# Comparison of Iris Recognition between Active Contour and Hough Transform

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***Abstract*—Research in iris recognition has been explosive in recent years. There are a few fundamental issues in iris recognition such as iris acquisition, iris segmentation, texture analysis and matching analysis that has been brought up. In this paper, we focus on a fundamental issue in iris segmentation which is segmentation accuracy. The accuracy of iris segmentation can be negatively affected because of poor segmentation of iris boundary. Iris boundary might have unsmooth, poor and unclear edges. Because of that, a method that can segment this type of boundary needs to be developed. A method based on active contour is proposed not only to increase the segmentation accuracy, but also to increase the recognition accuracy. The proposed method is compared with the modified Hough Transform method to observe the performance of both methods. Iris images from CASIA v4 are used for our experiment. According to results, the proposed method is better than the modified Hough Transform method in terms of segmentation accuracy, recognition accuracy and implementation time. This shows that the proposed method is more accurate than the Hough Transform method.**

***Index Terms*—Iris Recognition; Iris Segmentation; Active Contour; Modified Hough Transform.**

## I. INTRODUCTION

Iris biometric is one of many biometrics used to identify human based on their behavioral and physical characteristics. Other biometrics are finger print, palm print, ear, DNA, gait, voice, face and many more. There is tremendous interest in biometric in order to replace the traditional identity verification such as an identification card, ATM card, username, password and token. This is because the identification card, ATM card, token can be stolen, and username and password can be forgotten. The biometrics cannot be lost and forgotten easily such as the traditional methods. The biometrics can also reduce waiting time to verify the identities that they are claim to be such as in airport, immigration and high security area. The researches on spatial pattern of iris have been exploded in recent years due to believe that it has high recognition accuracy even more than fingerprint. According to [1], the growth of iris biometric is because of the expiration of patent [2] and [3], which are the pioneer in iris recognition researches.

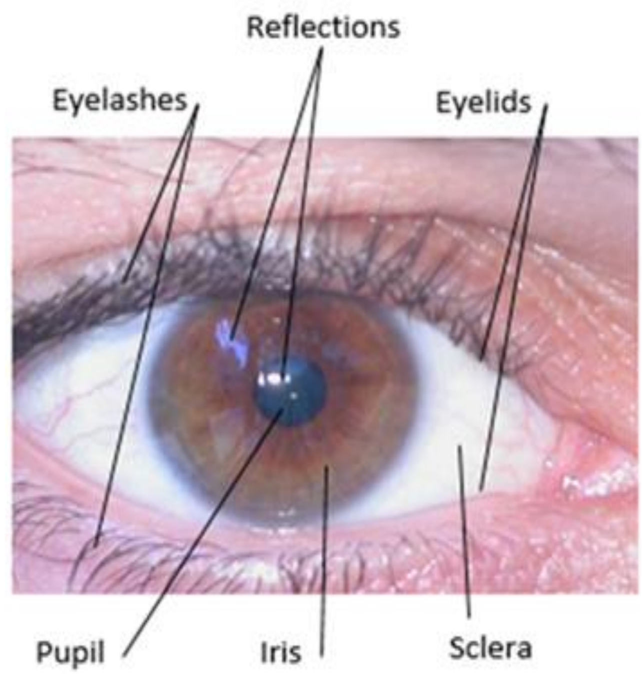



Figure 1: Anatomy of an iris

The anatomy of iris is depicted in Figure 1. Iris is a color tissues inside the human eyes. The iris color varies between amber, blue, brown, grey, green, hazel and violet, and depends on the amount of pigment in our iris. The amount of pigment is different between each individual which depends on the amount of cellular density in stroma, melanin in stroma and epithelium. Human iris is covered from the external and harsh environment by cornea and pupil. Meanwhile, pupil is a black region which is located at the center of the eye, surrounded by iris. Pupil will control the amount of light that enters the retina. Next, sclera is a white region that surrounds the iris. It acts as a protective layer of the eye. Iris consists of rich pattern and texture such as pigment spots, ridges and furrows [4]. Then according to [5], iris is suitable for human identification because of it has rich features of collarette, ring, crypt, corona, freckle and arching ligament.

The iris starts to form in the third month of pregnancy. The color of iris might change during childhood and will be stable right after that. It is believed that iris pattern might not change for entire human life [6]. The iris pattern is different between each individual, even our right and left irises have different set of pattern [6]. But according to [7], iris pattern might change over the time due to aging effect. To counter this statement, Mehrotra et al. [8] said that the iris pattern is primarily changing due to presence of noise, blur, occlusion and pupil dilation, and minimally changing because of aging. The iris pattern and texture might change after the cataract surgery [9] and diabetes, and re-enrollment is needed.

The iris biometric concept was introduced in 1987 by [2]. Theoretically, there is no similar iris between each individual. After that, they reached John Daugman to help them to develop a practical system using iris pattern. In 1994, a system for human identification based on iris pattern was patented [3].

There are four main modules in iris recognition. Most of the researches in iris recognition are focused on these modules. The modules are: iris acquisition, iris segmentation, texture analysis and matching analysis. In iris acquisition, iris images are captured using a camera or video camera in near infra-red (NIR) or visible wavelength (VW) environment. There are a few iris databases taken in NIR such as CASIA, MMU and WVU. Meanwhile, the iris database taken in VW is UBIRIS. Then in iris segmentation, the iris region is segmented from the rest of eye image with specific methods such as integro-differential operator [10,11], Hough transform [12,13], active contour [14-17] and many more. Next in texture analysis, the iris texture and pattern are analyzed and extracted with Gabor filter, Gaussian filter, Haar filter, Dyadic wavelet transform, key local variation and many more. Then in matching analysis, the enrolled and input irises are compared to determine their similarity and scores using Hamming distance, Euclidean distance and many more methods.

The most well-known algorithms for human iris identification are from Daugman [10] and Wildes [12]. Daugman introduced an integro-differential operator (IDO) method to locate the boundaries of pupil and iris. For feature extraction, Gabor filter is used to extract the iris features. For matching, Hamming distance is used to calculate the matching scores. Meanwhile, Wildes introduced a Hough transform (HT) method to detect the location of pupil and iris boundaries in an iris image. Laplacian of Gaussian filter is used for feature extraction, and Laplacian pyramid is used for matching. Later on, Daugman [14] in 2007 introduced an active contour method to locate the pupil and iris boundaries that have irregular shapes.

Our proposed method is based on Chan-Vese [18] method instead of Snake [19] and Geodesic [20] active contour methods. Our proposed method is depicted as in Figure 2. The contributions of this work are in terms of increasing segmentation accuracy and recognition accuracy of the iris recognition system compared to the well-known HT method.

This paper is organized as follows. Section 2 describes the methodology of the proposed method and the modified HT method. Section 3 shows the results of our experiment. Finally, section 4 concludes the findings of this paper.

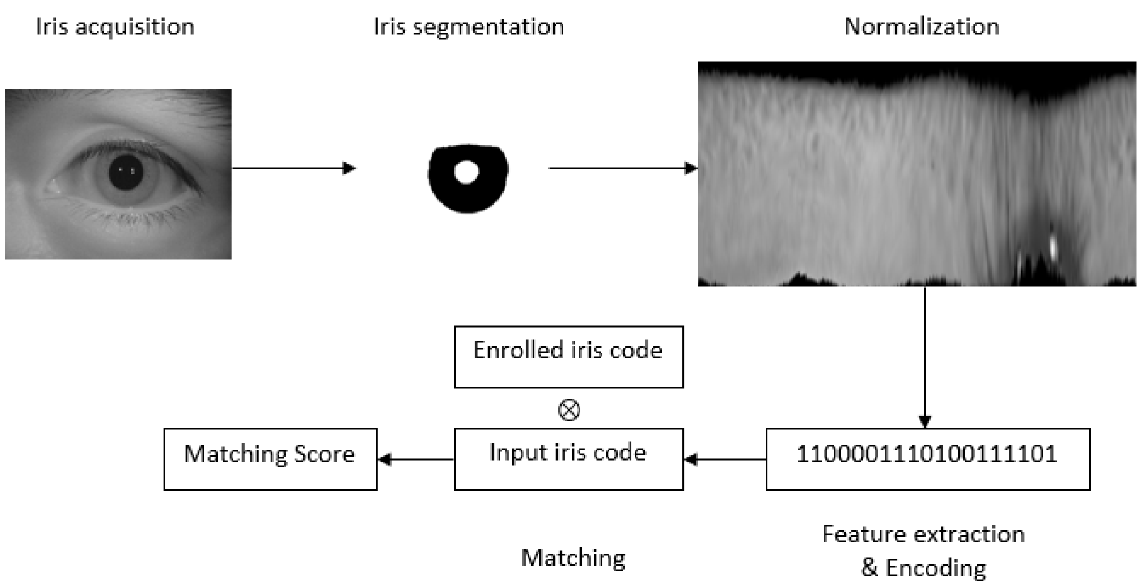



Figure 2: The proposed iris recognition system

## II. METHODOLOGY

### A. Active Contour

Chan-Vese active contour is developed based on the level set method [21] and the segmentation method [22]. This method is used in our work to segment the desired iris and pupil boundaries in the iris image. Basically, this method is defined as:

$$F(c_1, c_2, C) = \mu . Length(C) + v . Area(inside(C)) + \lambda_1 \int_{inside(C)} |\mu_0(x, y) - c_1|^2 dxdy + \lambda_2 \int_{outside(C)} |\mu_0(x, y) - c_2|^2 dxdy \quad (1)$$

where $C$ is the curve in the image, $c_1$ is average $C$ when $\varphi \geq 0$, $c_2$ is average $C$ when $\varphi < 0$, $\mu$ is smooth factor, $v$ is contraction bias, $\lambda$ is fit weight, $\mu_o$ is the input image, *Length* is the length of curve $C$ and *Area* is the area of curve $C$. The values are set where $\mu$, $v \geq 0$ and $\lambda_1 = \lambda_2 = 1$.

Radman *et al.* [23] stated that active contour has low accuracy, low speed and medium memory usage. Because of that, the Chan-Vese active contour is optimized in this work to overcome those problems.

Generally, active contour is a segmentation technique that relies on gradient information in the image. The segmentation performance of active contour also depends on the edges of the desired boundary. The weak edges will reduce the segmentation accuracy of active contour. Meanwhile, the strong edges will increase the segmentation accuracy. The Chan-Vese active contour is quite different from the Snake and Geodesic active contour. This active contour is less dependent on edges or gradient information which is suitable to segment the iris and pupil boundaries. The iris and pupil boundaries usually have unsmooth and weak edges which are difficult for any segmentation methods to accurately segment the correct boundaries.

### *B. Hough Transform*

Hough transform is introduced by Hough [24] and reinvented by [25] in order to detect the arbitrary shapes of lines, circles and ellipses in the image. This method is widely used in image processing and computer vision. In iris recognition, HT is used by Wildes [12] to detect two circles in an iris image which represent pupil and iris regions respectively. This method has been improved by [13,26-28] to optimize the performance of iris recognition system.

Basically, HT is a set of edge points $(x_j, y_j)$, $j=1,\ldots,n$ and is defined as:

$$H(x_c, y_c, r) = \sum_{j=1}^{n} h(x_j, y_j, x_c, y_c, r) \tag{2}$$

where :

$$h(x_j, y_j, x_c, y_c, r) = \begin{cases} 1, \rightarrow g(x_j, y_j, x_c, y_c, r) = 0 \\ 0, \rightarrow otherwise \end{cases} \tag{3}$$

with:

$$g(x_j, y_j, x_c, y_c, r) = (x_j - x_c)^2 + (y_j - y_c)^2 - r^2 \tag{4}$$

$X_c$ and $Y_c$ are the center coordinate, and $r$ is radius.

### *C. Iris Recognition based on Active Contour*

The first step to develop the proposed iris recognition system based on active contour is iris acquisition. Iris images from CASIA v4 [29] database are used in this work.

The second step is iris segmentation. In this step, the iris region must be segmented from the pupil, sclera, eyelid and eyelash region. Firstly, the pupil region needs to be detected in the iris image. Since pupil region has a low gray-scale value, we assume that it is below than 35. This value might be different under certain environment, database, distance and lighting. Then, any pixels that below than 35 are analyzed to locate the region that has the largest area. The region that has the largest area is considered as a pupil region because of pupil is the largest black region in the iris image. After detecting pupil region, the Chan-Vese active contour is deployed to detect the iris region. Before that, the initial contour needs to be assigned on the iris image. The initial contour is important in active contour since it will assign the direction of segmentation. The initial contour must be closed to the iris boundary in order to detect the accurate iris region. The shapes of initial contour can be circle, rectangle, square, octagon and many more. In this work, the circle function is assigned as the shape of initial contour. This is because the iris region shape is almost similar with the circle shape. Other than that, the contraction bias ($v$), smooth factor ($\mu$) and iteration number ($N$) also need to be assigned. The contraction bias will control the tendency of active contour to grow inward or outward of initial contour. If the iris region is bigger than initial contour, the contraction bias must be set to negative value so it will grow outward. Meanwhile if iris region is smaller than initial contour, the contraction bias must be set to positive value so it will grow inward. The contraction bias is set to 0.9 in this work since the initial contour is bigger than the iris region. Next, the smooth factor can control the smoothness level of the desired boundary. A small value of smooth factor can capture more details of the boundary. Meanwhile, large value of smooth factor can create smoother boundary but with less details. In this work, the smooth factor is set to 0.001 since we need to capture more boundary details. Then, iteration number is the amount of curve, $C$ to converge into the desired boundary. A high number will accurately detect the iris boundary but will require longer time and vice versa. In this work, the iteration number is set to 35 since this value is suitable to detect the accurate iris boundary with fast time. After the initial contour, contraction bias, smooth factor and iteration number have been assigned, the Chan-Vese active contour can be deployed to detect the iris region. The deployed active contour can also exclude the eyelid region. Meanwhile for eyelash region, a simple thresholding technique is used to detect that region. Finally, the segmented iris region can be obtained by subtracting the detected iris region with pupil, eyelid and eyelash regions.

The third step is normalization where the segmented iris region is converted from a circular shape to a fixed rectangular polar coordinate. It can also compensate the pupil dilation and iris size. This normalization technique is called as a rubber sheet model which is based on [10]. In this work, the algorithm for normalization from [26] is optimized by reducing the number of points to be mapped from the segmented iris region.

The fourth step is feature extraction. The iris feature in normalization is extracted by using 2D Gabor filter [10]. After that, the extracted features are converted into a binary code that represents all values of the iris feature. This binary code is also called as a template or iris code.

The final step is matching. This step will calculate the similarity scores of the input template and the enrolled template. Hamming distance is used since this method is fast and easy to implement.

### D. Iris Recognition based on Hough Transform

The HT methods of [12,13,26] are modified in this work in order to reduce their complexity and implementation time. The same methods from the previous section are used for the iris acquisition, normalization, feature extraction and matching steps.

Meanwhile for iris segmentation, the pupil region is detected with the same method as in the previous section which is based on the largest black region in the image. After that, the eyelid region is detected with linear HT. Then for eyelash region, thresholding technique is used to detect it. For iris region detection, the searching area of iris is reduced by creating a bounding box which is based on the upper and lower eyelids, and the center point of the detected pupil region. Finally, the segmented iris region is extracted by subtracting it with the pupil, eyelid and eyelash regions.

## III. Results And Discussion

### A. Segmentation Accuracy

The segmentation accuracy is calculated with:

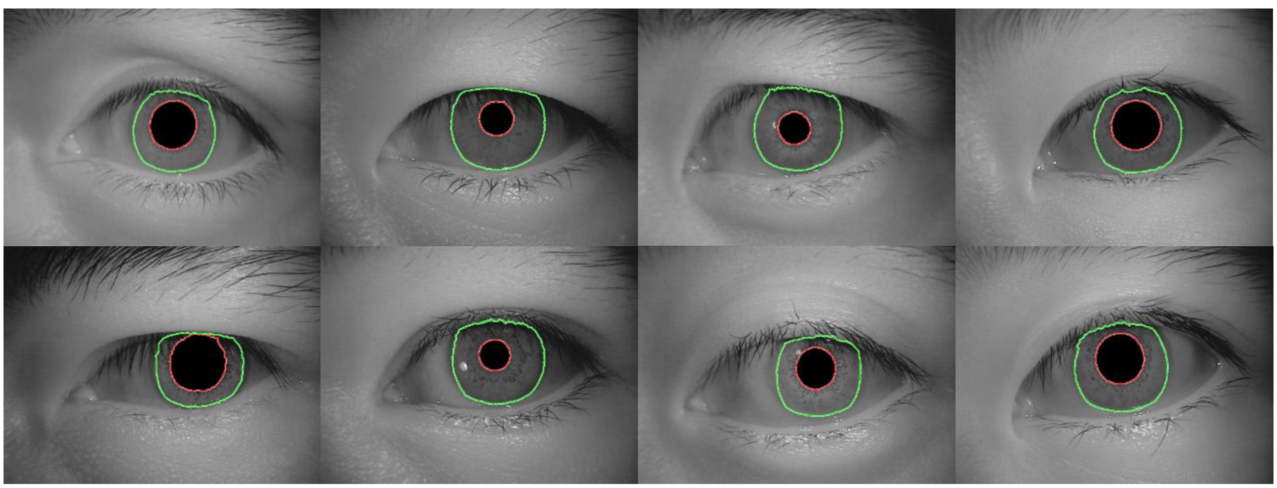
$$SA = \frac{1}{r \times c} \sum_{i=1}^{r} \sum_{j=1}^{c} (I_{i,j} \otimes G_{i,j}) \tag{5}$$

where $r$ is the height of both images, $c$ is the width of both images, $I$ is the input image and $G$ is the ground-truth image. Both images must be in the same resolution. This equation will calculate the disagreeing pixels between image $I$ and $G$.

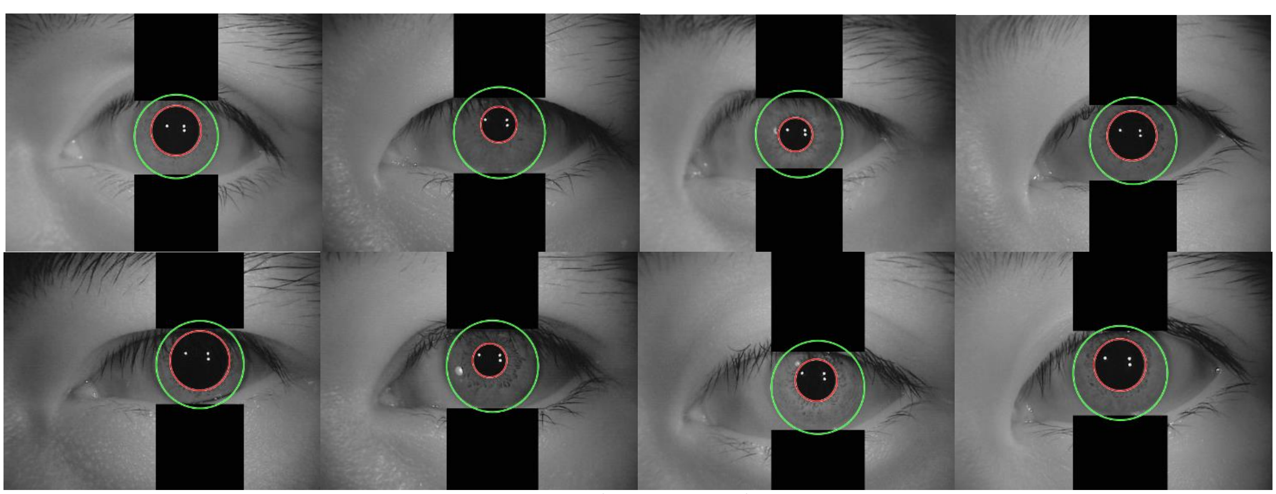
In terms of segmentation accuracy, the proposed method achieves highest accuracy than the modified HT method. It also manages to segment the irregular shapes of iris boundary. This method can create a smooth and detail iris boundary even with the occlusion of eyelids. At the same time, the eyelids are excluded from the iris region which reduce the process and time taken to perform the segmentation. The results are shown in Table 1 and Figure 3.

Table 1
Segmentation accuracy

| Methods | Segmentation Accuracy (%) |
|---|---|
| Modified HT | 80.78 |
| Proposed Method | 90.97 |



(a) Proposed method



(b) Modified Hough transform

Figure 3: Segmentation results

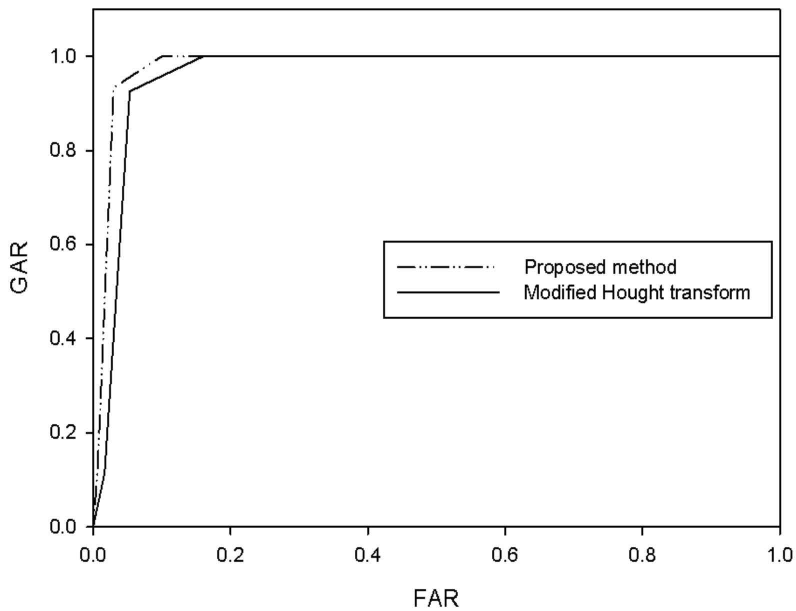



Figure 4: ROC curve

### *B. Recognition Accuracy*

The recognition accuracy can be calculated by plotting the genuine acceptance rate (GAR) against the false acceptance rate (FAR) to create the receiver operating characteristic (ROC) curve. Then, the equal error rate (EER) is calculated on the ROC curve where GAR=FAR. Another performance evaluation for recognition accuracy is the area under curve (AUC). The AUC value of 1 represents the most accurate recognition.

Based on the results in Table 2, the proposed method obtains the better recognition accuracy than the modified HT method. This is because our EER value is lower than the modified HT method. Other than that, the AUC value of our method is also higher and almost equal to 1, than the modified HT method. These results show that, our segmentation method positively affects the recognition accuracy of the iris recognition system. The ROC curve is depicted in Figure 4.

Table 2
EER, AUC and implementation time

| Methods | EER (%) | AUC | Average Time (s) |
|---|---|---|---|
| Modified HT | 13.8 | 0.9627 | 1.62 |
| Proposed Method | 9.71 | 0.9804 | 0.76 |

### *C. Implementation Time*

In terms of implementation time as in Table 2, the proposed method achieves faster implementation time than the modified HT method. This is because our method has simple algorithm, easy implementation, and can detect the iris boundary faster than the modified HT method.

## IV. CONCLUSION

In this paper, the iris recognition method based on the active contour has been proposed. The Chan-Vese active contour has been improved by modifying the initial contour, contraction bias, smooth factor and iteration number. The normalization step also has been optimized by reducing the number of points to be mapped. The proposed method is compared with the modified HT method. Based on the results, our method has higher segmentation accuracy, higher recognition accuracy and faster implementation time than the modified HT method. These prove that, the active contour method can achieve better performance than the HT method for the iris recognition system.

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