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IRIS RECOGNITION BASED ON THE MODIFIED CHAN-VESE ACTIVE CONTOUR

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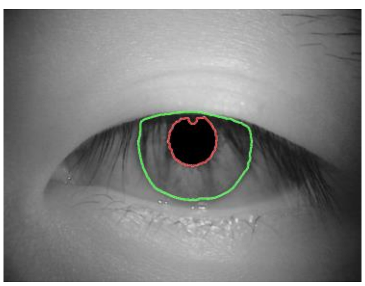
Graphical abstract



Abstract

Over recent years, iris recognition has been an explosive growth of interest in human identification due to its high accuracy. Iris recognition is a biometric system that uses iris to verify and identify human identity. Iris has pattern that is rich with textures and can be compared among humans. There are many methods can be used in iris recognition. The methods based on the integro-differential operator and Hough transform are the most widely used in iris recognition. Unfortunately, both methods require more time to execute and has less accurate recognition accuracy due to the eyelid occlusion. In order to solve these problems, the Chan-Vese active contour is modified to reduce the execution time and to increase the recognition accuracy of iris recognition. Then, this method is compared with the integro-differential operator method. The iris images from CASIA-v4 database are used for the experiments. According to the results, the proposed method recorded 0.91 s for execution time which was 61.28 % faster than the integro-differential operator method. The proposed method also achieved 0.9831 for area under curve (AUC) which was 2.66 % higher recognition accuracy than the integro-differential operator method. To conclude, the modified Chan-Vese active contour was able to improve the performance of iris recognition compared to the integro-differential operator method.

Keywords: Iris recognition, Chan-Vese active contour, execution time, recognition accuracy

1.0 INTRODUCTION

Over recent years, iris recognition has been an explosive growth of interest in human identification due to its high recognition accuracy. Before this, fingerprint is widely used in human identification since it has high recognition accuracy and fast operation. Since security has become more challenging in recent years due to the current demographic and politic, it is important to find other method for human identification instead of fingerprint. Iris can be combined with fingerprint to recognize the identity of humans.

Iris recognition is a biometric system that uses iris to verify and identify human identity. The other biometric systems are fingerprint, DNA, ear, hand geometry, palm print, face, voice, signature, retina, blood vessels, gait, odour and many more. The biometric can be divided into three: morphological, behavioural and biological [1]. Iris is categorized as a morphological biometric since it has specific, rich of texture and unique pattern that are different among humans.

Iris is located in human eyes between pupil and sclera region. Iris is externally visible part of our eyes [2]. It has a small pigmented tissue that is well located behind the cornea [3]. It can be occluded by upper and lower eyelids, and upper eyelashes. Iris feature has a high degree of freedom [4]. The probability to find two same irises is 1 in 10^{72} [5]. This is because, each human has different iris pattern. Even irises of identical twins are not similar [6]. Other than that, our right and left eyes have different iris patterns [7]. Iris is suitable for human identification because it has complex features such as crypt, freckle, ridge, ring, arching ligament, corona, furrow and collarette [1].

Historically, the concept of using iris pattern to recognize humans was introduced in 1886 by Alfonse Bertillon [8]. Alfonse Bertillon from his book titled 'The Color of the Iris', motivated the idea to differentiate humans with the use of iris texture and colour. Meanwhile in current generation, the work of iris recognition was introduced by ophthalmologists Flom and Safir in 1987. Based on their experiences in ophthalmology, there is no similar iris among humans. Then, they submitted a patent [5] which proposed a simple iris recognition method. After that, both ophthalmologists worked with Daugman to develop a practical iris recognition system [8]. This work was patented [9] in 1994 and reduced the competition among research companies. This also prevent the research and development by the third-party researchers [8]. This biometric took off dramatically in 2008 since the expiration of both patents [5, 9].

Basically, iris recognition contains five steps which are: iris acquisition, iris segmentation, normalization, feature extraction and matching. Iris images are captured using camera or video camera in iris acquisition. Then, iris region is extracted from eye region in iris segmentation. After that, the circular shape of iris region is converted into rectangular fixed polar coordinate in normalization. Next, iris pattern is extracted in feature extraction and coded into binary code. Finally, binary code is compared with other binary code in database for matching.

There are many methods that can be used in iris recognition. The methods based on Integro-differential operator (IDO) and Hough transform (HT) are the most widely used in iris recognition. The method of [10] is introduced by Daugman where it used IDO to detect a circle of iris in the eye image. Then, Radman et al. [11] modified the IDO using circular Gabor filter and live-wire technique to reduce the complexity of IDO. Meanwhile, the method of [12] is introduced by Wildes where it used HT to detect an iris circle in the eye image. Then, Hilal et al. [13] introduced the combination of HT and active contour to reduce the complexity of HT. Unfortunately, both IDO and HT methods are complex and require more time to execute. Even though the complexity of IDO and HT has been reduced by [11] and [13], they still require more time to execute. Because of that, the Chan-Vese active contour is introduced and modified to reduce the execution time and increase recognition accuracy of iris recognition.

The contribution of this study is to modify the Chan-Vese active contour to obtain a fast execution time and a high recognition accuracy of iris recognition system compared to other conventional methods.

This paper is organized as follows. The methodology of the proposed method is explained in section 2. Then in section 3, the experimental results are discussed. Finally, this paper is concluded in section 4. The suggestion for future improvement is also proposed in section 4.

2.0 METHODOLOGY

Basically, the biometric is proposed to change the conventional method when dealing with security and identity fraud. The biometrics are well investigated in order to replace the traditional identity identifiers or tokens such as an ATM card, driving license, identification card, password and many more. The purposes of biometrics are to reduce the time and complexity during verification and identification processes without compromising the security itself. Because of that, the biometric such as iris recognition must be able to recognize the human identity in a fast time without compromising the security.

2.1 Active Contour

Iris recognition based on IDO and HT has high recognition accuracy but slow due to the complexity of its algorithm. Meanwhile according to [14], active contour has medium complexity, low speed, medium memory usage, low accuracy and high noise sensitivity. Mostly, the active contour methods are based on Snake [15], Chan-Vese [16] and Geodesic [17]. Fortunately enough, there are a few factors in [16] that can be improved in order to optimize the performance of active contour for iris recognition. Before that, let us explain about the Chan-Vese active contour.

Chan-Vese active contour is introduced by Chan and Vese in 2001 in order to overcome the disadvantages of segmentation method of Mumford and Shah [18]. The level set method by Osher and Sethian [19] is also added into [18] to overcome the minimization problem. The F^{MS} function of [18] can be derived as,

$$F^{MS}(\mu, C) = \mu \bullet Length(C)$$
$$+\lambda \int_{\Omega} |\mu_O(x,y) - \mu(x,y)|^2 dxdy$$
$$+\int_{\Omega\backslash C} |\nabla\mu(x,y)|^2 dxdy \qquad (1)$$

where the piecewise-smooth function is $\mu: \bar{\Omega} \to \mathbb{R}$, the curve in the image is C, the fit weight is λ, the input image is μ_o and the domain of image μ_o is Ω. The regularity of curve C is represented in the first term of the equation. Then, μ is ensured close to μ_o in the

second term. Finally, μ is differentiable to $\Omega\backslash C$ in the third term of the equation. The boundary of the segmentation process is set to inside curve C.
Meanwhile, the proposed function of [16] can be described as,

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

where λ_1 & $\lambda_2 = 1$ and μ & $v \geq 0$. The parameter of c_1 is the average of input image when $\varphi \geq 0$. Meanwhile c_2 is the average of input image when $\varphi < 0$. Then, λ_2 is the force outside C, and λ_1 is the force inside C. The forces inside and outside of C are balanced by setting both forces to 1. The regularity by penalizing the length of curve C is represented in the first term of the equation (smooth factor, μ). The size of area C is controlled in the second term (contraction bias, v). Finally, the discrepancies between μ_0, c_1 and c_2 are represented in the third and fourth terms of the equation. Based on our observation, the smooth factor (μ), contraction bias (v), iteration number (N) and contour initialization are the main factors that can be modified and improved in order to optimize the performance of Eq. (2). Because of that, these factors will be modified to reduce the execution time and increase recognition accuracy of iris recognition method based on the Chan-Vese active contour.

Basically, most of active contour methods are based on edge or gradient information to segment the desired boundary such as [15, 17]. Meanwhile, the Chan-Vese active contour is not relied on gradient information but it depends on energy function. This method is also called 'Segmentation without edges' since it is able to segment the desired boundary that has weak and unsmooth edges which is suitable for iris recognition.

2.2 Implementation of the Proposed Iris Recognition

2.2.1 Iris Acquisition

For iris acquisition, the CASIA-v4 iris image database collected by the Chinese Academy of Sciences' Institute of Automation (CASIA) [20] is used as the sample data. About 400 images from 100 subjects are used in this work. All iris images are captured under the near infra-red (NIR) environment.

2.2.2 Iris Segmentation

In iris segmentation, the iris region needs to be extracted from the sclera, pupil, eyelids and eyelashes regions. Firstly, the glare/reflection and noise regions can be isolated by creating a noise template. Any regions that are not belong to the iris will be placed in the noise template for the later matching process.

Secondly, the pupil and eyelashes regions need to be located. The pupil region is detected by searching the largest black component in the iris image. In this database, the value of pupil region is below than 35 (from average of 400 images). After that, the pupil reflections are eliminated with morphological closing. Then eyelashes are detected with thresholding technique.

Thirdly, the eyelids and sclera regions need to be isolated by using the Chan-Vese active contour. Due to its slow execution time, the contour initialization in the Chan-Vese active contour is modified to reduce the convergence time. In this work, the contour initialization is closer to the iris boundary (Fig. 1). The closer its position to the iris boundary, the less time is taken to segment that boundary. Our contour initialization is based on the circle function,

$$Contour = r - \sqrt{(x-a)^2 + (y-b)^2} \quad (3)$$

where r is the radius value where it does not exceed eyelids regions, (x, y) is the center coordinate of pupil region. The radius value is less than 3 times of pupil radius (observation from 100 images). The center coordinate is calculated from the pixels property in the detected pupil region. It can be shifted to accommodate iris boundary.

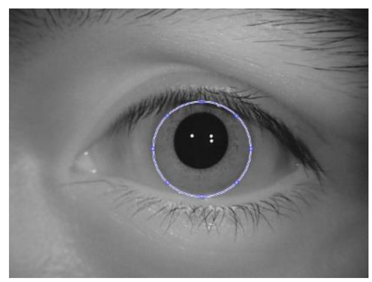


Figure 1 Contour initialization

Other than contour initialization, the other factors such as smooth factor (μ), contraction bias (v) and iteration number (N) need to be optimized to improve the Chan-Vese active contour performance. The optimal values obtained from the pre-test of 100 images are: $\mu < 0.7$, $v < 1.5$ and $N < 35$.

Next, the Chan-Vese active contour can be deployed to segment the desired iris boundary based on the contour initialization and the improved factors of μ, v and N. By doing this, the eyelids and sclera regions can be isolated from the iris region.

Finally, the detected and isolated pupil, eyelashes, eyelids and sclera regions are subtracted from the eye image to obtain the segmented iris region.

2.2.3 Normalization

Normalization is used to convert the segmented iris region from a circular shape to a fixed rectangular polar coordinate. The Rubber sheet model [10] is chosen in this work for the normalization process. Normalization is important in iris recognition since it can compensate the iris size and pupil constriction. It acts as a reference point for the same iris region. The normalization process has been improved where it is faster than Masek [21]. The new code is written from the same algorithm which has less lines of code and less functions to perform the normalization process. The example of normalization is shown in Fig. 2.

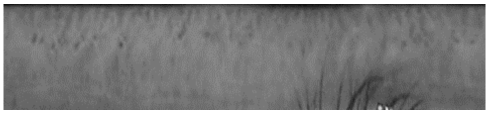


Figure 2 Normalization

2.2.4 Feature Extraction

Next, the features of iris are extracted from the normalization image as in Fig. 3. The 2-D Gabor filter [22] is used for the feature extraction which is based on [10]. After that, the extracted features are encoded into a binary code to create an iris template. This template is also called as Iris code. The programming code of algorithm is based on [21].

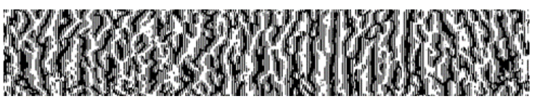


Figure 3 Feature extraction

2.2.5 Matching

In matching, there are many methods can be used to compare the input iris code and the database iris code such as Euclidean distance, Hamming distance and many more. In this work, Hamming distance (HD) is used for iris matching due to simpler algorithm and faster matching speed. The noise template/mask that contains parts that are not belong to iris region is also compared with the iris code as in Eq. 4 where A is the input iris and B is the database iris. The code of algorithm is based on [21].

$$HD = \frac{\left|\left|(codeA \otimes codeB) \cap maskA \cap maskB\right|\right|}{\left|\left|maskA \cap maskB\right|\right|} \tag{4}$$

3.0 RESULTS AND DISCUSSION

3.1 Iris Segmentation

Based on Fig. 4, the iris region was successfully segmented by using the modified Chan-Vese active contour. This method was able to segment the iris region with various shapes and unsmooth edges. The various shapes of iris can be segmented due to the proposed method can locate the irregular boundary. Then, the unsmooth edges can be segmented since this method was less dependent on gradient information. Moreover, the iris region occluded by the eyelid can also be segmented due to the contour initialization was accurate enough in order for the active contour to locate the eyelid boundary.

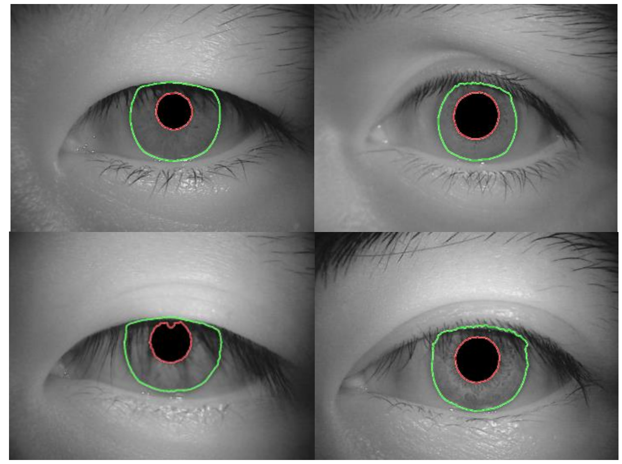


Figure 4 Iris segmentation

3.2 Execution Time

Next, the proposed method was compared with the IDO method [11] to differentiate the execution time of both methods. Our method was significantly fast because of the contour initialization was accurate thus reduced the number of N to be used in active contour. The less number of N can reduce the time taken to segment the iris region. Other than that, this method used no separate eyelid detection to detect the eyelid boundary. The active contour can detect the eyelid simultaneously with the segmentation process of iris boundary. Moreover, the modified normalization code also managed to optimize the performance of the Chan-Vese active contour since this code can create the normalization image faster than the original one [21]. The less lines of code and less functions can further reduce the execution time of the proposed method. Meanwhile, [11] used the IDO which had complex algorithm with extensive computation. In the other hand, this method used 2 IDOs in its algorithm which used more computations. This method also needed a separate eyelid detection to detect the eyelid boundary. Because of that, this method was slower than the proposed method. The result can be observed in Table 1 where the proposed method was 61.28 % faster than [11].

Table 1 Execution time

Methods	Average Execution Time (s)
[11]	2.35
Proposed Method	0.91

3.3 Recognition Accuracy

In terms of recognition accuracy as in Fig. 5, the proposed method was more accurate because of the area under curve (AUC) of our method was higher than [11]. This happened since the location of iris features in our segmented iris region were almost similar with the iris features in the database. Moreover, our method can differentiate the correct iris region from the proposed segmentation method. This proved that our method can reduce the possibility to accept the wrong person and to reject the right person into the iris recognition system. The proposed method was 2.66 % higher recognition accuracy than [11].

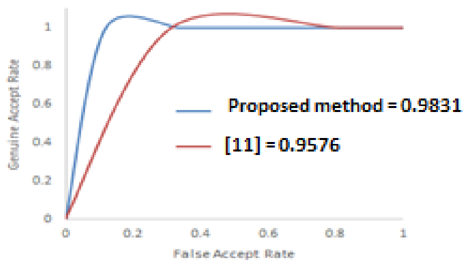


Figure 5 Recognition accuracy

4.0 CONCLUSION

In this study, the Chan-Vese active contour has been modified to improve the execution time and recognition accuracy of iris recognition system. Based on the results, the proposed method achieved accurate iris segmentation, faster execution time and higher recognition accuracy than the IDO method. This proved that the performance of iris recognition can be further improved by using the Chan-Vese active contour. For future enhancement, the proposed method can be compared with the method of HT to observe the execution time and recognition accuracy. The speed of the proposed method can be reduced by using sub-iris region instead of full-iris region.

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