# Hybrid Method Of Iris Detection Based On Face Localization

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***Abstract*— This paper presents a hybrid method of iris detection system based on edge detection and Hough Transform, with the help of skin segmentation in face detection algorithm, Golden Face Ratio and geometric definition. The algorithm starts with skin detection using Gaussian mixture model to find the bounding area of the face. Next, the facial area is used to mask the area for eye segmentation process. After the potential eye regions have been obtained, the centroids of the potential eyes and the edge detection process is performed. Then, using the obtained information, the coordinates of the irises are determined through the circular Hough Transform formula. For verification, several geometrical tests are performed onto the centroids to find out the best pair to be the irises of the eyes. The output image is displayed with the face bounded and its irises marked.**

***Keywords*— *iris detection; face detection; skin segmentation; edge detection; Hough transforms***

## I. INTRODUCTION

In the human face, the eyes are considered the most salient and stable features which show a lot of information about a person's emotional state, desires and needs[1]. Iris detection and recognition is one of the active areas in the research for biometric recognition since the last decade. However, the real-life challenges in iris detection are yet to be solved. Iris detection is one of the important steps before the iris recognition process. The accuracy of this biometric recognition is depending on the precise location of the iris[2].

Eye detection methods can be categorized into three categories, which are feature-based, template-based and photometric-based. Feature-based methods focus mainly on the distinctive characteristics of the eyes such as shape, size and special points of the eyes for eye recognition [3, 4]. On the other hand, photometric-based methods use appearance factors like color, gray level, intensity level and saturation level to detect the eyes. Template based methods usually have templates or blueprints of a generic eye model used for matching to find the images for the eyes[5].

Feature-based method [3, 6] used among others projection functions (Integral Projection Function (IPF), Variance Projection Function (VPF) and Hybrid Projection Function (HPF)), and Hough transform. The formulae need to be fully comprehended before being used effectively as they usually involve some trials of threshold values in order to obtain the best results. For example, the approximate size of the pupil must be estimated before using Hough transform and it is computationally expensive.

Template-based method [3, 7] often has the side effect of using a lot of computational power during the template matching process. A good template-based method needs a lot of templates for the matching process due to different variation of eyes in terms of shape, size, contour and color. Templates need to be designed beforehand before being able to use them. While these templates can help to detect the eyes accurately, the process is very time consuming. This is because this method is required to match pixel by pixel with the whole face. To make matters worse, the size of the image eyes may not be known, thus matching needs to be done repeatedly on different eye template sizes. A more efficient template based method is principal components template and nonlinear coefficient[8].

Photometric-based method [3, 9] may be considered the easiest method to implement. This is because it focuses on the appearance factors which do not require much mathematical calculations and high computational power consumption as in feature-based and template-based methods. Usually, this method focuses on the darkest part of the face to be the eyes, but it may not work well for people with dark skin tone. However, these advantages come with a major drawback, which is the detection rate is the worst among the three.

In this paper a hybrid method is introduced for iris detection. Hough transform in feature-based method is used to find the shape of the eyes after proper geometrical restrictions are applied on the target face. Skin segmentation algorithm is used to detect the target face.

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## II. PROCEDURES OF THE DEVELOPMENT

The flow chart of the proposed approach is shown in Fig. 1.

### A. Skin Segmentation

The face region needs to be segmented apart from the background to reduce the processing area for the eye detection region. YCbCr space was used to build skin color model as the chrominance components are independent of luminance components in the space. This makes it well suited to segment skin regions from non-skin regions.

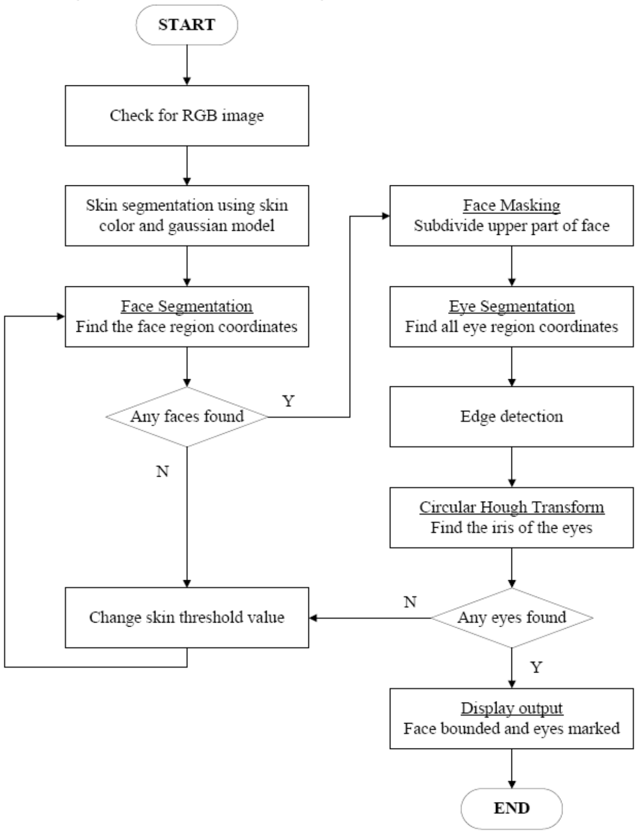


Fig. 1. Flowchart of the proposed method.

Besides, there is also a non-linear relationship between chrominance and luminance of skin color that allow many existing skin color models to operate. After that, a Gaussian model is used to classify each pixel into the skin or non-skin pixels[10].

The Gaussian variable and the density function used are as follows:

$$X = (Cb\ Cr)^T \in R^2 \quad (1)$$

$$f(Cb\ Cr) = \frac{1}{2\pi |C|^{1/2}} \exp\left\{-\frac{1}{2}(X-\mu)^T C^{-1}(X-\mu)\right\} \quad (2)$$

$$where\ X = \begin{pmatrix} Cb \\ Cr \end{pmatrix},\ \mu = \begin{pmatrix} \mu_{Cb} \\ \mu_{Cr} \end{pmatrix},\ C = \begin{pmatrix} C_{CbCb} & C_{CbCr} \\ C_{CrCb} & C_{CrCr} \end{pmatrix}$$

The following parameters [11]

$$\mu_{skin} = \begin{pmatrix} 112.1987 \\ 151.3993 \end{pmatrix}, C_{skin} = \begin{pmatrix} 89.3255 & 32.2867 \\ 32.2867 & 252.9236 \end{pmatrix}$$

apply morphological process to clear them up and this helps to reduce the rate of fault detections for faces interfered by the background images.

After the calculations for the Gaussian model on the image, a low pass filter is applied onto the image to smoothen its noises. Then, a binary image is obtained by letting the skin likelihood image to undergo the threshold process with an appropriate threshold value. Thresholding will be performed to transform the skin likelihood image to binary image. It was found that if the threshold value was fixed at a certain value, it would cause the algorithm codes to become less flexible towards images of different conditions such as lighting, contrast and illumination. This is shown from Fig. 2 to Fig. 5. From the comparisons in these two examples, the value of 0.5 for the threshold value is suitable for image 1 but not for image 2. The subject in image 2 has a darker or paler color for his skin compared to the one in image 1 due to lighting conditions. So, when the threshold of 0.5 is used, the segmented binary image barely has a facial shape. The binary image using a threshold value of 0.3 still has a badly segmented facial shape, having too many holes. The best threshold value for image 2 is 0.1. Therefore, the threshold value is made into a variable which constantly changes starting from 0.1 to 0.5 with an increment interval of 0.05 each time until the face and the eyes in an image are found. Face Segmentation

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### B. Face Segmentation

After the binary image is segmented out, the next step is to find the region of the face. The following conditions need to be met before the segmented binary image is considered as the candidate of potential faces.

- The minimum for the width and height of the face are 100 and 150 pixels respectively. This is to refrain from box-bounding background noises which are smaller than these widths and heights.
- Orientation of the face – the angle (in degrees ranging from -90 to 90 degrees) between the *x*-axis and the major axis of the ellipse; must be either larger than 45 degrees or less than -45 degrees (assume that in the extreme case when the face of the subject can tilt his/her face until 45 degrees to the left or right from his/her neutral position).
- The major axis of the ellipse must be longer than the minor axis. The face shape is normally an ellipse rather than a circle.

**Images from CVL Face Database [12]**

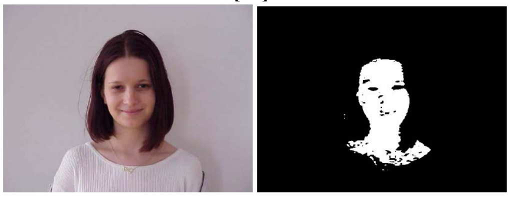


Fig. 2. Original image 1 and binary image 1 (threshold value = 0.5).

Fig. 3. Binary image 1 (threshold value = 0.4) and binary image 1 (threshold value = 0.3).

Fig. 4. Original image 2 and binary image 2 (threshold value = 0.5).

Fig. 5. Binary image 2 (threshold value = 0.3) and binary image 2 (threshold value = 0.1).

(a) (b)

Fig. 6. Binary images before and after face classification.

• The object with the largest area and the previous three conditions fulfilled will be selected as the face region.

For the cases that the face and eyes are not detected in the first threshold value, the process is repeated in the next cycle and the threshold value for the segmentation process is changed. Each time the threshold changes, the box-bounding coordinates are different which means the candidates of the potential facial regions different from the previous set. The facial candidate with the largest area will be chosen. The output of the potential face region is shown in Fig. 6. Fig. 6(a) shows the binary image after thresholding (yellow circle indicates background noises, non-face regions). Fig. 6(b) shows the potential face region after face classification and hole filling process.

### *C. Face Masking and Eye Segmentation*

Based on the Golden Face Ratio [13-15], we can assume that the eyes are located on the upper part of the face. The golden ratio or phi value is 1.618 [13-15] . It occurs at “top of forehead-nose-tip: nose-tip-chin” where the ratio is 1.618: 1.0. So, the upper part of the face which is 1.618 takes up 60 percent of the total face height. Since our focus is to only find the eyes, the lower part of the face (40 percent of total height) can be eliminated. This is shown in Fig. 7.

The mask of the upper portion of the face is used to mask out only a limited area for processing to find the eye region candidates. The limited area will be the region of interest (ROI) for the classification of the eye process. Fig. 8 shows how the mask segments out the region of interest.

An object that fulfills the following conditions will be regarded as the candidate of potential eyes:

• The eye ratio (width of the eye divided by its height) must be more than 1.0 and less than 3.5. Since the width of the eye is normally longer than its height, the ratio should be more than 1.0. We restrict the max value for the ratio to 3.5 so as to restrict the algorithm from choosing long and thin objects as the eyes. These long and thin objects could be the eyebrows or background noises.

• Orientation of the eyes – the angle (in degrees ranging from -90 to 90 degrees) between the *x*-axis and the major axis of the ellipse must be either smaller than 45 degrees or larger than -45 degrees (assume that in the extreme case that the eyes of the subject can be slanted until 45 degrees to the left or right from their horizontal position).

Fig. 7. Mask used to find the eye region.

(a) (b)

Fig. 8. Process of masking region of interest-eyes (a) Inverted binary image of threshold image, (b) Region of interest after masking the Fig. 8(a) with the mask in Fig. 7.

### D. Edge Detection and Hough Transform

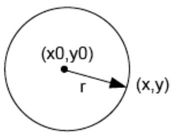
The Hough Transform relies on the circular shape of the edges to determine the irises. The original color image is transformed into a grayscale image and edge detection using edge detector methods, Sobel or Canny is performed. The Sobel method tends to produce minimal edges on regions of high spatial gradients, while canny method produces too many edges which are unnecessary. The Canny method may cause the problem of fault detections by identifying other areas like the eyebrows to be the eyes. However, images that have slightly low or bad contrast in the eye area can fail the Sobel method in producing edges at that area, thus leading to failure in finding the eyes. The same situation does not pose a problem to the canny method as edges for both eyes are still visible.

The edges will be masked by the eye region mask to produce minimal edges for the Hough Transform to process them. From the result, both edges for the eyes do not show much difference because all other parts of edges are already omitted. So, the usage of either one of these two methods is acceptable as their weaknesses become less significant, provided the suitable eye mask is obtained in the previous stage. Fig. 9 shows the example of the masked edges.

(a) (b) (c)

Fig. 9. Edges after being masked by eye region mask (a) Eye region mask (b) Sobel edges for the eyes after masking, (c) Canny edges for the eyes after masking.

After the edge detection process, the masked edges, the information of centroids and the minor axis lengths are fed into the Hough Transform function. The minor axis length is the radius of the circle. The Hough Transform uses the equation as follows:




$x = x_o + r\cos(t)$ $y = y_o + r\sin(t)$

where $r$=radius, t=angle x $\frac{\pi}{180}$

$(x_o, y_o)$ is the centroid of teh circle - resembel the centre of iris

(x, y) is the perimeter of the circle - resemble the circular edge of the iris

Before it is started, an accumulator of the same size as the original image with all values equals to zero is created. It will be used as a platform for casting votes when conditions are fulfilled. The centroids and the radius are put into calculations one after another to find out the coordinates of $x$ and $y$. The condition is – if there is a white pixel in the binary edge image at the $x$ and $y$ coordinates, the accumulator at the coordinates of that current centroid is incremented by one, otherwise the process is ignored. This repeats for different variation of angles for the $t$ value and radius, $r$. The centroids which have votes in the accumulator are put into geometrical tests to identify the actual irises.

## III. Geometrical Tests and Verification

There are two geometrical tests being adapted from [16] to filter false positive centroids for the irises. The geometrical tests include the following:

• Eye Angle Test

According to the structure of the face, the two centroids cannot be located at one side of the face. When one centroid is on the left side, the other one must be on the right side of the face, and vice versa. Here, the face center is determined through the width of the face coordinates being divided by two. However, the face center is only a rough estimation due to the inaccuracy in box-bounding the face.

•Eye Pair Distance Test

The distance between both the centroids must be larger than the distance between one of the centroids to the face center.

•Two centroids of the shortest distance between their y-coordinates and after having passed the eye angle test and eye pair distance test will be chosen as the irises of the eyes. When the subject keep his/her head straight, both his/her irises are approximately on the same horizontal row.

After these geometrical verification tests, the face boundaries and the irises are marked on the output image. If the centroids failed these tests, the whole process is repeated with another skin threshold value until the irises are found or the maximum threshold value is reached. In certain cases when only one iris can be found, it is still marked onto the output image.

## IV. Experimental Results

The face database used for testing is the CVL Face Database[12]. There are 114 persons in the database with each person photographed in 7 different types of images: 4 side view images and 3 frontal images. All the frontal images of each person are chosen because it matches our project scope which involves the frontal view with different expression. In this database, there are 8 persons wearing spectacles being used as testing subjects to test the flexibility and robustness of the algorithm. The resolution of the images is 640*480 pixels.

The experiments are performed on a PC with an Intel(r) CPU G645 @ 2.90GHz and 2GB memory. All the simulations are implemented on this PC by engineering software, Matlab version 7.8.0 run on Windows 7 Professional 32-bit Operating System.

The results in Table 1, show the performance of the algorithm in detecting eyes. Successful detection is the ability to mark both the irises of the eyes. Examples of the successful detection images are shown in Fig. 10. Its rate is calculated by the number of images with accurately detected irises divided by the total number of images used for testing. Similarly, the fault detection will be the number of faults detected divided by the total number of tested images.

The proposed hybrid method is compared with the state of the art methods, the multi-cue facial information [17] and ternary eye-verifier [18] on the CVL database. The algorithm proposed by Kalbkhani is used for eye location and not for iris. The results are shown in Table 1.

TABLE I. RESULTS AFTER APPLYING FLEXIBLE THRESHOLDING IN SKIN SEGMENTATION

| Database/Total tested images | Detection | Accurate detection | | Average operation time for each image /s |
|---|---|---|---|---|
| CVL /339 | **Proposed hybrid method** | **327[a]** | **96.46%** | **5.7** |
| | Guan[17][c] | 329 | 96.2% | N/A |
| | Kalbkhani [18] | 323[b] | 95.32 | N/A |

[a] Both of the irises are accurately detected (Total of 339 images are tested)
[b] Only for eyes and not iris [c]342 images are used


Fig.10. Examples of success detection of face, eyes and iris.

## V. CONCLUSION

In this paper, a novel hybrid method has been implemented which is not only able to detect the human face (red-bounded box), but also to locate the position of their eyes (green cross). The detection accuracy is 96.46% with average detection rate of 5.7second within certain confined conditions. The limitation conditions are as such: plain or non-skin color background images, faces which look straight to the front with slight variations – rotation to the left or right/head tilting to the left or right, single face detection, and normal contrast images.

The proposed method achieves better results than the other methods evaluated on the CVL database.

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