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New Approach of Iris Localization for Personal Identification

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Abstract

Iris region extraction is an important stage of iris recognition system. The correctness of iris segment allocation affects the recognition accuracy. In this paper, a sophisticated system for localizing iris region is introduced; the Leading Edge Detector (LED) method is utilized to detect the iris boundary points. Also, the developed system implies different image enhancement and analysis pre-stages to improve the performance of leading edge method and make it capable to allocate the boundaries of iris area under different radiometric condition. Many problems face the eye image processing tasks, mainly these problems are addressed under "noise area" appearance, among these problems are: eyelash, eyelid and specular reflections. The proposed method is based on the morphological attributes of iris image, taking into account the noise area may found at different regions of the eye image. A set of tests was conducted on a collection of iris images consist of 2639 images belong to CASIA V4.0, 756 images belong to CASIA V1.0, and 457 images belong to MMU V1.0 databases. The attained results show that the developed system has a good performance and the time required to perform iris localization is low in comparison with time required by the traditional methods.

Keywords: Biometric identification, Hough transform, Seed filling, CASIA, Segmentation.

1. Introduction

The human iris has recently attracted the attention of biometrics-based identification and verification research and development community [1]. Human iris is an internal organ of the eye and as well as protected from the external environment, yet it is easily visible from one meter of distance; which makes it a perfect biometric for an identification system [2].

Among the physiological biometrics, iris is an important feature of human body and it has the characters of uniqueness and stability. It is encircled by two concentric circles. The inner boundary is the junction of the iris and pupil which is defined by the gray scale change and the border where the outer boundary is the junction between iris and sclera which is characterized by smooth gray scale change and little vogue border. Several researchers in the field of human recognition have been conducted and investigated the iris localization tasks. The most well known iris segmentation approach is that proposed by Daugman [3] who become the inventor of the most successful commercial iris recognition system now. He made use of differential operator for locating the circular iris and pupil regions, along with removing the possible eyelid noises [4]. This algorithm achieves high performance in iris recognition, but it is having a drawback that, it suffers from heavy computation [5].

Wildes [6] proposed an iris segmentation method through using edge detection followed by Hough transform to locate iris boundaries. Much of the subsequent work on iris localization was built on this basic approach. Wildes et al [7] have made use of parabolic Hough transform to detect the eyelid, approximating the upper and lower eyelid with parabolic arc. Hung et al [8] investigated the implementation of iris localization on downscale eye image to reduce search space. Yahya and Nordin [9] referred that iris boundaries are not exactly circles. They applied direct least square fitting of ellipse to detect the inner boundaries of iris, then, they used Hough transform to detect the outer boundaries of iris. Ling and Brito [10] proposed an

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algorithm to speed up the segmentation process and to have accurate result. In 2011, Tariq et al. [11] proposed an iris segmentation method for pupil and iris localization. In the proposed algorithm pupil is localized using Eccentricity based Bisection method which looks for the region that has the highest probability of having pupil. While iris localization is carried out in two steps. In the first step, iris image is directionally segmented and a noise free region (region of interest) is extracted. In the second step, angular lines in the region of interest are extracted and the edge points of iris outer boundary are found through the gradient of these lines. T. Muhammad et al [12] investigated the implementation of iris localization based on a local histogram and standard deviation. The pupil region is detected by of enclosing the pupil by using a circular moving window. Once the pupil is localized, the effect of scattered eyelashes is minimized and the boundary of the iris is extracted based on the peaks of the first derivative of the rows within the pupil. All the above algorithms have its advantage and disadvantage, some of them focus on the accuracy rate of segmentation while other go toward minimize time computation.

In this paper, a sophisticated iris localization method is proposed using a combination of image processes; such as intensity thresholding, image equalization, smoothing, and some morphological operations. Image intensity thresholding and morphological operations are used to allocate the pupil region. The combination of image contrast stretching and smoothing operations are used to locate the iris outer boundary. The proposed method deal with two direction of iris localization by increasing accuracy rate of segmentation and reducing time computation.

2. The Proposed Method

Iris localization is an important step in iris recognition system; it is related to the exact allocation of iris boundaries. Human iris is an annular part between the pupil (inner circle) and the white sclera (outer circle) as shown in figure (1).

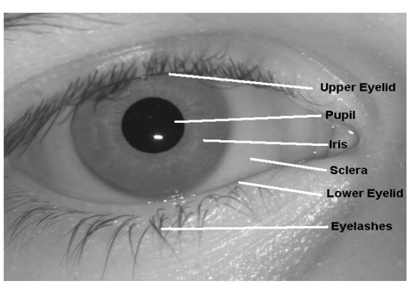


Fig. 1.The eye structure

The main stages of iris localization are: (1) pupil boundary detection for allocating the inner boundary of iris area and (2) outer boundary detection of iris area.

2.1 Iris Inner Boundary Localization

In order to detect the inner circle of iris, image intensity behaviour in both pupil/ eye is taken into consideration. The overall intensity value in pupil area is relatively smaller than its value in other region in the whole eye image. Beside to that pupil represents the largest connected and packed dark area will appear in the eye image. So, to get the benefit of these attributes the following steps were applied:

Step1 (Find a Seed Point): This stage consists of two steps

Step1-1 (Image Integration): In order to remove the effect of eye image artifacts, smoothing the eye image is produced by applying 21x21 mean filter.

Step1-2 (Select a Seed Point): A seed point in the pupil region (i.e., a pixel that shows lowest gray value) corresponds to the minimum pixel value of the image produced from previous step. Sometimes the eye image may contain dark and thick eyebrows, so to prevent the pixels belong to these regions from being considered as seed point the pixels belong the first 20% rows and the last 20% rows of eye image are excluded from seed point scanning domain. Also, the pixels belong to the first 20% columns and last 20% columns are excluded.

Step2 (Convert to Binary): In this step, the proper intensity value that used as threshold to binarize image into pupil and non pupil pixels should determined. Due to the wide range of variation of the brightness distribution of iris images; the task of finding an optimal threshold value applicable for all eye images is considered an irrational task. Also, for any threshold value, there may be some pixels which do not belong to pupil area and they may have intensity value less than the adopted threshold value. So, to handle these two problems the threshold value is determined according to the intensity distribution by using first order statistical analysis, and some cleaning steps are applied on the produced binary image to remove the non-pupil points.

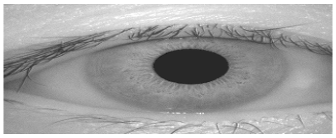
By analyzing the histogram of the original eye image the highest dark intensity value correspond to an accumulated histogram value close to 10% of the total image pixels is determined for CASIA (V4) database (which is 5% for CASIA V1.0, and 4% for MMU1 database). for example, for CASIA V1.0 database threshold value T should satisfy the following condition:

$$T < (0.05 * \text{eye image size})$$

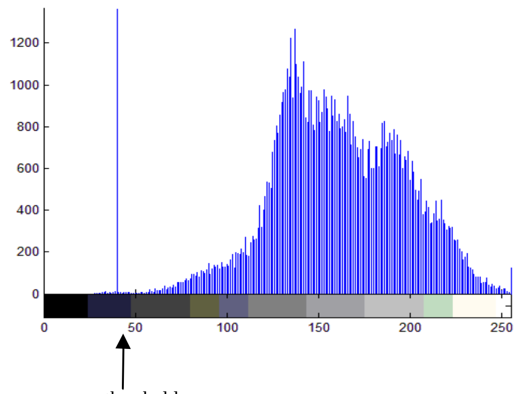
So, the intensity gray level that verifies this criterion is considered as a threshold value (T) as shown in figure (2). Then, all intensity values in the eye image below T are changed to 1 (object) and above or equal to T are changed to 0 (background), as:

$$g(x, y) = \begin{cases} 1 & \text{if } img(x, y) \leq T \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where img(x,y) is the intensity value at location (x,y), and g(x,y) is the converted pixel value.



(a) Original image



(b) image histogram

Fig. 2. Selecting threshold value T for image from CASIA V1.0 database

Step3 (Cleaning Operation): to remove the effect poses/gaps appearance in the produced binary morphology operations (i.e., erosions) is applied. The erosion operator is performed by taking window with size 3×3, then checking the centred of the window if its value is 0 then it will check its 8-neighboors if at least three pixels have the value 1 then the centred value will replace by 1 as shown from figure (3).

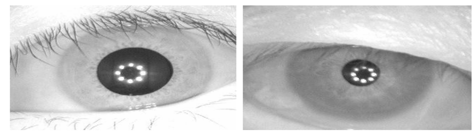
1	1	1
1	0	1
1	1	1

→

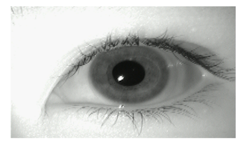
1	1	1
1	1	1
1	1	1

Fig. 3 . Erosion operation

Step4 (Removing Reflection Points): as shown in figure (4) CASIA V4.0 and MMU V1.0 databases contain white points in pupil region. In CASIA V4.0 the pupil region contain approximately eight white points distributed randomly in pupil region. In order to remove reflection points region growing on binary images from previous step is used to detect these points. Where the background represents the large white segment and other white points represent the reflection points which are converted to black points in late step.



(a) Iris images samples from CASIA V4.0



(b) Iris images samples from MMU V1.0

Fig. 4. Samples of iris images

Step5 (Seed Filling): to collect the pupil region the seed filling algorithm is applied using the selected seed point that found in step1-2. The first step in this algorithm is to save the seed point coordinates into a temporary point array type, and then starts checking its 4-neighboors, if any of the four tested points is found white then register it in the temporary array and convert the value of the detected white point to black.

Step6 (Compute Pupil Center): the pupil center (xp,yp) is computed by taking the average of points in pupil region in x-axis and y-axis directions according to the following formulas:

$$x_p = \frac{1}{N}\sum_{i=1}^{n} x_i, \quad y_p = \frac{1}{N}\sum_{i=1}^{n} y_i \quad (2)$$

Where N is the number of collected points in pupil regions.

Step7 (Compute Pupil Radius): from the point (xp, yp), we move around along the four directions (i.e., top, right, down, and left) and find the first background pixel in each direction. Let xl be the first background pixel to the left side that met the conducted horizontal scan along the line (y=yp) and xr be the first background pixel found at the right during the same horizontal scan. Then, the horizontal radius Rh is computed as follow:

$$R_h = \frac{1}{2}(x_l - x_r) \quad (3)$$

Let xb, xt be the first background pixels to the bottom side and top side, respectively those met during the vertical scan made along the column (x=xp). The vertically assessed radius Rv is computed as follow:

$$R_v = \frac{1}{2}(x_t - x_b) \qquad (4)$$

Then, the pupil radius Rp is computed using the following formula

$$R_p = \frac{1}{2}(R_h + R_v) \qquad (5)$$

Figure (5) illustrates the outcome results of each step.

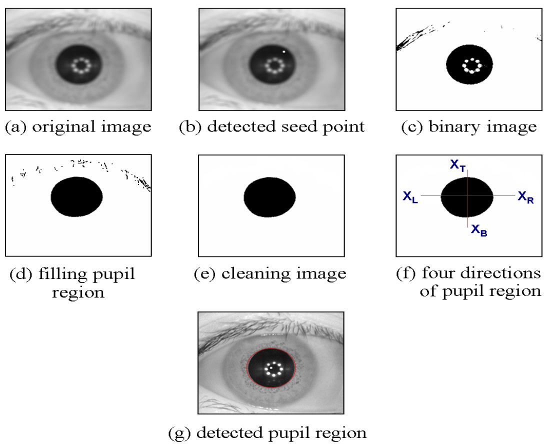


Fig. 5. Pupil detection steps

2.2 Iris Outer Boundary Localization

Because vertical scan may pass through black non-pupil area (such as eyelash, eyelid). Our developed iris segmentation method is dependent on finding the iris boundary points in horizontal direction, exclusively, by applying the following steps:

Step1 (Eye Image Enhancement): iris image consists of two regions (pupil, iris) and (iris, sclera). In order to make the border of the iris more apparent; at first we will apply histogram stretching based mapping process on the original eye image. This image mapping step can be done by applying the following steps:

A. Compute the image histogram.
B. Compute the mean (m) and standard deviation (σ) of the eye image.
C. Determine the Low and High values according to the following equations:

$$Low = m - \alpha \times \sigma$$
$$High = m + \alpha \times \sigma \qquad (6)$$

Where, α is the scaling factor whose value is within the range [1..3].

D. Then, the contrast stretching is done by applying the following mapping equation:

$$E(x,y) = \begin{cases} 0 & Img(x,y) \le Low \\ 255 \times \dfrac{Img(x,y) - Low}{High - Low} & \text{if } Low < Img(x,y) < High \\ 255 & Img(x,y) \ge High \end{cases} \qquad (7)$$

Where, E(x,y) is the enhanced image, Img(x,y) is the original image.

Step2 (Image Smoothing): It makes smoothing to the produced enhanced image, from step (1) using a mean mask with size 9×9 for t times, where the value of t is database depended. For CASIA V4.0, V1.0 the value of t is set 2 because the iris region is a sharp area, so the mean filter applied for two times only to prevent production of false edges. for MMU V1.0 the value of t is set 1 because the iris region is always appeared dark and smooth.

Step3 (Region of Interest): Find the relevant region of interest in the input image based on pupil parameters centers and radius (yc, xc, Rp). The pupil center is already known, so a crop is applied to region further than (size factor x Rp) where size factor is parameter its value depend on database. For CASIA the size factor is set 4, and for MMU the size factor is set 3.

Step4 (Horizontal Scan): because the vertical scan overlaps with the eyelash and eyelid. So, only the horizontal scan is applied with window size (its width=20 pixel, and length=280). The scan of each column of the window is started from yc-10 to yc+10. For each column the sum of scanned pixels within the window is determined and save its values in a temporary array D.

Step5 (Horizontal Gradient): find the difference array, Dif(), of columns sums, D(), according to the following

$$Dif(i) = D(i) - D(i-1) \qquad (8)$$

Step6 (Difference Array Normalization): Find the relative difference of the difference array rDif() according to the following equation:

$$rDif[i] = \frac{Dif[i]}{\overline{D}} \qquad (9)$$

Where $\overline{D}$ is average value of the absolute differences; and its value is computed as follows:

$$\overline{D} = \frac{1}{n}\sum |Dif[i]| \qquad (10)$$

Where n is the number of items in difference array, and rDif () array will contain positive and negative values.

Step7 (Detection of Outer Iris Boundary): search rDif() array to find the two top peaks which represent the edge points (xir, xil) of the iris border which are the right and left side, respectively. The search process depends on the pupil region parameters center, left and right points (xc, xr, xl). The search process begins from the point x3 in the relative difference array, rDif ( ), to find the iris border edge point (xir) from the right which must be positive point. To find the left iris border edge point (xil) another search scan should begin from the point x4 to find the iris border edge point (xil) at the left side which must be negative point. The points x3 and x4 are defined using the following equation:

$$x_3 = x_r + 0.75 \times R_p \\ x_4 = x_l - 0.75 \times R_p \qquad (11)$$

To compute the iris radius (Ri), and iris center (xiris, yir) the following formula can be used

$$R_i = \frac{1}{2}(x_{ir} - x_{il}) \\ x_{iris} = \frac{1}{2}(x_{ir} + x_{il}) \qquad (12)$$

Step8 (Refinement Scan): to ensure the search scan for iris does not lead to be false edge points the scan of iris center will be restricted around:

$$y_{ir} = y_p, \quad x_p - 5 < x_{ir} < x_p + 5.$$

Figure (6) illustrates the iris localization steps.

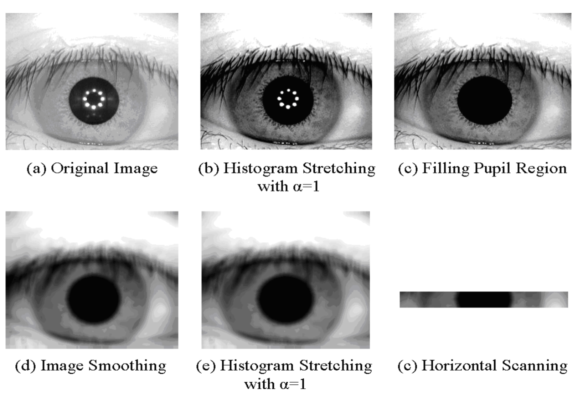


Fig. 6. Iris localization steps

3. Experimental Result

The proposed method was tested on CASIA V4.0, **V.1 iris image database [13], and MMU [14] iris image** database. In CASIA V4.0 there are 2,639 iris images belong to 359 different subjects. The size of the iris image is 320×280 pixels. CASIA version 1.0 iris image database contains 756 images belong 108 different people. For each eye, 7 images have been captured in two sessions, where three samples are collected in the first session and four in the second session. Each iris image is in grayscale with a resolution of 280×320 pixels. MMU Version 1.0 iris database contains a total number of 457 iris images. Figure (7) present one sample of iris image from each database.

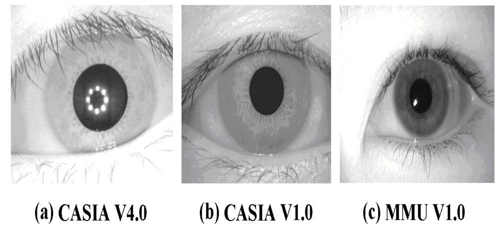


Fig. 7. Iris image samples

As illustrated above, the proposed segmentation method consists of three stages. In the first stage a seed point is taken from the pupil region, in the second phase the pupil region is detected, and in the third stage iris boundary region is detected. The performance of each of these three stages is evaluated using iris images belong to the following three databases:

(1) CASIA V1.0: Table (1) presents the attained accuracy of the proposed system when applied on CASIA V1.0. Also, figure (8) shows samples of the localization results.

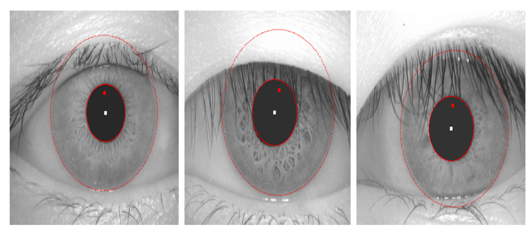


Fig. 8. Samples of accurate iris localization for CASIA V1.0

The results listed in Table (1) indicate that the first stage which is concerned with finding a proper seed point is achieved for all images in CASIA V1.0, According to our proposed method there are two important key points lay in the pupil region; one represents the seed point and the other represents the pupil center. The second stage which is concerned with finding the correct pupil parameters (yp, xp, Rp), and the third stage is aimed to find the iris parameters (yi, xi, Ri) are correctly detected for all images in CASIA V1.0.

(2) CASIA V4.0: the proposed method was evaluated on CASIA V4.0 Interval class. All images in this database contain reflection spot points in pupil region. These bright areas will affect the accuracy of pupil and iris localization. Table (2) and figures (9) and (10) below demonstrate the localization accuracy results.

(3) The seed point detected correctly for all images belong to the database. The error in pupil detection is result from the appearance of bright spots close or on the pupil boundary which makes the task of pupil boundary detection is too hard to be achieved.

Table 1 The results of the three stages on CASIA V1.0 database images

Number of stages	Stage name	Total number of images	Accuracy
1	finding seed point in the pupil region	756	100%
2	Pupil region localization	756	100%
3	Iris region localization	756	99.7%

Table 2 The results of the three stages on CASIA V4.0 database images

Number of stages	Stage name	Total number of images	Accuracy
1	finding seed point in the pupil region	2639	100%
2	Pupil region localization	2639	0.981%
3	Iris region localization	2639	0.972%

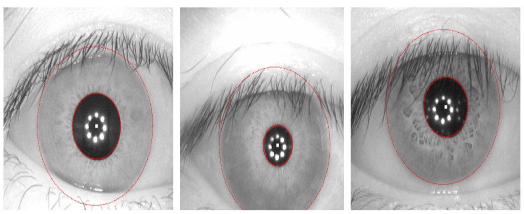


Fig. 9. Samples of accurate iris localization for CASIA V4.0

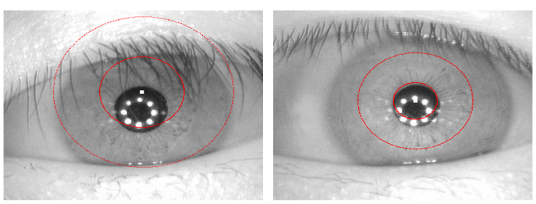


Fig. 10. Two samples of inaccurate iris localization for CASIA V4.0

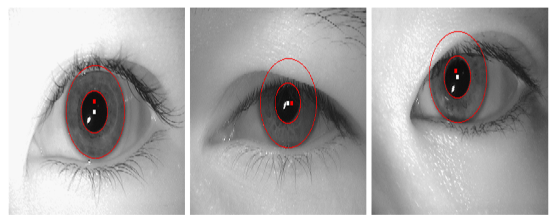


Fig. 11. Samples of accurate iris localization for MMU V1.0

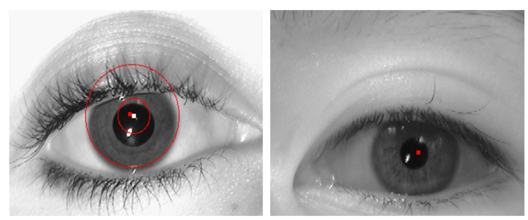


Fig.12. Two samples of inaccurate iris localization for MMU V1.0

Table 3 The results of three stages applied on MMU V1.0 database

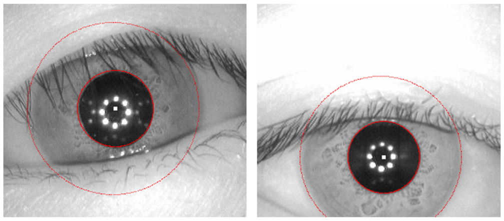
Number of stage	Stage name	Total number of images	Accuracy
1	finding seed point in the pupil region	457	100%
2	Pupil region localization	457	0.969%
3	Iris region localization	457	0.98%

Other cause of error is due to eyelash overlap. These two failure cases are the most common types of iris boundary localization failure.

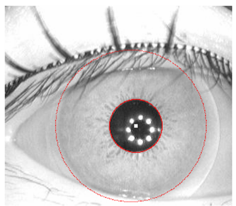
(4) MMU V1.0: this database contains 457 images, all of them have bright reflection points, table(3) and figures (11) and (12) below demonstrate the attained localization results.

The results shown in table (3) indicate that the seed point have been detected correctly for all images, while some errors occurred in the determined pupil parameters. These errors are due to reflection points and eyelash. The inaccuracies in pupil parameters cause the most problem in iris localization.

To test the performance of our method against different issues that affect on the iris segmentation such as: varying illumination, occlusion by eyelids and eyelash, specular highlights on pupil which come from spot of light during image acquisition, and decentralization of iris image which cause by the gaze of an individual. Figures (13 and 14) depict the performance of the proposed method against different previously mentioned problems that can be arising during iris segmentation.



(a) Occlusion and specular highlights



(b) Subject wearing contact lens

Fig.13 . Localization performance of the proposed method

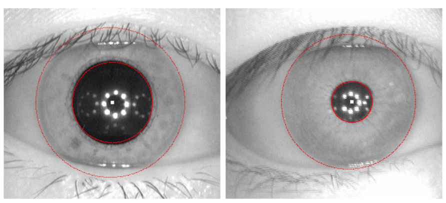


Fig. 14. Localization performance of the proposed method for variation in illumination

4. Conclusion

A new method for pupil and iris localization is reported in this paper. The proposed method adopted Leading Edge Detection to decide the both inner and outer iris boundary edge. Firstly, because iris images are subject to varying illumination, it will not prefer to use static threshold. In our method, the pupil region is determined by adaptive threshold which its value is compute according to the intensity distribution using first order statistical analysis, then the noise added to iris image by spot of lights which create specular highlights on pupil is remove using morphological operation. At second phase, outer iris boundary is detected using simplest new method which is depend on crop local window with size depend on pupil parameters of iris image. Finally, the iris radius is detected from those points which have highest changes in gray values. This method has been tested on CASIA V1.0, CASIA V4.0, and MMU V1.0 databases. It has been observed that the proposed method performs with average accuracy 99.86%, 0.981%, and 0.984% for CASIA V1.0, CASIA V4.0, and MMU V1.0 databases respectively. As shown from figures (12) and (13) that the proposed method is proficient in performance against illumination variation and occlusion. Also, the results of CASIA V1.0 show that the developed method had successfully localize iris region for images, while the reflection area lie on (or near) pupil boundary in both CASIA V4.0, MMU V1.0 have negatively affected the iris localization task.

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