Iris Location Algorithm Based on the CANNY Operator and Gradient Hough Transform

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Abstract. In the iris recognition system, the accuracy of the localization of the inner and outer edges of the iris directly affects the performance of the recognition system, so iris localization has important research meaning. Our iris data contain eyelid, eyelashes, light spot and other noise, even the gray transformation of the images is not obvious, so the general methods of iris location are unable to realize the iris location. The method of the iris location based on Canny operator and gradient Hough transform is proposed. Firstly, the images are pre-processed; then, calculating the gradient information of images, the inner and outer edges of iris are coarse positioned using Canny operator; finally, according to the gradient Hough transform to realize precise localization of the inner and outer edge of iris. The experimental results show that our algorithm can achieve the localization of the inner and outer edges of the iris well, and the algorithm has strong anti-interference ability, can greatly reduce the location time and has higher accuracy and stability.

1. Introduction

The human eye is made of three parts: the sclera, iris and pupil. The iris which is located between the sclera and the pupil contains the most abundant texture information, occupying 65% of the total texture information of the human eye. The iris is determined by genetic genes, so the characteristics of the iris, such as unique, stability and irreversible, are the material basis for the iris to be used for identification. Iris recognition is the most convenient and accurate method in the all biological recognition technology recently, and become the most promising biometric authentication technology in the twenty-first Century[1]. In the future, iris recognition will be used in the field of security, national defense and electronic commerce, etc. Iris recognition technology consists of iris image acquisition, location, feature extraction and matching. Iris localization is the key step of the iris recognition, and the accurate localization will directly affect the final recognition result. So the research of iris location is of great significance[2].

In recent years, iris localization algorithms include gray threshold segmentation method[3-4], active contour method[5], Integro-Differential Operators method[6-7]and Hough transform method[8], etc. Gray threshold segmentation is to compare the gray values of each pixel with the threshold, and to classify the pixels in the image according to whether or not it exceeds the threshold value. Threshold segmentation is a really nice way to separate the pupil, but this method can only be used to the iris image with uniform illumination[9-10]. Active contour method, that is snake model, is an effective method for image segmentation and edge detection, but it has large computational complexity and
poor anti-interference. The Integro-Differential Operators method uses the blind search method based on the annular geometric characteristics of the iris, so the detection time is long. Dr. Wildes, from the MIT Artificial Intelligence Lab, proposed the Hough transform algorithm, which gets the binary iris image, and then uses the Hough transform to locate the iris edge. The method needs to search the center and the radius of the circle according to the change of the three parameters, and the computation and storage are exponentially related to the parameter space, which makes the search become complex and takes a long time, so it doesn't work with a lot of images[11]. The iris localization algorithm proposed by Wang Yunhong and Tan Tieniu of the Institute of automation of Chinese Academy of Sciences uses the binary image to separate the pupil, and the Canny operator is used to extract the edge of the image. Then the outer boundary is fitted by the least square algorithm. However, due to the presence of low gray areas beyond the pupil, the method still fails to locate the pupil accurately. In the study of iris localization algorithms, researchers have to keep improving. With the continuous development, a variety of iris localization algorithms have been developed[12-13], but there are always some defects and deficiencies, and a universal detection algorithm has not been found yet[14].

The data in this paper were obtained by the pupil detection instrument which was developed by Kunming Animal Research Institute of Chinese Academy of Sciences. The obtained images contain noise such as eyelids and eyelashes, and the whole image is not obvious gray change, so it is very difficult to locate the inner and outer edges of iris. In this paper, a Canny operator and gradient Hough transform algorithm were proposed for locating the inner and outer edges of iris. Firstly, Gauss low-pass filtering was used to smooth the image. Then, the hysteresis threshold Canny operator was used to roughly locate the inner and outer edges of iris based on the gradient information of the image. Finally, the gradient Hough transform was used to realize the precise localization of the inner and outer edges of iris according to the rough positioning image.

2. The rough positioning for the inner and outer edges of iris

2.1. Data acquisition

In highly non-invasive systems, the position and size of the iris in the image will change. At the same time, the change in the size of the iris’s inner border (the pupil) will cause deformation of the iris texture. The data in this paper take into account the actual situation, the subjects were stimulated by visual stimuli in the acquisition process, so the pupil in the collected data would scale, and that is, the iris of the same subject was different in size and location. The data were collected using a pupil detection instrument, which was developed by Kunming Animal Research Institute of Chinese Academy of Sciences. The subjects were all 18–23 years old, non-neurological, and healthy university students. The involved subjects are 300, 150 of them are male, and the other half are female. The used dataset has 150000 images and the environment condition during acquisition is bright. The collected iris image is shown in Figure 1.

Figure 1. The original image obtained

As is shown in Figure 1, the noise in the image is very high. Noises include eyelids, eyelashes, border lines and spots in the pupils. The whole image is concentrated in the low gray area; the iris is
almost indistinguishable from the muscle gray around it, so it is very difficult to locate the inner and outer edges of iris.

2.2. Preprocessing of iris images
Firstly, in order to enhance the iris part of the iris image, remove the interference of black lines from the upper and lower boundaries of the original image, so crop the image. The cropped image is shown in Figure 2. Then, because the gray level of the whole image is relatively concentrated, leading to the outer edge of iris is not obvious, and further preprocessing is necessary. The Gauss function was used to smooth the image, which can eliminate the local noise and protect the contour information of the object. The image after Gauss smoothing filtering is shown in Figure 3.

![Figure 2. Pre-processing 1-cropped image](image1) ![Figure 3. Pre-processing 2-image after Gauss filtering](image2)

The comparison between Figure 1 and Figure 3 shows that the interference of black lines at the boundary has been removed and that the iris portion of the image has been significantly enhanced at the same time.

2.3. The rough positioning for iris edges of Canny operator
Canny operator edge detection method has many advantages, such as no loss of crucial edges, without false edges, the deviation between the actual edge and the detected position at edges is minimum, the edge accuracy can be set by parameter to adapt to different classes of images, strong noise immunity and keep the weak edge. Canny operator is very suitable for edge detection of noisy images, so this paper uses Canny operator to roughly locate the inner and outer edges of iris.

2.3.1. The basic process of the Canny operator
Firstly, the annular two-dimensional Gauss function was used to smooth the image. Secondly, the gradient image and the angle image of each pixel in the image were calculated. Thirdly, the gradient amplitude image was suppressed with the non-maximum value according to the degree of the four directions of the gradient angle and the gradient value of each pixel point. Finally, hysteresis threshold processing and connection analysis were used to detect and connect edges.

2.3.2. Realization of the rough positioning for the inner and outer edges of iris
The results of edge location by the Canny operator are shown in Figure 4. As can be seen from figure 4, Canny operator is used to locate iris edge, and the location of inner edge is better than that of outer edge. But there's still a lot of noise.

3. The accurate positioning for the inner and outer edges of iris- gradient hough transform
Iris boundaries can be defined as circular model. Hough transform circle detection algorithm is affected by noise and boundary discontinuities very small, and the positioning accuracy is higher. So Hough transform circle detection is a good algorithm to locate the iris boundary. The method needs to search the center and the radius of the circle according to the change of the three parameters, and the computation and storage are exponentially related to the parameter space, which results in complex
search. The time consumption and memory requirement of the Hough transform are dramatically increased, which is almost impossible to achieve in practice.

![Rough positioning of iris inner edge](image1)
![Rough positioning of iris outer edge](image2)

**Figure 4.** The results of edge location by the Canny operator

The gradient Hough transform can reduce the computational complexity and solve the problem of invalid accumulation when the edge information is detected by using the information of the edge gradient direction and the continuity of the curve. By introducing the gradient direction information, the accumulated matrix of the circular contour measurement can be reduced from three dimensions to two dimensions, and then the Hough transform algorithm can be improved. The result of the accurate positioning for the inner and outer edges of iris using the gradient Hough transform algorithm are shown in Figure 5.

![Gradient Hough transform algorithm for accurate positioning of iris inner edge](image3)
![Gradient Hough transform algorithm for accurate positioning of iris outer edge](image4)

**Figure 5.** The accurate positioning of iris edges with gradient Hough transform

As can be seen from the figure, the gradient Hough transform can well locate the inner and outer edges of iris. There is a slight error in the results of Figure 5a because we assume that the inner and outer edges of iris are circular.

As can be seen from Figure 6, the algorithm used in this paper can well locate the inner and outer edges of iris.

4. **Experimental results**

When we collected data, we gave the subjects visual stimulation, so the pupil of each iris image was collected had a scaling process. The algorithm is applied to female subjects, male subjects and data which has large noise in eye movements. The result is shown in Figure 7-9.
Figure 6. The localization results for iris edges of the algorithm

(a) localization result of original image inner edge  
(b) localization result of original image outer edge

Figure 7. The localization results of iris edges in female subjects

Figure 8. The localization results of iris edges in male subjects
In Figure 7 and 8, subjects with different sexes can locate the inner and outer edges of iris in different pupil sizes. In Figure 9, the noises of three images are particularly large. Due to the impact of factors such as eye movement during data acquisition, iris outer edge is not successfully obtained. Moreover, in the case of eyelash interference, the algorithm can still locate the inner and outer edges of iris very well. In summary, the algorithm in this paper can realize the localization of iris both inner and outer edges, the percent of the iris that are correctly localized is 98%, and the anti-interference ability of this algorithm is very strong, which shows the superiority and accuracy of this localization algorithm.

5. Conclusions
For data containing eyelashes, spots and eyelids and other noise, especially the whole image of the gray concentration of the situation, on the basis of the original random Hough transform, a simpler and more accurate algorithm based on Canny operator and gradient Hough transform was proposed. First, the image was cropped and Gauss filtered. Then, through the transformation of image gradient, the Canny operator with hysteresis threshold was adopted to realize the rough positioning for the inner and outer edges of iris. Finally, the gradient Hough transform algorithm is used to locate the image accurately. In this paper, the algorithm overcomes the disadvantages of the traditional random Hough transform, such as the large amount of calculation and selection of many invalid points, avoid blind search, and effectively shorten the positioning time, more accurate positioning of the inner and outer edges of iris. Meanwhile, this algorithm can also achieve excellent inner and outer edge localization for noisy large iris images.

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