Iris Segmentation and Normalization Algorithm Based on Zigzag Collarette

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Abstract. In this paper, we proposed iris segmentation and normalization algorithm based on the zigzag collarette. First of all, iris images are processed by using Canny Edge Detection to detect pupil edge, then finding the center and the radius of the pupil with the Hough Transform Circle. Next, isolate important part in iris based zigzag collarette area. Finally, Daugman Rubber Sheet Model applied to get the fixed dimensions or normalization iris by transforming cartesian into polar format and thresholding technique to remove eyelid and eyelash. This experiment will be conducted with a grayscale eye image data taken from a database of iris-Chinese Academy of Sciences Institute of Automation (CASIA). Data iris taken is the data reliable and widely used to study the iris biometrics. The result show that specific threshold level is 0.3 have better accuracy than other, so the present algorithm can be used to segmentation and normalization zigzag collarette with accuracy is 98.88%

1. Introduction

Biometrics technology has grown rapidly this decade, a technology that uses human characteristics can be used as a self-replacing passwords or ATM card at a signing at the important place that requires a fairly high level of security [1]. Some biometric technologies such as fingerprint recognition and voice has been developed and attract attention but the required technology is sufficiently advanced so that the security system for the better. One biometric technology that is reliable and still needs to be developed is individual recognition through the iris texture [2]. Texture human iris are many and complex consists of two layers, namely epithelium layer and the stromal layer, the combination of that layer to form a color pattern that is very diverse and naturally occurring three months of birth [3], in addition to the iris pattern is unique even iris left and right eyes on each individual has a different pattern. When compared with other textures such as face, fingerprint or voice, iris texture is more stable due to the location of the iris in the body so that it can be used as a reliable individual recognition [4].

The method of segmentation and normalization in iris has role important to the next process, selection of part of the iris is very important because it determines the percentage of the introduction of the iris recognition system. [5] only select the $(175^0, 225^0)$ and $(310^0, 360^0)$ regions to detect iris outer boundary by using gradient operator for vastly reducing the obscured by eyelashes and eyelids.

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only select interval \((0, 45^\circ) \cup (105^\circ, 225^\circ) \cup (315^\circ, 360^\circ)\) to avoid noise by eyelid, in this paper, zigzag collarette area of the iris is selected for iris feature extraction because it captures the most important areas of iris complex pattern and concentric with the pupil. The radius of zigzag collarette areas is restricted in a certain range, in Figure 1 describes part of eye image

![Figure 1. Part of Eye image](image)

2. Iris Segmentation

2.1. Edge Pupil Detection

The pupil is a brown area that is in the middle of the eye, pupil color is very dominant and uniform so that it can be seen the differences between pupils and iris. Edge detection of the pupil is required to seek the boundary between pupil and iris, the method used in this study is the Canny edge detection with initial threshold. Canny edge detection has the advantage that the resulting edge as the edge of the actual picture [7]. Here is the Canny edge detection algorithm:

a. Convert image to binary image based on threshold with specific level
b. Removal of noise in the image so that it looks the difference between the edge and not edge with a Gaussian filter \(5 \times 5\)
c. Calculate the gradient intensity and direction of the edge with Sobel operator
d. Grouping toward the edges at an angle \(0^\circ, 45^\circ, 90^\circ, 135^\circ\)
e. Eliminate pixels which is not a maximum value in the direction of the edge by comparing two neighboring pixels
f. Eliminate lines disconnected as the edges of objects using two threshold values are \(T_1\) and \(T_2\).

Mathematically as follows:

\[
f(x, y) = \begin{cases} 
0 & , f(x, y) < T_1 \\
128, T_1 \leq f(x, y) \leq T_2 \\
225 & , f(x, y) > T_2 
\end{cases}
\]

(1)

In this study, the value \(T_1 = 0.5\) and \(T_2 = 0.5\)

Perform testing to get the condition in the Figure 2, as follows:

![Figure 2. Testing change the value 128 to 255](image)

In this research Canny algorithm successfully detects the edge of the pupil in Figure 3.

![Figure 3. Results Canny Edge Detection of eye image CASIA](image)
Figure (3). (a) an original image of gray of the database eye image CASIA seen that there is a difference of color contrast between the pupil with the iris, (b) the result of Canny edge detection visible edges boundary the pupil and iris.

2.2. Finding Circle Pupil

Pupil in the eye shape resembling the geometric shape of a circle so the edge between pupil and iris can be represented in the form of a circle. One method of image processing to detect the shape of a circle is a circle Hough transform [8]. This method requires a binary edge image as an input to describe artificial circles, then circles of artificial sought the maximum cut-off point to find the center point. For all edge points $(x_i, y_i)$, a Hough transform can be written as

$$H(x_c, y_c, r) = \sum_{i=1}^{n} h(x_i, y_i, x_c, y_c, r)$$ (2)

where

$$h(x_i, y_i, x_c, y_c, r) = \begin{cases} 1, & \text{if } g(x_i, y_i, x_c, y_c, r) = 0 \\ 0, & \text{otherwise} \end{cases}$$ (3)

where $g(x_i, y_i, x_c, y_c, r) = (x_i - x_c)^2 + (y_i - y_c)^2 - r^2$. The three coordinate $(x_c, y_c, r)$ for which $H(x_c, y_c, r)$ is highest will become the coordinate of centre and radius of the circle. In this experiment, the limit radius of between 28-50 pixels for CASIA database [9]. Circle Hough transform algorithm managed to find the coordinates of the center of the pupil and the pupil radius, as in Table 1 below.

| Number | Eye Image | Centre of Pupil | Radius |
|--------|-----------|----------------|--------|
| xxx.bmp | 135,183   | 37             |
| xxx.bmp | 141,183   | 50             |

By using the parameters of the center and the radius of the pupil, this research is described a circular shape on the original image with the pixel value $f(x, y) = 255$ where

$$x = A + r \cos \theta, 0 \leq \theta \leq 360$$ (4)
$$y = B - r \sin \theta, 0 \leq \theta \leq 360$$ (5)

In the image coordinates can be illustrated form above equation as follows.
2.3. Zigzag Collarette Isolation

The next processing is to isolate the area of the iris which is the area zigzag collarette. The area is selected for capture critical information from complex patterns of the iris, but it has little impact on noise such as eyelids and eyelashes. This area is generally concentric and close to the pupil so that this area used to detect the pupil center information and radius limited to a certain distance. In a study conducted by Rai concluded that the zigzag collarette is within 24 pixels of the pupil [10]. In this research zigzag collarette isolation area there are still noise around the pupil resulting geometric shape of the pupil is not completely circular, there are still the eyelashes and eyelids were a little caught up in the area so we need to make noise processing. The following steps are taken to isolate the area zigzag collarette:

a. Draw a circle with a distance of 24 pixels from the pupil
b. Closing pixels outside the zigzag collarette far as 40 pixels by 140 pixels values
c. Limiting the only region with a zigzag collarette equation
   \[ f(x, y) = g(x + x', y + y') \]  
   where \( x' = [A - r + 24, A + r + 24] \) and

4. Close the pupil and eyelashes with a threshold value
   \[ f(x, y) = \begin{cases} 
   140, & f(x, y) \leq 100 \\
   f(x, y), & \text{other} 
   \end{cases} \]  

5. Close the eyelid with a threshold value
   \[ f(x, y) = \begin{cases} 
   140, & 200 < f(x, y) \leq 255 \\
   f(x, y), & \text{other} 
   \end{cases} \]  

In Table 2 below is the result of processing to isolate areas zigzag collarette. The results obtained show that the area has been isolated zigzag collarette well.

**Table 2. Isolation zigzag collarette process**

| Draw zigzag boundary | Close outer zigzag | Limiting the only region with a zigzag collarette | Close the pupil and eyelashes | Close the eyelid |
|----------------------|--------------------|-----------------------------------------------|-------------------------------|-----------------|
| ![Image 1]           | ![Image 2]         | ![Image 3]                                   | ![Image 4]                    | ![Image 5]       |
3. Iris Normalization

Further processing is to change the iris shape which is represented by zigzag collarette circular area into a rectangular shape. [4] proposed normalization iris to reduce inconsistencies due to improper iris acquisition by converting to polar form, the method used is called the Daugman Rubber Sheet Model. In this experiment used the formulation Daugman Rubber Sheet Model to map the zigzag collarette into polar form as follows:

\[
I(x(r, \theta), y(r, \theta)) \rightarrow I(r, \theta)
\]  
(9)

with

\[
x(r, \theta) = (1 - r)x_p(\theta) + rx_z(\theta)
\]  
(10)

\[
y(r, \theta) = (1 - r)y_p(\theta) + ry_z(\theta)
\]  
(11)

where

- \(x_p(\theta)\) is the coordinates of the x-axis pupil boundary
- \(y_p(\theta)\) is the coordinates of the y-axis pupil boundary
- \(x_z(\theta)\) is the coordinates of the x-axis zigzag collarette boundary
- \(y_z(\theta)\) is the coordinates of the y-axis zigzag collarette boundary

The equation above interval radius is \([0,1]\) and interval angle is \([0,2\pi]\). This implies that the radius of zigzag collarette has a length of 1 unit while the radius pupil converted into units acquired

\[
f_p = \frac{r_p}{r_p + 24}
\]  
(12)

where \(r_p\) is the radius of the pupil in pixels.

The next step is to determine the length and width of a pixel on polar coordinates, the research conducted by Rai (2014) obtained the value of the length is 512 pixels and wide 64 pixels to obtain information zigzag collarette. Here are the steps in normalizing zigzag collarette:

a. Determine the length and width of a pixel on polar coordinates that is the width of M pixels and a length of N pixels
b. Calculate the difference of the radius of formula
\[
\Delta r = \frac{r_z - r_p}{M - 1}
\]  
(13)
c. Calculate the difference of angle of formula
\[
\Delta \theta = \frac{2\pi}{N}
\]  
(14)
d. Remapping of each pixel in accordance with the size of radius \(f_p + \Delta r\) and angle \(\Delta \theta\)

The results obtained show that the normalization process goes well and can map each pixel zigzag collarette to a rectangular shape in Figure 6.

![Figure 6. Normalized iris image](image)

4. Experiment Result

Our experiment are performed in MATLAB on a PC AMD A6 1.8 GHz and RAM 2 Gb. The images used in our experiments come from CASIA image database, in our experiments we used 90 images (3 images per person), the proposed iris segmentation and normalisation algorithm has been calculated and accuracy with specific threshold level. The experimental result is shown in Table 3 below:
Table 3. Accuracy of Specific Threshold Level

| Threshold Level | Accuracy |
|-----------------|----------|
| 0.2             | 88.88%   |
| 0.3             | 98.88%   |
| 0.4             | 97.78%   |
| 0.5             | 73.33%   |

Table 3 illustrates maximum accuracy rate of each level threshold. The result show that specific threshold level is 0.3 have better accuracy than other, so the present algorithm can be used to segmentation and normalization zigzag collarette with accuracy is 98.88%

5. Conclusion
In this paper, we present iris segmentation and normalization algorithm based on zigzag collarette. The iris image segmented based on zigzag collarette. Canny edge detection and Hough transform can be localized pupil near zigzag area very well then Daugman Rubber Sheet Model can represent isolation zigzag collarette. The experiment result show that algorithm high performance of 98.88 percent with specific threshold level is 0.3.

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