determined as below:

$$r_i = r_p + \frac{d_I + d_{II}}{2} \qquad (2)$$

where r_p is the known radius of pupil. The center of iris is determined:

$$x_i = x_p + \frac{d_{II} - d_I}{2}$$
$$y_i = y_p \qquad (3)$$

where x_i, y_i are x and y coordinates of the iris; x_p, y_p are x and y coordinates of the pupil. Figure 7 shows an illustration to get d_I from the region I in figure 6.

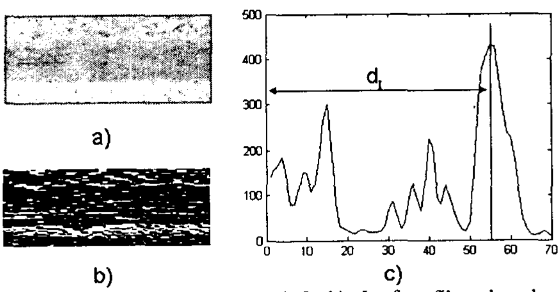


Figure 7: a) the converted I_I, b) I_I after filtered and binarized, c) plot of the vector which is the result of projection of b) in the horizontal direction

A similar procedure can also be applied to the section 2.2.2 to gain the coarse radius of pupil in order for the algorithm to reduce the running time by decreasing the running time of circular Hough transform.

3. Experimental results

The algorithm is tested on the CASIA database. There are two versions in this database. The version 2 is good for testing the robustness of algorithms to occlusion, pupil dilation, the present of hairs, make-up, reflection, illumination, off-focus etc. A collection of images which are in bad quality due to these factors were chosen and tested. The performance of the proposed algorithm shows promising results. Also, the running-time of the algorithm is short, so that it can be realized in real-world systems. Typical results are shown in figure 8 where we can see the robustness of the algorithm to factors that affect the quality of the iris images the most.

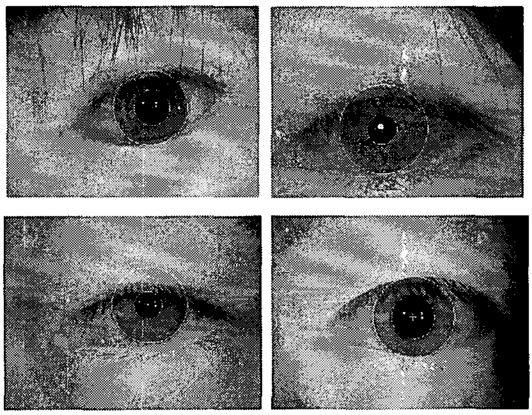


Figure 8: Some experimental results

5. Conclusions

This paper proposes a novel, robust and accurate approach to iris segmentation, which is considered to be the most time-consuming and the least accurate in the whole iris recognition. In practical application, iris images are not always in good quality condition due to many factors. Therefore, the systems should be able to cope with these disadvantages to enhance the quality of the performance.

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