Iris Segmentation Analysis using Integro-Differential Operator and Hough Transform in Biometric System

Z.Zainal Abidin[1], M.Manaf[2], A.S.Shibghatullah[1], S.H.A.Mohd Yunos[1], S.Anawar[1], Z.Ayop[1]
[1] *Faculty of Information and Communication Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100, Durian Tunggal, Melaka.*
[2] *Faculty of Computer & Mathematical Sciences, Universiti Teknologi MARA, Shah Alam, 40450, Selangor.*
zaheera@utem.edu.my

Abstract*—Iris segmentation is foremost part of iris recognition system. There are four steps in iris recognition: segmentation, normalization, encoding and matching. Here, iris segmentation has been implemented using Hough Transform and Integro-Differential Operator techniques. The performance of iris recognition system depends on segmentation and normalization technique. Iris recognition systems capture an image from individual eye. Then the image captured is segmented and normalized for encoding process. The matching technique, Hamming Distance, is used to match the iris codes of iris in the database weather it is same with the newly enrolled for verification stage. These processes produce values of average circle pupil, average circle iris, error rate and edge points. The values provide acceptable measures of accuracy False Accept Rate (FAR) or False Reject Rate (FRR). Hough Transform algorithm, provide better performance, at the expense of higher computational complexity. It is used to evolve a contour that can fit to a non-circular iris boundary. However, edge information is required to control the evolution and stopping the contour. The performance of Hough Transform for CASIA database was 80.88% due to the lack of edge information. The GAR value using Hough Transform is 98.9% genuine while 98.6% through Integro-Differential Operator.

Index Terms*—Iris Recognition, Iris Segmentation Technique, Iris Normalization Technique, Iris Pattern, Performance measurement of a Biometric System, FAR and FRR and Matching Technique.

I. Introduction

Biometric technology is the key to identify a unique feature of personal individual for biometric identification. It can be defined by their different pattern owned by the human. Recently, iris biometric becomes a newest technology in the security technologies after fingerprint. Iris biometric is more secure than the other security technology. The iris of each eye is unique. No two irises are alike in their mathematical detail, even between identical twins and triplets or between one own left and right eyes. Furthermore, each iris has its own information.

The process of capturing the iris image is called as enrolment. There are several devices for enrolment process such as iris sensor, DSLR camera and mobile iris camera. The iris image intensity depends on how the iris captured whether using indoor device or outdoor device. The value of the iris would affect the way of displaying the data that can be computed for performance parameter values, namely FAR and FRR

There are four stages for iris recognition; segmentation, normalization, encoding and matching. Each stage applies a different technique.

Iris segmentation refers to the process of extracting features that provide information of iris pattern. It is a process that when iris recognition begins with finding an iris in an image, detecting the upper and lower eyelid boundaries if they were bar, and detecting and excluding any superimposed eyelashes or the reflection from the cornea or eyeglasses.

Normalization refers to preparing a segmented iris image for the encoding process. It measures the range of pixel intensity and binary values using suitable technique to identify the uniqueness in each iris.

The next stage is the encoding technique, where the iris code is generated. Then, the iris code is stored in the database and it is useful for the verification process or matching.

Our work focuses on an analysis of iris segmentation using Hough Transform and Integral Differential Operator techniques for iris recognition system. It is because the technique determined the perimeter of simple geometric object. The main idea is to implement the segmentation technique using iris pattern for identification. This leads to high reliability for personal identification and at the same time, the difficulty in effectively representing such details in an image.

This study experiments the differences of the two techniques based on the accuracy and performance parameters. The parameter which measures the performance is False Acceptance Rate (FAR) and False Rejection Rate (FRR). FAR is the frequency that a non authorized person is accepted as authorized, since, security measure non-stationary statistical quantity. FRR is the frequency that an authorized person is rejected access. The accuracy parameter, measures the percentage of successful segmentation process in both techniques.

As the result, iris gives different value in each image of iris. Whether he or she is the same person, the left and right eyes are different output. Here, iris image from CASIA database is used for the experiment analysis.

In the next section, several segmentation techniques are discussed, such as Hough Transform, and Integro-Diffential Operator.

II. RELATED STUDIES

Segmentation is a process of acquiring information from the iris image. The information of the eye is focused on iris part and the other part is ignored as shown in Figure 1. The information of the iris image is more meaningful to authenticate each user because the image was partition into a multiple segment. These technique is use to calculate the image whether in intensity or form the matrix of the image. The characterization of regions in an iris image shows their texture contents. Most of the researchers use Hough Transform and Daugman's Integro-Diffential Operator technique to segment the iris. Thus, the experiment is implemented in analyzing the performance of both techniques.

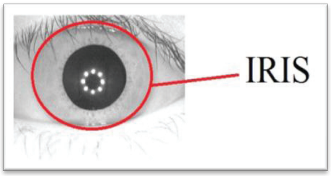


Figure 1: Image of Iris

A. *Iris Segmentation*

Iris has been preferred due to its accuracy, reliability and simplicity as compared to other biometric modality [1]. In fact, iris is the most accurate and effective means of biometric identification.[2] John Daugman is known for his biometric identification, and has developed the fundamental algorithm as described in [3] and followed with the enhancement of the algorithm in [4].

The iris is segmented using Integro-Differential Operators. Iris segmentation refers to the process of automatically detecting the pupil and limbus boundaries of an iris in a given image [5]. This process helps in extracting features from the discriminative texture of the iris, while excluding the surrounding regions. Iris segmentation plays a key role in the performance of an iris recognition system. This is because improper segmentation can lead to incorrect feature extraction from less discriminative regions such as sclera, eyelids, eyelashes, pupil, etc., thereby reducing the recognition performance.

According to [6], the Integro-differential operator and Hough transform techniques [7] has been used as segmentation technique. In order to effectively extract a pupil boundary, it is essential to define the contour characteristics that the system aims to capture. In general, a pupil boundary is a closed, continuous and smooth curve, which is near-circular.

To achieve a better performance in the normalization of an iris recognition system, it is essential to capture this contour with respect to a proper center point and a proper angular resolution. In [8], Hough Transform is used to locate the region of interest. Feature extraction is performed with an application of Laplacian of Gaussian filters at different resolutions. A normalized correlation between the acquired iris representation and the stored one is employed for pattern matching. As described in [9], Bachoo uses principal component analysis (PCA) in preprocessing technique to remove the noise and redundancy. Then the Hough Transform technique is applied to find the circular iris. Other algorithms can be used for iris segmentation. For instances, Lim combines Haar wavelet and a neural network to achieve iris recognition [10]. For extraction, multi-channel Gabor filtering is implemented [11].

B. *Iris Normalization*

The human has different characteristics [12], which the behavioral traits can be used in biometric characteristic. It satisfies the following requirements of universality, distinctiveness, permanence, collectability, performance, acceptability and circumvention. The evaluation of recognition of iris can be evaluated by the biometric performance such as false accept rate or false match rate (FAR or FMR), false reject rate or false non-match rate (FRR or FNMR).

Other performance parameter includes receiver operating characteristic or relative operating characteristic (ROC), equal error rate or crossover error rate (EER or CER), failure to enroll rate (FTE or FER) and failure to capture rate (FTC).

In iris normalization, the data is trained which resulting the FAR to produce zero value and FRR produced results. The algorithm could detect the iris database which provides samples of trained data. However, Lenina stated that the process of normalization only consumes the substantial amount of time of the system [13]. Therefore, the computational time has been reduced by 0.3342 sec which means the proposed algorithm has improved the performance parameters. By omitting the normalization process, the accuracy is 99.4866% lower than John Daugman's method that contributes to 99.90% accuracy.

III. IMPLEMENTATION

A. *Experimental Design*

The research experiment is conducted using Matlab R2010a. Iris recognition has to pass through the segmentation technique and normalization technique to produce a template to measure the biometric system. The process flow for iris recognition is shown in Figure 2. The flow starts by first getting the data from iris CASIA database.

The iris is reduced to smaller size. Then the iris is converted from RGB to grayscale iris image. After that, the random noise is applied to the grayscale iris image for removing the noise. It is to provide better texture of iris and iris information. Then, the pupil localization and the iris localization were extracted. The iris feature is produced through the segmentation technique, either using Hough Transform or Integro-Differential Operator. There are two forms of information we gathered from iris feature; pixel values and the binary code. Once this information achieved, it is stored into the database. For matching process, hamming distance is used for detecting the same binary code either in the database is same or vice versa.

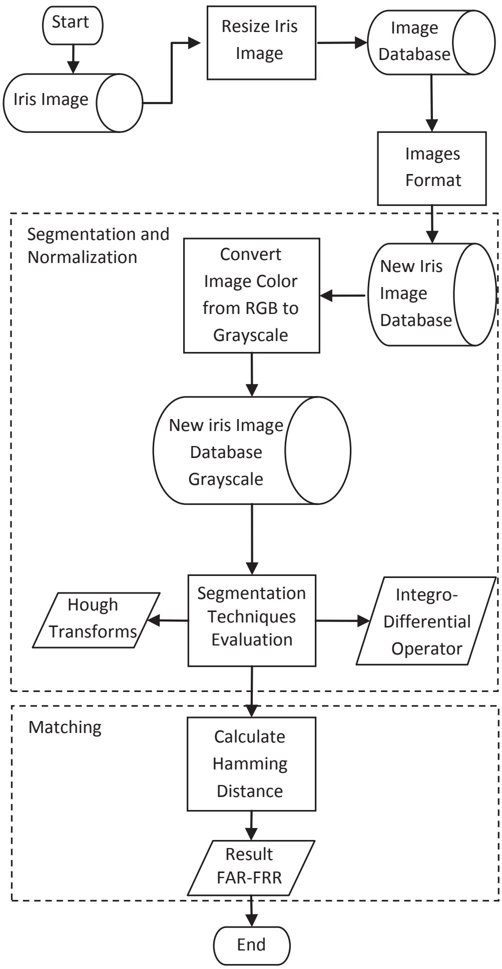


Figure 2: Flowchart of iris recognition

From the flowchart, there are three main stages in the experiment which is segmentation, normalization and matching. Figure 3(a) shows the original iris image and 3(b) shows the segmented iris, as a result of the segmentation process. In 3(b), the pupil is localized and errors are removed from the segmented iris. The information inside the segmented iris is extracted through the normalization process.

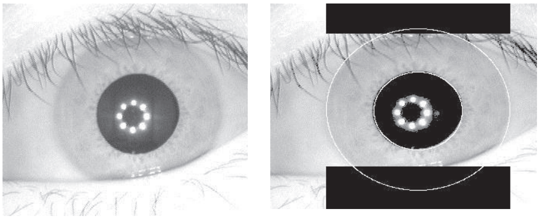


Figure 3(a)(b) : Example image before and after the image apply segmentation technique of pupil and iris localization

In the normalization stage, the image of iris is gathered by reducing the errors and a rectangular shape of segmented iris is produced. The normalization process is illustrated as in Figure 4.

Using Hough Transform, there is a scheme to detect and match the iris code in the database compared to live iris code during verification stage. However, Integro-Differential Operator do not has this feature, therefore another technique of normalization need to be integrated with it, such as the Gabor Wavelet, for extracting the iris information.

The output from the normalization technique is stored into the database in two forms; pixel values and iris code.

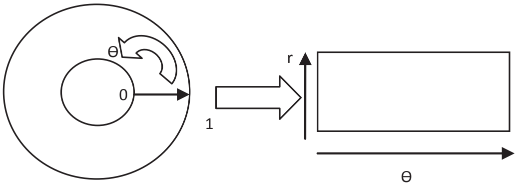


Figure 4: Normalization technique

The final step is matching the iris code by using the iris feature stored in the system. The matching is carried out by measuring the distance between two images of iris code. In this work, the Hamming Distance (HD) is used to measure the distance between of two iris code [14].

B. Segmentation Techniques Evaluation

In this work, we are focusing on the iris segmentation technique, Hough Transform and Integro-differential Operator. In iris segmentation research, accurate boundaries are needed to normalize and match iris image with the database. Inaccurate iris segmentation would affect the iris recognition accuracy quickly no matter how discriminative the irises feature is. The diagram of iris recognition is shown in Figure 5.

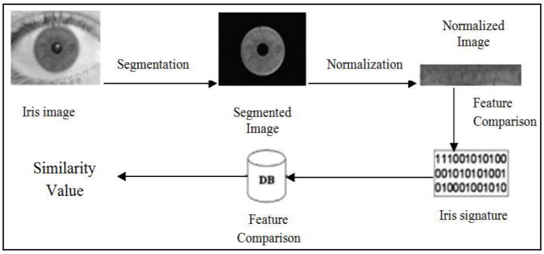


Figure 5: Iris recognition overview

Hough Transforms technique is used for detecting the iris and pupil boundaries. This involves first employing canny edge detection to generate an edge map. Gradients were biased in the vertical direction for the outer iris boundary. Vertical and horizontal gradients were weighted equally for the inner iris boundary. A modified version of Kovesi's Canny edge detection using Matlab function was implemented, which allows for weighting of the gradients. The range of radius values to search for was set manually, depending on the database used. Figure 6 (a)(b)(c)(d) shows the implementation of the modified Kovesi's Canny at the segmentation stage. Furthermore, the step by step process produces the results in Table 1 and 2 using each technique; Hough Transform and Integro-Differential Operator.

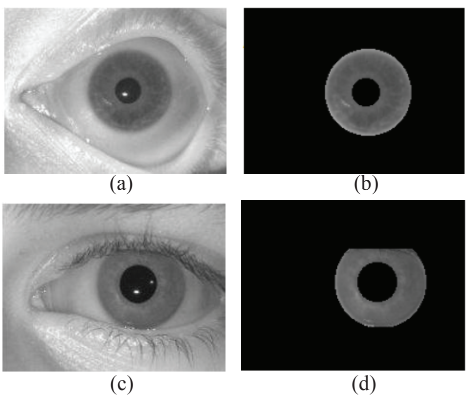


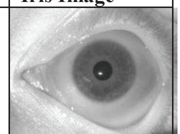
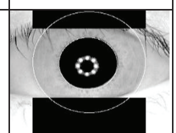
Figure 6(a)(b)(c)(d) : Image segmentation of the iris without distorting the eyelids and eyelashes

Circular Hough Transform is to localize iris boundaries. The Hough Transform searches the optimum parameters of following:

$$\mathrm{H}(xc, yc, r) = \sum_{i=1}^{n} \mathrm{h}(xi, yi, xc, yc, r) \qquad (1)$$

Where $h(x_j,y_j,x_0,y_0,r) = (x_j-x_0)^2 + (y_j-y_0)^2 - r^2$ for edge point (x_j, y_j) ,j=1...,n. One weak point of the edge detection and Hough transform approach is the use of thresholds in edge detection. Different settings of threshold values may result in different edges and then affect the Hough transform results significantly. However, in table 1, the error from the original iris is removed using the white noise for better image performance.

Table 1
Hough Transform Segmentation Process

Description	**Iris Image**
The declaration of images in the database.	
Display the image of iris.	
Write noise image to the iris image.	
The process to display out the iris image with the image with noise.	

The other segmentation technique is using Integro-Differential Operator (IDO). It was implemented as well, with a few modifications involving due to processing speed, and 136 image irises in database has been tested out of in this study.

The Integro-differential Operator is based on the fact that the illumination difference between inside and outside of pixels in iris edge circle is maximum. In other words, if you calculate the difference in values of pixels gray level in iris circle, this value is higher than any other circles in images. This fact turns to color of iris and color of sclera. Sclera is the white region outside of iris.

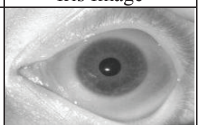
The algorithm for locating inner and outer boundaries an iris via the following optimization:

$$\max_{(r, x_p, y_o)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r, x_o, y_0} \frac{I(x,y)}{2\pi r} \, ds \right| \qquad (2)$$

Where I(x,y) containing an iris image. The Integro-differential Operator search over the image domain (x, y) for the maximum in the blurred partial derivative with respect to increasing radius, r of the normalized contour integral of I(x, y) along a circular arc ds of radius, r and center coordinates(x_0, y_0). The symbol * denotes convolution and $G\delta(r)$ is a smoothing function. Integro-differential Operator actually behaves as a circular edge detector.

The Integro-differential Operator searches the gradient maximum over the 3D parameter space, thus, there was no need to use any threshold as the traditional canny edge detector. Integro-differential Operator suggests that the radius of the pupillary boundary can range from 0.1 to 0.8 of the limbus boundary radius. Refer Table 2.

Table 2
Integro-Differential Operator Segmentation

Techniques	John Daugman
Description	Iris Image
The declaration of images in the database	
This process removes specular reflections by using the morphological operation 'imfill'. Define the circle of iris.	
This process is used to define the circle of pupil	
The outcome of 1 devide the `out1` and `out1` by using the codes.	
The process of display the iris image that has been segmented	

Based on the experiment, the Integro-differential technique is not computationally efficient, because the search area in a couple of parts has been reduced, and the elimination of errors due to reflections in the eye image has not been implemented. This will be discussed further in the next section.

IV. Results And Discussions

The iris images of CASIA-IrisV3-Interval are tested in this study. The database of the iris was captured with self-developed iris camera. CASIA-IrisV3-Interval is a superset of CASIA V1.0 which has been requested by and released to more than 1,500 researchers or teams from 70 countries and regions.

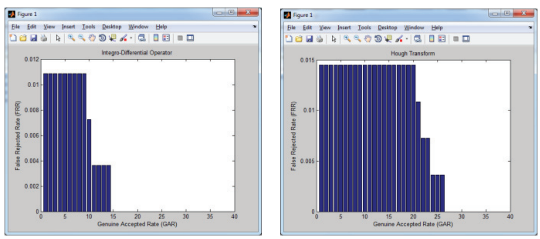
The result of the segmentation using Integro-Differential Operator is a vain attempt. Hough Transform technique performs better than Integro-Differential Operator technique. Although Hough Transform takes more time to segment the 136 grayscale iris images in database, on the other hand, it produces a successful attempt. In fact, it also produces an image of iris using template that can hide the noise of the iris image. The full texture of iris can be manipulated to get the data of the iris.

We will discuss the performance on two basis; Comparison of GAR based FRR, and Comparison of GAR based RE-rate. The equation of Genuine Accepted Rate is defined as one minus the false rejected rate:

$$(GAR) = 1 - (FRR) \quad (3)$$

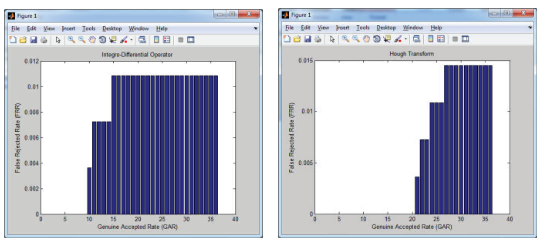
Figure 7 shows the Hough Transform versus the Integro-Differential Operator technique with respect to FRR. The comparison between Hough and John Daugman's techniques illustrate the accuracy of segmentation results in percentage. Figure 7 (a) refers to Integro-Differential Operator technique while Figure 7 (b) refers to Hough Transform technique.

From the graph, it shows that 98.9% segmentation using Hough Transform is genuine while Integro-Differential Operator evidences that 98.6% is genuine. Furthermore, the Integro-Differential Operator technique recognizes less genuine iris compared to Hough Transform technique, which is able to identify genuine iris more than Integro-Differential Operator.



(a) (b)

Figure 7 (a) (b) : Comparison of GAR based FRR



(a) (b)

Figure 8 (a) (b) : Comparison of GAR based RE-rate

Next, we show the results of successfully segmented iris image. The Integro-Differential Operator only segment 22.06% of the images due to poor imaging conditions, while Hough Transform successfully segment 80.88% from the CASIA database. This is because Hough Transform has the additional features compared to the other technique, for instance, a scheme for matching and error correction function to improve the accuracy and performance. Refer figure 8(a) Integro-Differential Operator technique with respect to RE-rate and Figure 8(b) refers to Hough Transform technique with RE-rate. It is clearly shown that Hough Transform shows less error rate in iris segmented.

In Table 3, iris image presented at different segmentation apply to the S1001L03 left iris image. The difference of the technique can be defined from the segmented images using the Hough Transforms and Integro-Differential Operator. The results show that the Hough Transform is able to accurately define between the circle iris and circle pupil. However, Integro-Differential Operator segmentation is not able to define the accuracy of circle pupil and circle iris on this iris image.

Table 3
The Comparison of Hough Transforms and Integral-differential Operator in CASIA database

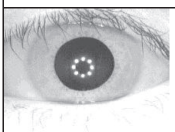
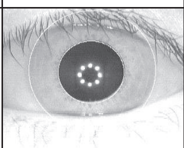
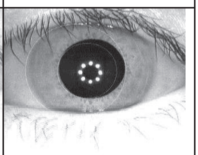
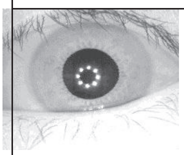
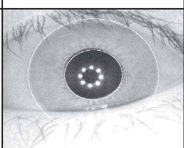
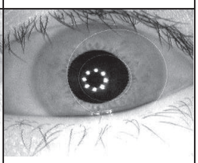
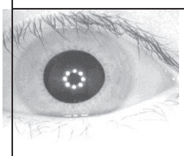
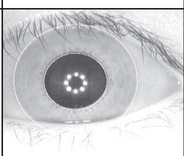
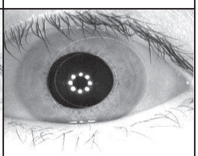
Original Iris	Hough Transform	Integro-Differential Operator
 S1001L01		
 S1001L02		
 S1001L03		

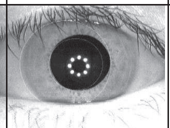
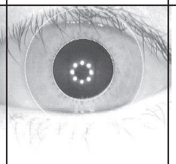
Table 4 is the comparison of segmentation value of the iris image based on their circle iris and circle pupil between the two techniques. From the result, each image has different value when two different techniques of segmentation are applied. The results of Hough Transform technique fulfil the requirement of circle pupil and circle iris. The image S1001L01 is successfully segmented accurately by Hough Transform. The average of the circle pupil of the Hough Transform is 112 and average of circle pupil value using Integro-Different Operator is 106.67. From the result, we can conclude that the value of Integro-Different Operator is lower that the Hough Transform. Average circle iris of Hough Transform is 127.67 while Integro-Differential Operator is 110 as depicted in Table 5.

Table 4
The Comparison of segmentation for pupil and iris using two different algorithms

DATABASE	Hough Transform						Integro-Differential Operator					
	Circle Pupil			Circle Iris			Circle Pupil			Circle Iris		
S1001L01	118	156	57	115	158	110	120	148	52	120	128	88
S1001L02	132	160	50	133	160	113	132	172	44	124	192	84
S1001L03	142	130	55	140	130	108	140	140	52	140	160	84

For each subject, the average value of circle iris and circle pupil is calculated as in Table 5 and compared in Figure 9. There are 7 images per subject and the total iris images gather from CASIA-IrisV3-Interval is 136 images, which means 136 x 7 gives 952 irises.

Table 5
Average value of pupil and iris with different segmentation techniques

Technique of Segmentation	**Segmented Iris image**	**Average circle pupil**	**Average circle Iris**
Integro-Differential Operator		106.67	110
Hough Transform		112	127.67

The output of the eye center detector was used only for two techniques Hough Transform and Integro-Differential

Operator techniques. The performance of an iris segmentation technique was measured by computing the segmentation accuracy, defined as follows:
Segmentation accuracy =

$$\frac{\text{Number of correctly segmented image}}{\text{Number of input images provided}} \times 100$$

The considered set of iris segmentation techniques ensures a balance between the classical approaches, and the relatively newer approaches to handle challenging iris images. The Integro-Differential Operator requires relatively less computations, in comparison with the Hough Transform technique. However, their performance was observed to be low, due to the poor quality input data.

On the other hand, Hough Transform algorithm, provide better performance, at the expense of higher computational complexity. It can be effectively used to evolve a contour that can fit to a non-circular iris boundary. However, edge information is required to control the evolution and stopping of the contour.

The performance of Hough Transform for this database was 80.88% due to the lack of edge information, which is caused by poor illumination levels. The GAR of the Hough Transform is 98.9% genuine while 98.6% from Integro-Differential Operator.

The errors of segmentation by Hough Transform technique show that the segmentation is lower than Integro-Differential Operator. From the result, we could conclude that Hough Transform technique resulted is the best performance compare to the Integro-Differential Operator techniques.

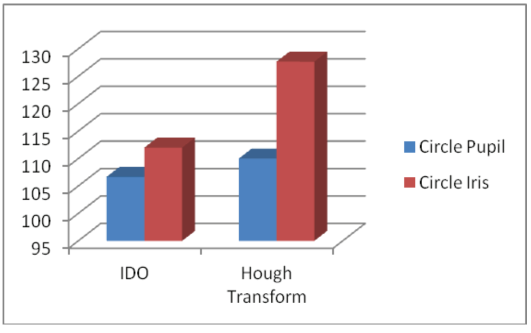


Figure 9 : Average of circle pupil and circle iris comparison between Hough and Integro-Differential Operator

V. Conclusion and Future Work

The pre-processing schemes appeared to have a significant role in the segmentation performance for all techniques. Sufficient illumination before capturing image helps in increasing the contrast of the image, thereby highlighting the iris boundaries. Similarly, eye centre detector helps in localizing a region for iris boundary search process.

Both the pupil boundary and the iris boundary of a typical iris can be taken as circles. However, the two circles are usually not co-centric. When compared with the other part of the eye, the pupil is much darker. The iris detected is in the inner boundary between the pupil and the iris by means of threshold. The outer boundary of the iris is more difficult to detect because of the low contrast between the two sides of the boundary. We detect the outer boundary by maximizing changes of the perimeter-normalized sum of grey level values along the circle. The technique is found to be efficient and effective. Improper segmentation can lead to incorrect feature extraction from less discriminative regions such as sclera, eyelids, eyelashes and pupil hereby reducing the recognition performance.

Analysis of the developed iris recognition system has revealed a number of interesting conclusions. It can be stated that segmentation is the critical stage of iris recognition, since areas that are wrongly identified as iris regions is corrupted biometric templates resulting in very poor recognition. The results presented in segmentation can be the most difficult stage of iris recognition because its success is dependent on the imaging quality of eye images.

The segmentation techniques evaluated in this study contains pro and cons. A high speed accuracy scheme needs to be issued in iris biometric system for future work. Moreover, the algorithm must be able to comply with future iris devices such as portable or mobile iris scan or non-contact scanning from enormous distance for future biometrics system.

Acknowledgment

A highly appreciation to Universiti Teknikal Malaysia Melaka (UTeM) for sponsor this research through the short term grant (no. PJP/2011/FTMK(19B)/S00965). Thank you to all friends and staff from Faculty of Information and Communication Technology (FTMK) for giving support to complete this project. A special thanks to CASIA for sharing iris images.

References

[1] P. Gupta, H. Mehrotra, A. Rattani, A. Chatterjee, A.K. Kaushik, “Iris Recognition using Corner Detection,” Indian Inst. Of Technology Kanpur, India, 2006.

[2] M.Almualla, “The UAE iris expellees tracking and border control system”, Biometrics Consortium, Crystal City, VA, Sept 2005.

[3] J. Daugman, “High confidence visual recognition of persons by a set of statistical independence,” *IEEE Trans. Pattern Analysis. Mach. Intell.*, vol. 15, no. 11. pp. 1148–1961, 1993.

[4] J. Daugman, “The importance of being random: statistical principles of iris recognition,” *Pattern Recognition*, vol. 36, no. 2. pp. 279–291, 2003.

[5] Raghavender Jillela, Arun Ross, Vishnu Naresh Boddeti, B. V. K. Vijaya Kumar, Xiaofei Hu, Robert Plemmons, Paul Pauca (2002). "An Evaluation of Iris Segmentation Algorithms in Challenging Periocular Images".

[6] Niladri B. Puhan · N. Sudha Anirudh Sivaraman Kaushalram . "Efficient segmentation technique for noisy frontal view iris images using Fourier spectral density". Verlag London, 2009.

[7] Wildes L.P., “Iris recognition: An emerging biometric technology,” *Proceedings of the IEEE*, vol. 85, no. 9. 1997.

[8] Technique’Boles L.P. and Boashash B., “A human identification technique using images of the iris and wavelet transform,” *IEEE Trans. on Signal Processing*, vol. 46, no. 4. 1998.

[9] Bachoo, A.K.; Tapamo, J.R. "A segmentation method to improve iris based identification", 7th AFRICON Conference in Africa, IEEE Conference . Vol 1, pp. 403 – 408, 2004.

[10] O. Byeon Lim K., K. Lee and T. Kim, "Efficient iris recognition through improvement of feature vector and classifier," *ETRI Journal*, vol. 23, no. 2, pp. 61–70, 2001.

[11] Y. Wang Lim K. and T. Tan, "Iris recognition based on multichanel gabor filtering," in *Fifth Asian Conference on Computer Vision*, vol. 1, pp. 279–283, 2002

[12] Nithyanandam..S, Gayathri. K. S. and Priyadarshini P.L.K, "A New IRIS Normalization Process for Recognition System with Cryptographic Techniques", International Journal of Computer Science Issues, Vol. 8, Issue 4, no 1, July 2011.

[13] Lenina Birgale and M. Kokare, "Iris Recognition Without Iris Normalization", Journal of Computer Science vol 6 (9), pp. 1042-1047, 2010.

[14] Ashish kumar Dewangan, Majid Ahmad Siddhiqui, "Human Identification and Verification Using Iris Recognition by Calculating Hamming Distance", International Journal of Soft Computing and Engineering (IJSCE), Vol 2(2), May 2012.