An Iris detection and recognition system to measure the performance of E-security

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DECLARATION

We, hereby declare that this thesis is based on the results found by ourselves. Materials of work found by other researcher are mentioned by reference. This Thesis, neither in whole or in part, has been previously submitted for any degree.

Signature of Supervisor	Signature of Co-supervisor	Signature of Author
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Abstract

Biometric is a system to identify the individual human by extracting distinguishable features from that particular person. Among many other biometric systems the iris recognition system is most accurate one right now since it has a high recognition rate. This thesis is proposing a system with four major division in the process: Segmentation, Normalization, Feature encoding and Matching. At early stage, Histogram equalization is used on the input image and to detect the objects present in the image, Canny Edge Detection model is employed. Inner circular boundary and center of the pupil in the Iris region is detected by using Hough Transformation. A circle is drawn with the help of Mid-Point Circle drawing algorithm which center is as same as pupil center and hence, outer circular boundary of the iris region can be detected. For the normalization, Daugman's Rubber Sheet model is used and in the feature encoding process, instead of Gabor filter to extract feature from the iris image, Log-Gabor filter is used in this thesis since it has non-zero DC component advantage over Gabor filter. Last but not the least, Hamming Distance is used to compare two binary iris template for matching purpose.

Acknowledgement

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Contents

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Keywords

Iris recognition

Biometric identification

Pattern recognition

Iris segmentation

Feature extraction

Hamming Distance

Abbreviation

HD = Hamming Distance

SVM = Support Vector Machine

HCT = Hough Circle Transformation

RGB = Red Green Blue

GS = Gray Scale

CASIA = Institute of Automation, Chinese Academy of Sciences

1. Introduction

A biometric system recognizes an individual automatically based on distinguishable characteristics an individual possesses. There are several types of biometrics. Such as Fingerprints, Voice recognition, Hand geometry, Hand writing, the Retina, Iris Recognition and so on. In this thesis, the Iris recognition system is presented.

The biometric system has several process. First of all, the system captures some samples which vary for every specific biometrics. For example, voice sample for voice recognition system, sample fingerprint for fingerprint recognition, digital color image for face recognition and in this thesis, eye images are taken as a sample. After that, with the help of various mathematical equation a biometric template is created for every single individual. The biometric template will give a normalized, proficient and highly distinguished representation of the feature and comparing with other template this will identify an individual. First a reference template will be saved in the database and whenever a specific person needs to be recognized he/she will give a new sample. Furthermore, a new template is created from the new sample and thereafter, it is matched with the reference template. Thus the automatic system can tell whether the person is recognized or not.

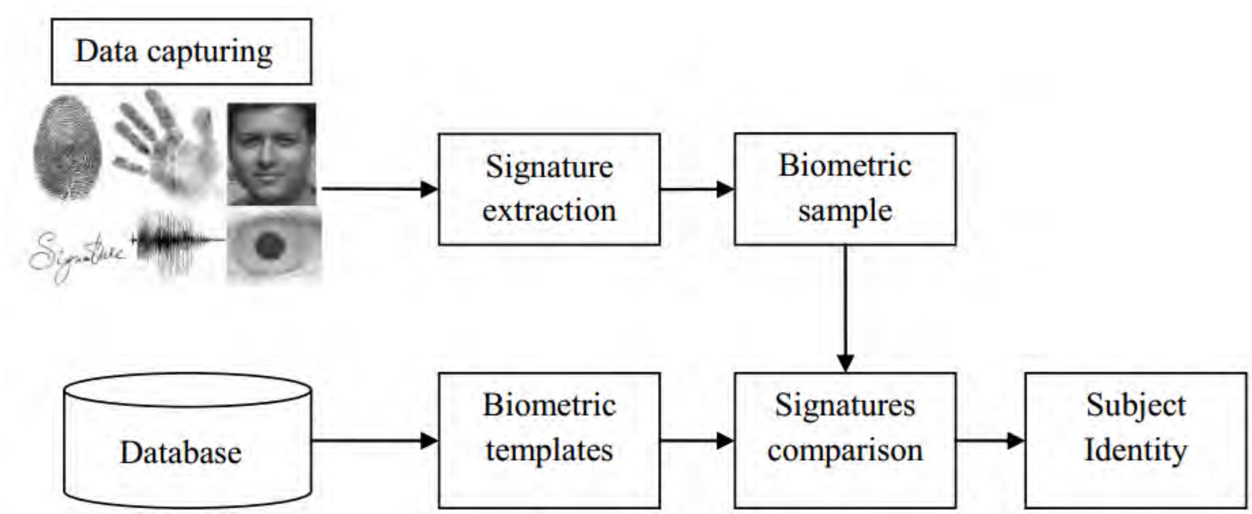

Figure 1: General representation of Biometric System

The quality of a biometrics depends on

1. How efficiently it can distinguish the most unique features from the sample so that two people having the same characteristics is minimized.
2. The extracted features must be stable so that they do not change over time.
3. The feature must be easy to extract.

By definition, the iris is a thin, circular structure in the eye which is responsible for controlling the diameter of the pupil and by doing so it controls the amount of lights are entering into the retina. Iris defines the eye color.

The iris is consist of two layers: the stroma and the pigmented epithelial cells beneath the stroma. The stroma is connected with a sphincter muscle. A set of dilator pupillae (dialator muscle) draw out the iris radially to enlarge pupil. Thus the sphincter muscles and diameter muscles together adjust the pupil. The epithelium layer contain dense pigmented cells. The anterior uvea is consist of the iris and ciliary body. The average diameter of the iris is 12mm and the pupil size can vary from 10% to 80% of the iris diameter [1],

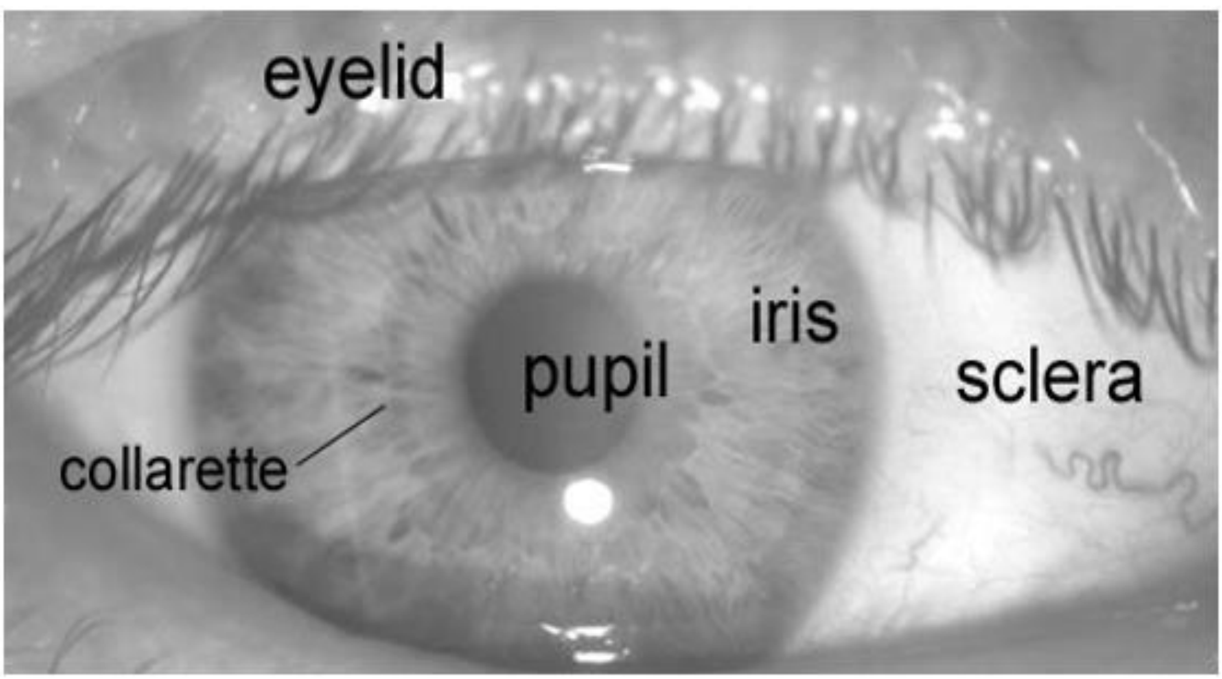

Figure 2: A front end view of the human eye [1].

The iris is the combination of the pupil and collarette region. Pupil is the darkest part of eye and surrounded by the collarette portion which contains the sphincter muscles and diameter muscles.

There are two circles in the iris. One is known as the inner or iris/pupil circle and another one is called iris/sclera boundary which separates the iris region from the sclera region. During the third month of pregnancy the formation of the iris begins [2]. The unique pattern of the iris region is developed at developed during first year of life. The pigmentation takes place for a few more years. The iris pattern doesn't depend on any genetic factor [3]. Only the color of the iris depends on genetics. Because of this independency of iris over genetics, the two eyes of the same human are totally different from one another and even for the identical twins [2].

The characteristic of iris that defines it as a good biometrics:

- The iris is highly visible.
- It is an extremely protected organ.
- The pattern in the iris remain stable throughout the adult life.

Because of these above mentioned characteristics, iris recognition has widely accepted as a biometrics to identify any individuals. By applying image processing technique, the unique pattern of the iris can be extracted from a digitized iris image and then save the extracted data for later matching. Now, we can consider a scenario where one person is willing to get registered by iris recognition so that he/she can be individually identified at later. First of all, an image will be taken of that particular person's eye and then, the automated system will analyze the image. Thereafter, a template which contains unique features of that particular person. After generating the template, it will be stored in the database. Hence, this person is registered by iris recognition. Whenever he/she needs to validate his/her identity another image will be taken of his/her eye. A new template will be generated from this new image and will be matched with the reference template. If the system find enough matching element then it will recognize the person and otherwise not.

1.1 Proposed System

For iris recognition, at first we need to find out the Iris region. The iris region is enclosed by two boundaries where the inner boundary is known as Pupil/Iris boundary and the outer one is known as Iris/Sclera boundary. The eyelids and eyelashes usually cover up the upper part of the iris region as well as the lower part of the iris region. Moreover, the iris region can be corrupted by the specular reflection and which will corrupt the iris pattern. So we need a reliable and effective technique to perform isolation of iris region from the given image and exclusion of above mentioned artifacts. In my iris recognition model we are using a combination of both Hough Transformation and Mid-point line drawing algorithm.

After successful segmentation of the iris region from the eye image, we need to transform this segmented region into a specific dimensions in order to allow comparisons. The iris regions produced by automated normalization process must have same dimensions, so that two iris regions of the same eye will contains features at the same location. Another important point is not all the pupil regions are circular. For the normalization process we are using Daugman's Rubber Sheet Model [1].

After the completion of the normalization process we need a way to store the extracted data. To do so, the system must extract the most discriminative information from the iris image. To identify a particular human iris, we will match the newly acquired image with the information saved in the database. So we need to make sure that only significant data points are encoded. In our system we are convoluting the normalized process with Log-Gabor filter.

The main purpose of the biometric is to identify an individual. Since we already made a template containing the most distinguishable features extracted from the given image, now we need to establish a method to match the new template with the referenced template saved in our database. Hence, one particular person can be identified through this system. Our system has an automatic matching process based on Hamming Distance algorithm.

1.2 Thesis Outline

The structure of the paper is as follows. Section 2 presents the Literature review of the other system and their recognition rate. In section 3, the technical overview of iris recognition system i.e. the details of the algorithms and methods used in various systems are explained. The detailed procedures of how I applied the algorithms and designed my system are mentioned in section 4. In section 5, the result and analysis is given. Finally the conclusion and future work is mentioned in section 6.

2. Literature Review

John Daugman is known as the inventor of Iris recognition system and his patented algorithm is being widely used in commercial Iris recognition system. Surprisingly, the daugman system has a perfect recognition rate which means it never gave a wrong identification. However, the published result are used in ideal situation. Daugman's system has four major division in the process: Segmentation, Normalization, Feature Encoding and Matching.

In 1949, the British ophthalmologist J.H. Doggart, [4] wrote that: "Just as every human being has different fingerprints, so does the minute architecture of the iris exhibit variations in every subject examined. [Its features] represent a series of variable factors whose conceivable permutations and combinations are almost infinite." In a 1953 clinical textbook F.H. Adler [5] referred to Doggart's comment and written that "In fact, the markings of the iris are so distinctive that it has been proposed to use photographs as a means of identification, instead of fingerprints." Later in 1994, John Daugman has patented his automatic iris recognition system and in present, his system is being widely used.

The characteristic of iris that defines it as a good biometrics:

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The Daugman's algorithm is being widely used and it tested in different conditions and it has a zero failure rate. Wildes et al. was tested with 520 images and also has no failure [6]. Lim et al. is tested with 6000 iris images and it has a recognition rate with 98.4% [7].

3. Technical review

3.1Technical review of the segmentation Algorithm

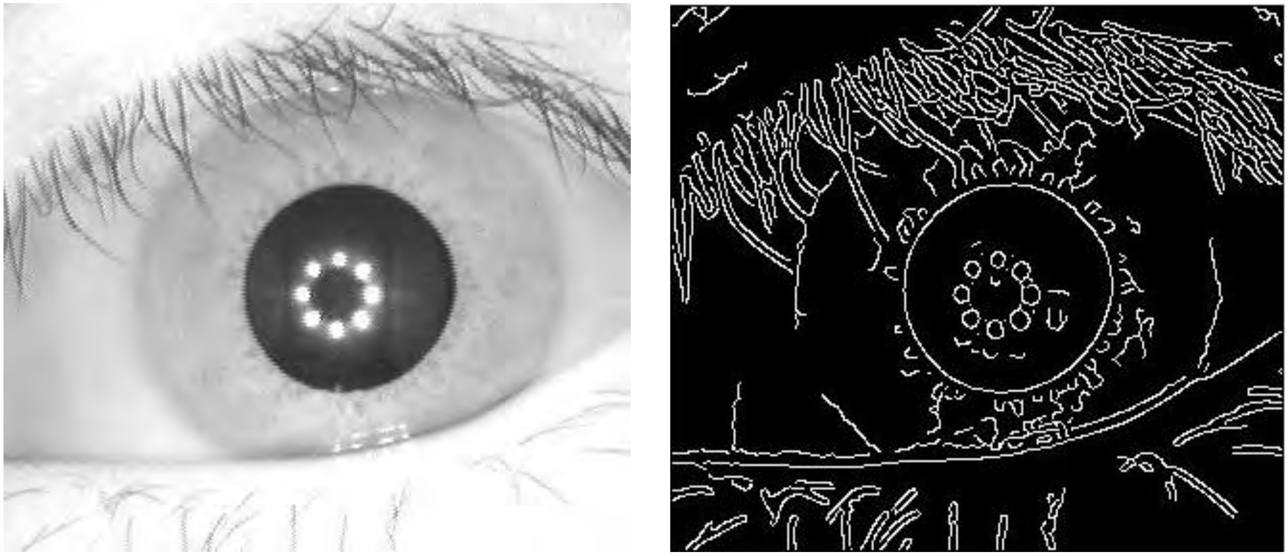
3.1.1 Hough Transform

In computer vision, the simple geometric element like lines and circles exist in an image are detected by the Hough transform algorithm. The circular Hough transform is appointed to detect the center of the pupil and iris region as well as to detect the pixels present in the boundaries. By doing so we can also find the radius of the circle. Based on Hough transform, Wildes et al. [6], Tisse et al. [8], Kong and Zhang [9] and Ma et al. [10] employed an automatic segmentation algorithm to segment the iris region. First of all, from the given image we need to calculate the first derivatives of intensity values and then by calculating the result based on threshold value we can generate an edge map. After that, the parameters of circles (center coordinates x_c^2 and y_c^2 and the radius r_c) are evaluated by voting in Hough space.

The equation of circle is

$$x_c^2 + y_c^2 - r_c^2 = 0 \qquad (1)$$

From the edge map, radius and circle coordinates will be defined based on the pixels where maximum point of Hough space will correspond. Wildes et al and Kong and Zhang employed parabolic Hough transform to the lower and upper eyelids. To perform edge detection, Wildes et al. biased the derivatives in the vertical direction to detect outer circle of the iris region and in the horizontal direction to detect eyelids.



(a) Original image (b) Edge map image

Figure 3: By using Hough transform an edge map is created.

Demerits of Hough transform

1. In Hough transform, edge are detected based on threshold values which can undermined critical edge point.
2. It uses 'brute-force' method and may not be applicable in real time application.

3.1.2 Daugman's Integro-differential operator

In Daugman's algorithm[1], the circular iris and pupil region are detected by an integro-differential operator and the eyelids and eyelashes are also detected by it. The equation of integro-differential operator is

Where,

$I(x, y)$Is the eye image

r Is the radius

$G_{\sigma}(r)$Is a Gaussian smoothing function?

s Is the contour of the circle given by r, x_0, y_0

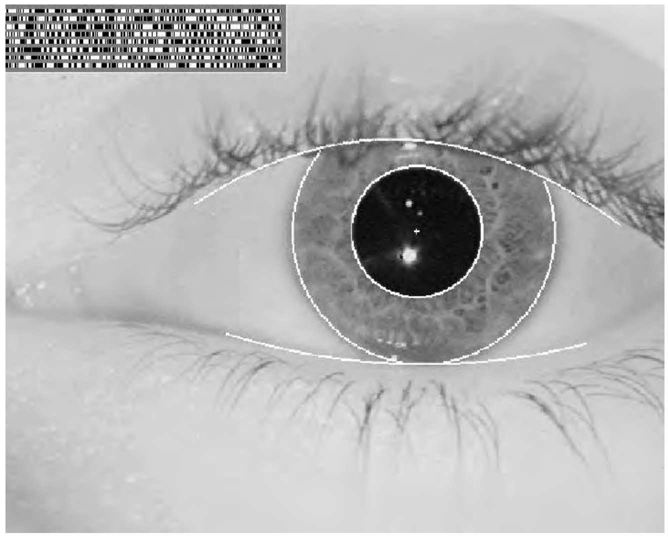


Figure 4: The outlines of eyelids, inner circle and outer circle computed by Daugman's Integro differential operator (image taken from [1])

By varying the value of radius and center coordinates, the operator searches for the circular path based on the maximum changes in pixel values.

3.1.3 Eyelash and Noise detection

Kong and Zhang [9] classified the eyelash position in an image in two class: Separable and multiple. They classified those eyelashes that can be distinguished from neighboring eyelashes as separable eyelashes and those are not distinguishable known as multiple eyelashes. These following two reasons are the reason behind this separation:

1. The neighboring pixels of separable eyelids are iris region pixels and the eyelid can be considered as edge.
2. The multiple eyelids region has less intensity difference than the separable eyelids because many eyelids overlap each other.

A threshold value is used to distinguish the eyelids in the eye image.

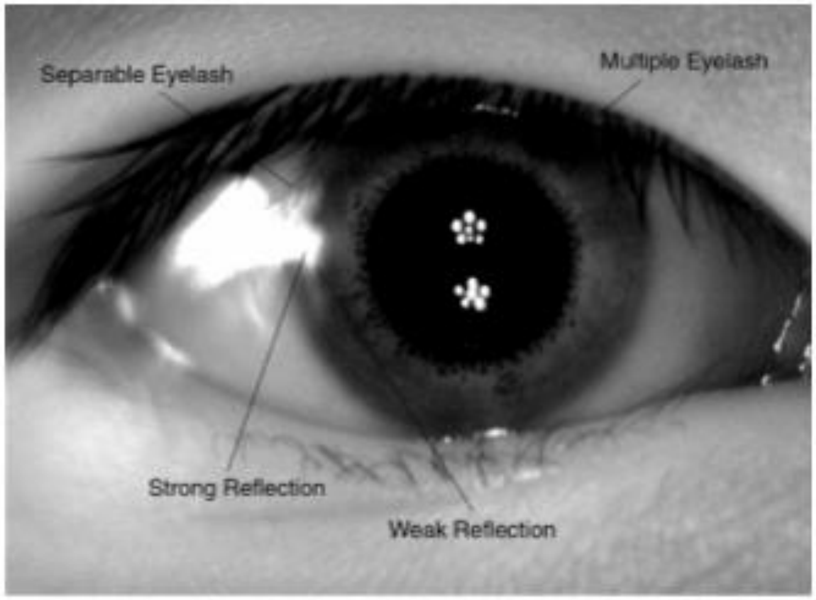


Figure 5: A cross section of a separable eyelash and part of iris around it [9].

3.1.4 Specular Reflection Detection

Because of the reflective properties of the cornea, sometimes our iris region contain corneal reflection which lids to error in estimation of the iris-pupil center as well as to locate inner boundary of the iris region [13]. There are three methods to cancel out the corneal reflection in the cornea.

A. Bilinear interpolation: In [8 of New corneal], Zhaofeng first detects a binary corneal reflection map with the help of threshold value (5% brightest intensity). Then bilinear interpolation method is used to fill up the reflection point. It works fine with the MMU iris database but it doesn't work with CHASIA iris database V3.0.
B. Connectivity of four pixels: In this method, as all the reflection points are white and from image complement we find all the white reflection points turn into dark and these points have the highest dark intensity. In this method, dark points are filled based on connectivity of four pixels.
C. Linear Interpolation extension: They noticed a critical point that specular reflections appear as the brightest point of the eye image. First of all, they are evaluating a

reflection map using white Top-hat (the difference between the input image and its opening by some structuring element). After that, these points are isolated by using threshold.

3.2 Technical review of Normalization Algorithm

3.2.1 Daugman's Rubber Sheet Model

To normalize the segmented iris region Daugman [1] proposed a rubber sheet model which will remap all the Cartesian points in the iris region into polar coordinate (r, θ) system.

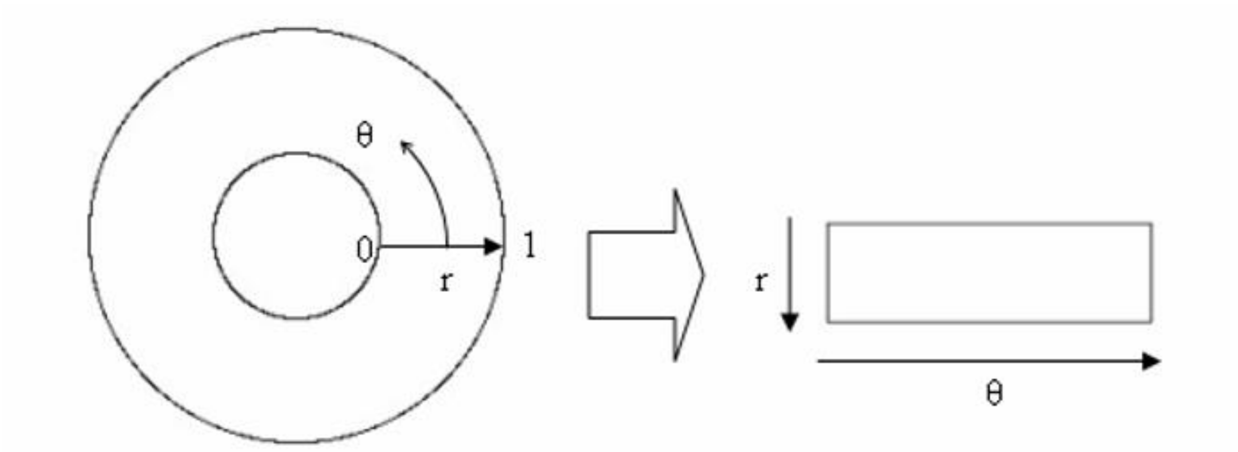


Figure 6: Daugman's Rubber Sheet model.

To remapping the Cartesian coordinates to polar coordinates, the used equations are

$$I\big(x(r,\theta), y(r,\theta)\big) \rightarrow I(r,\theta)$$
$$x(r,\theta) = (1-r)x_p(\theta) + rx_l(\theta)$$
$$y(r,\theta) = (1-r)y_p(\theta) + ry_l(\theta)$$

Here, I(x, y) is the Iris region Image and the original Cartesian coordinates are (x, y) and the corresponding polar coordinates are (r,θ). Moreover, (x_p, y_p) and (x_l, y_l) are the pupil and iris boundary coordinates along the θ direction. Pupil dilation and size inconsistent are also being in consideration to produce a normalized iris region. However, it doesn't fall in with rotational inconsistencies. In Daugman's Iris recognition and feature extracting algorithm, the rotation is compensated by shifting the iris template in the θ direction [1].

3.2.2 Image Registration

The Wildes et al. system wraps a newly acquired image geometrically based on alignment with a selected database image [3]. One mapping function is chose to transform the original coordinates by considering the new image intensity value are made to be close to the reference image corresponding points.

$$\int_x \int_y (I_d(x,y) - I_a(x-u, y-v))^2 \, dx \, dy$$

Here,

$I_a(x, y)$Is the new acquired image.

$I_d(x, y)$Is the referenced image.

u,v are the mapping function parameter

3.2.3 Virtual circles

In the Boles [11] system, iris images are first scaled so that they have constant diameter as a result when comparing two images, one image can be considered as the reference image. This system is different from the other techniques. In this system, normalization is performed at the time of attempting to match two iris regions. As the system made sure that two iris images have the same dimension, intensity values are stored from the iris regions for feature extraction based on the virtual concentration circle originated at the center of the pupil. Moreover, we need to make sure that the resolution of the two normalize iris images are same since the data point extracted from the both images must be equal.

4.2 Technical review of the Feature Encoding Algorithm

4.2.1 Wavelet encoding

The data in the iris region can be decomposed by wavelets into components that appears in different resolution. The wavelets are localized in both frequency and time. On the other hand, the Fourier transform has the frequency data is localized. The features that are present at same resolution and position can be matched up by wavelet transform. A wavelet bank is consist of different wavelet filters and each has a scaled version of some basis function. After completion of wavelet transform, the extracted data will be stored in a template which will be known as iris pattern.

4.2.2 Gabor Filters

Gabor filter, named after Dennis Gabor is used for edge detection. Gabor filter can provide optimum combined representation of a signal in space and spatial frequency. A Gabor filter is constructed from a Gaussian kernel function modulated by a sine/cosine wave. The localization in frequency of a sine wave is perfect, but it is not localized in space at all. When a sine wave is multiplied by Gaussian function, it provides localization in space with some loss of frequency localization. As a result, Gabor filter provides localization in both frequency and space. Gabor filter has a real part and an imaginary part. The real part is obtained by a cosine modulated by a Gaussian function. Moreover, the imaginary part is obtained by modulating a sine wave with a Gaussian function. The real part and imaginary part are also known as even and odd symmetric respectively.

Daugman's phase quantization and demodulation process can be described as

$$h_{\{Re,Im\}} = sgn_{\{Re,Im\}} \iint_{\rho\,\phi} e^{i\omega(\theta_0-\phi)} e^{\frac{-(r_0-\rho)^2}{\alpha^2}} e^{-\frac{(\theta_0-\phi)^2}{\beta^2}} I(\rho,\phi)\rho d\rho d\phi$$

Here,

$I(\rho, \phi)$Is the normalized iris image.

α And β are 2D wavelet size parameters.

(r, θ) Represents the polar coordinates and ω is wavelet frequency.

The phased coordinates are computed with the below functions [1],

$$h_{Re} = 1 \text{ if } \mathrm{sgn}_{Re} \iint_{\rho\ \phi} e^{i\omega(\theta_0-\phi)} e^{\frac{-(r_0-\rho)^2}{\alpha^2}} e^{-\frac{(\theta_0-\phi)^2}{\beta^2}} I(\rho,\phi)\rho d\rho d\phi \geq 0$$

$$h_{Re} = 0 \text{ if } \mathrm{sgn}_{Re} \iint_{\rho\ \phi} e^{i\omega(\theta_0-\phi)} e^{\frac{-(r_0-\rho)^2}{\alpha^2}} e^{-\frac{(\theta_0-\phi)^2}{\beta^2}} I(\rho,\phi)\rho d\rho d\phi < 0$$

$$h_{Im} = 1 \text{ if } \mathrm{sgn}_{Im} \iint_{\rho\ \phi} e^{i\omega(\theta_0-\phi)} e^{\frac{-(r_0-\rho)^2}{\alpha^2}} e^{-\frac{(\theta_0-\phi)^2}{\beta^2}} I(\rho,\phi)\rho d\rho d\phi \geq 0$$

$$h_{Im} = 0 \text{ if } \mathrm{sgn}_{Im} \iint_{\rho\ \phi} e^{i\omega(\theta_0-\phi)} e^{\frac{-(r_0-\rho)^2}{\alpha^2}} e^{-\frac{(\theta_0-\phi)^2}{\beta^2}} I(\rho,\phi)\rho d\rho d\phi < 0$$

Equation of Phased coordinates computation formula by John Daugman [1].

4.2.3 Log-Gabor Filter

The relationship between the number of samples and the frequency and space resolution is disproportional since more samples give the higher frequency information and lower space resolution whereas the low number of samples gives higher space resolution and lower frequency information. The quality of a filter depends on obtaining the maximum frequency information given a set of time resolution and vice versa. From this perspective, Gabor filter is a good filter because it provides excellent localization on space resolution and frequency information. However, at certain bandwidth, a Gabor filter contains non-zero DC component which means that the response of the filter is depending on the signal mean value [12]. On the other hand, non-zero DC component can be acquired for any bandwidth by using Log-Gabor filter. The frequency of the Log-Gabor filter can be represented as:

$$G(f) = \exp\left(\frac{-(\log(f/f_0))^2}{2(\log(\sigma/f_0))^2}\right)$$

Where,

f_0 Represents the center frequency.

σ Represents the bandwidth of the filter.

f Is the original frequency.

The details of the Log-Gabor filter explained by Field [12].

4.2.4 Haar Wavelet

In mathematics, the Haar wavelet form a wavelet family or basis by generating a sequence of rescaled "square-shaped" functions. In Lim et al. [9], to extract the feature from the iris images the wavelet transform is used. Here, Haar wavelet is used as a mother wavelet alongside of Gabor wavelet. Lim et al. also showed that the recognition rate of Haar wavelet transform is better than Gabor wavelet by 0.9%.

5.2 Technical review of Matching Algorithm

5.2.1 Hamming Distance

Hamming distance measures the number of different bits in two strings of the same length. In another way, it measures the number of bit shifting is required to match two strings. It is also used to count the error rate in matching.

By using Hamming distance algorithm, one system can decide whether two patterns are same or not. Hamming Distance, HD, Represents the sum of how many disagreeing bits of two pattern contains. Let us assume that there are two patterns and N is the total number of bits present in both patterns. HD is counted by doing exclusive-OR (XOR) of the bits of two patterns. So the equation we get for Hamming Distance

$$\mathrm{HD} = \frac{1}{\mathrm{N}}\sum_{\mathrm{j}=1}^{\mathrm{N}} \mathrm{X_j}(\mathrm{XOR})\mathrm{Y_j}\ .$$

Since an individual iris pattern contains features which have high degree of freedom, so that each iris image will produce a totally independent bit pattern from the other iris pattern. On the other hand, it is likely to have two iris pattern of the same person will be highly correlated.

Daugman used Hamming Distance to match the reference iris pattern and the new iris pattern [1].

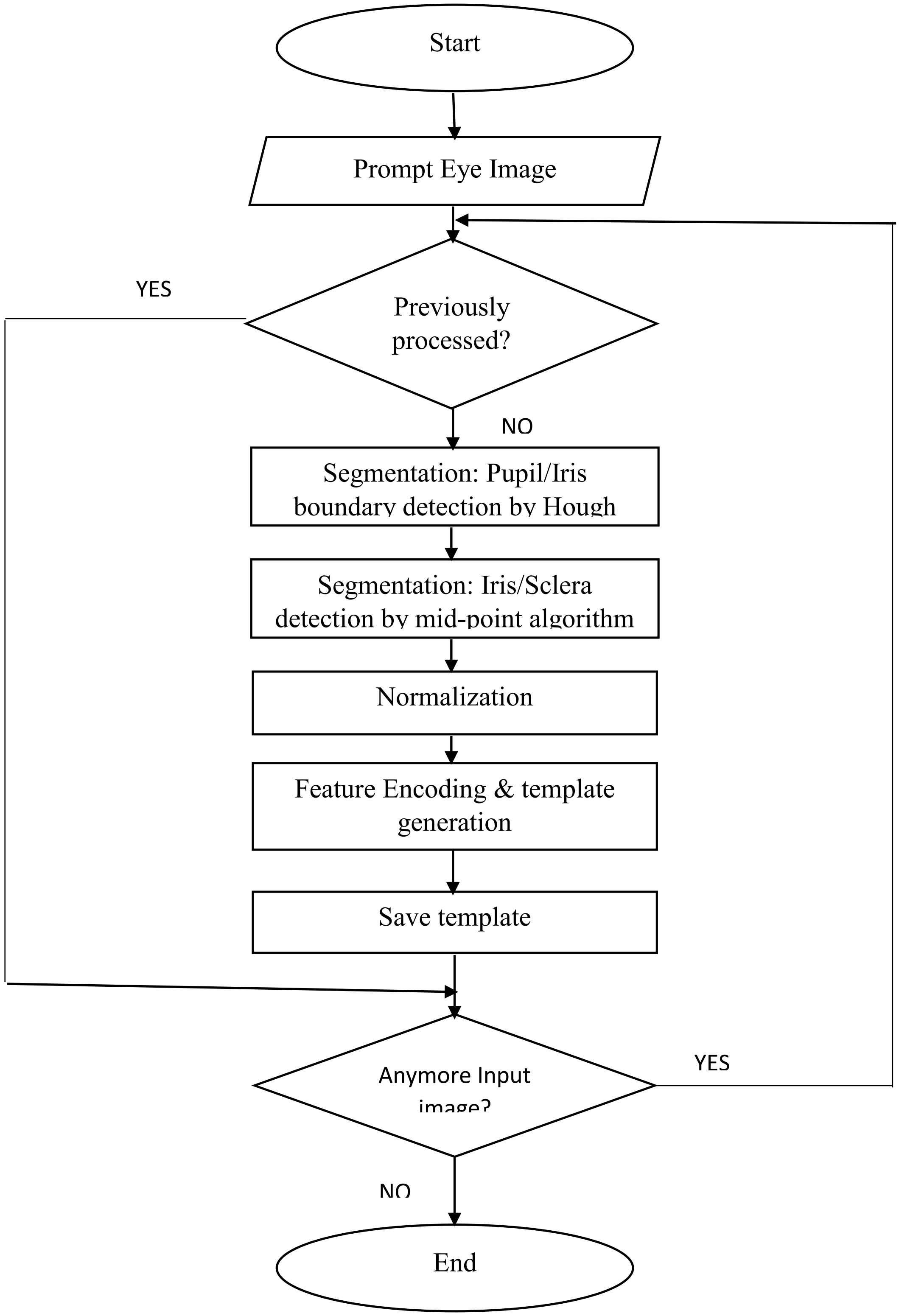
4. System Design

4.1 Tools and Methodology

MATLABR2011b is the tool used in this thesis.

Algorithm used are Hough circle transformation, Mid-point circle drawing algorithm, Daugman Rubber-Sheet Model, Log-Gabor filter, Hamming Distance.

4.2 Flow chart of the Binary template generation



4.3 Segmentation

4.3.1 Early Phased of the segmentation

At the beginning of the input image processing, some steps need to be made to ensure better performance from the system. In this thesis below steps were made:

1. Histogram Equalization: Histogram Equalization technique adjusts the image intensities in order to enhance contrast.
2. Image adjustment: Image adjustment can facilitate improved edge detection.
3. Canny Edge: Canny Edge detection algorithm is a multi-stage algorithm to detect a wide range of edges in the image. By smoothing the image with the help of Gaussian filter the noise will be removed. Then this algorithm finds the intensity gradients of the image and after that, Non-maximum suppression is applied to get rid of spurious response to edge detection.

4.3.2 Iris region detection

In our system, we implemented an automatic segmentation process with the help of two famous algorithm. The process is described below:

1. First of all, we need to check for the corneal reflection. We took the complement of the given image and then we removed the dark points (Reflection points).
2. Then, from the given image we calculated the first derivatives of intensity values and then by calculating the result based on threshold value we generated an edge map.
3. After that, the parameters of circles (center coordinates x_c^2 and y_c^2 and the radiusr_c) are evaluated by voting in Hough space.
4. We need to detect the pupil and to do so we need to bias the first derivative in vertical direction.
5. Thereafter, we kept the same center and then draw a circle by doubling the pupil radius.

4.4 Normalization

A similar technique like Daugman's rubber sheet model is used for the normalization of our segmented iris regions. We made sure that for all the normalized images must have the same resolution. We considered the center of the pupil as the reference point. As shown in Figure, we passed the radial vectors through the iris region. The selected data points along each radial line are known as radial resolution. The number of radial lines going around the iris region are known as radial resolution. The number of radial lines going around the iris region are defined as angular resolution. Because of the non-concentric nature of the pupil to the iris, to rescale points a remapping formula is needed based on the angle around the circle. The formula is

$$r' = \sqrt{\alpha\beta} + \sqrt{\alpha\beta^2 - \alpha - r_I^2}$$

With

$$\alpha = o_x^2 + o_y^2$$

$$\beta = \cos(\pi - \arctan\left(\frac{o_y}{o_x}\right) - \theta)$$

Here,

(o_x, o_y)Represents the center displacement of the pupil compare to iris center.

r'Represents the distance between the edges of pupil and iris.

θIs the angle based on the edges were counted.

r_IIs the radius of the iris?

The function first gives a 'doughnut' form to the iris region based on the angleθ. From this 'doughnut' form iris region we construct a 2D array with horizontal dimension of angular resolution and vertical dimension of the radial resolution.

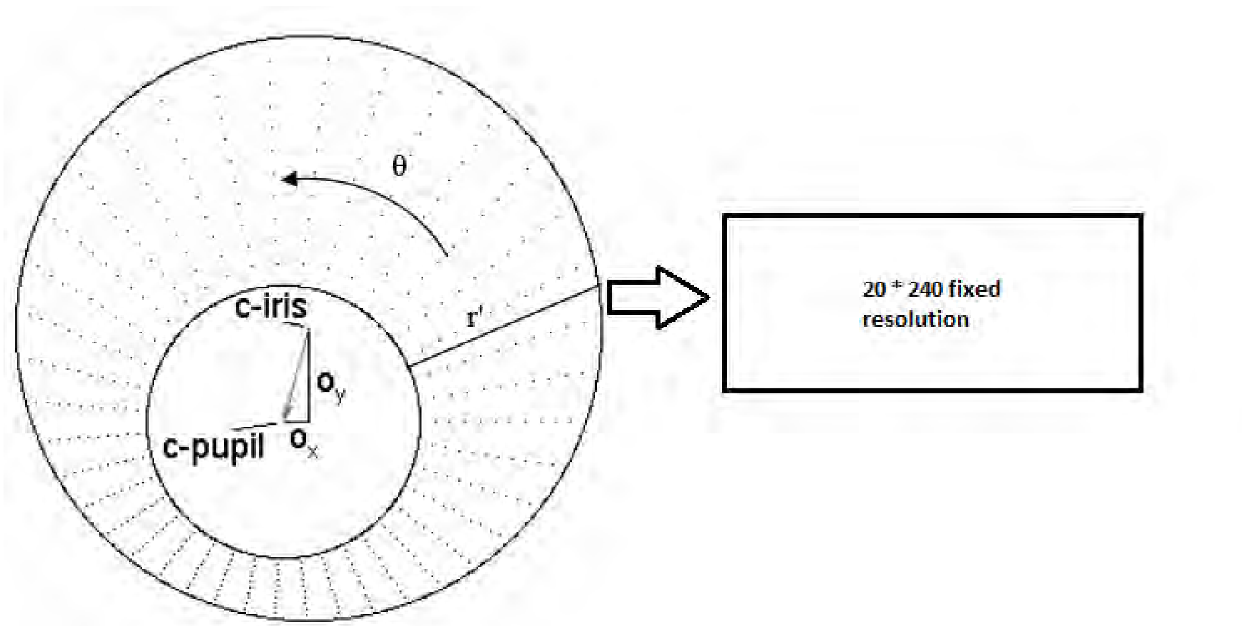


Figure 7: The doughnut form iris region is transformed into a rectangular normalized 2D array [1].

4.5 Feature Encoding

The method we used is explained step by step.

1. The template matrix size is set in such a way by doubling the column size of the normalized iris image and the row is kept same. The reason behind this – In our template both the real and imaginary value will participate.
2. After that, the normalized iris pattern is convoluted with 1D Log-Gabor wavelets. First 1D signals are generated from 2D normalized iris pattern and then Gabor filter is used to those 1D signals. In the Log –Gabor equation we used the following value. The value f_0 is set to 18 which represents a scale 4 Gabor wavelet. From the experiment, we set the value of sigma over frequency to the 0.5.

$$G(f) = \exp\left(\frac{-(\log(f/f_0))^2}{2(\log(\sigma/f_0))^2} \right)$$

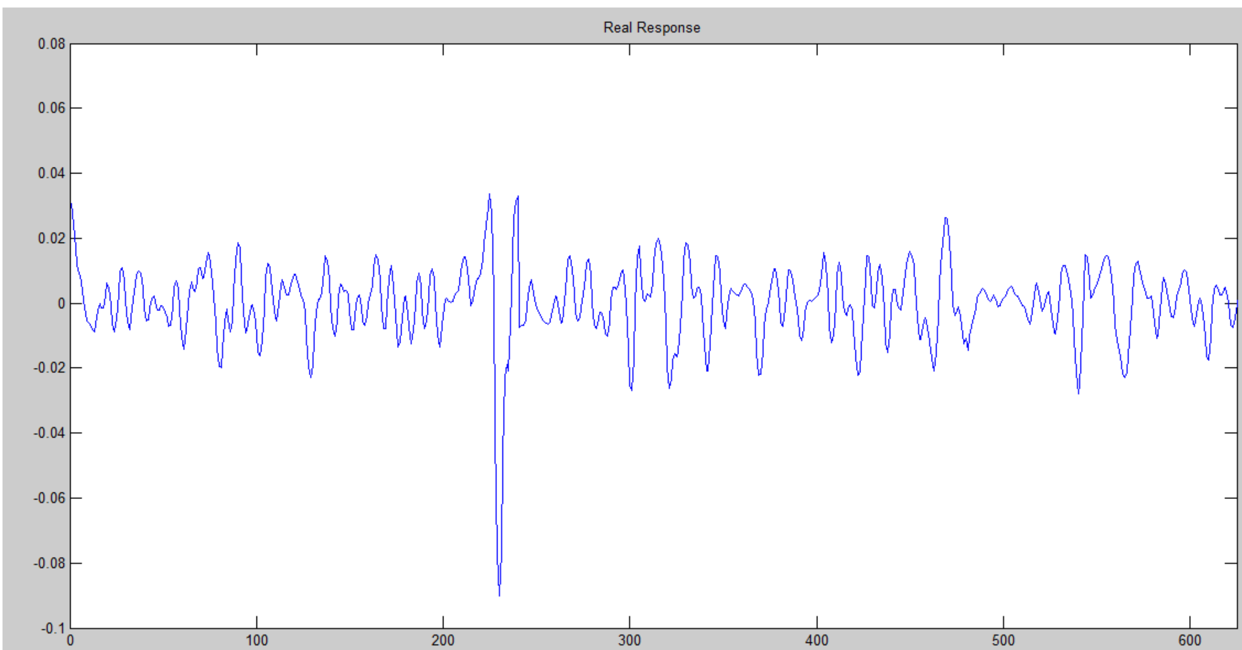
3. Log-Gabor filter returns a matrix with complex valued element with the size of normalized iris image.
4. After that, two new matrix is created from based on the real part and imaginary part of Log-Gabor returned matrix.
5. Thereafter, the raw data of these is converted to pseudo-polar coordinate system. So then, the values of the real part matrix and imaginary part matrix in converted into binary value.
6. Finally, by merging these two matrix we get the template of a human. The data is set in such a way that the odd columns contains real part matrix value and the even columns holds imaginary matrix value.

An image demonstration of the feature extraction and encoding process is given below:

4.5.1 Getting Real Resonse

The normalized Image

1D Log-Gabor Filter

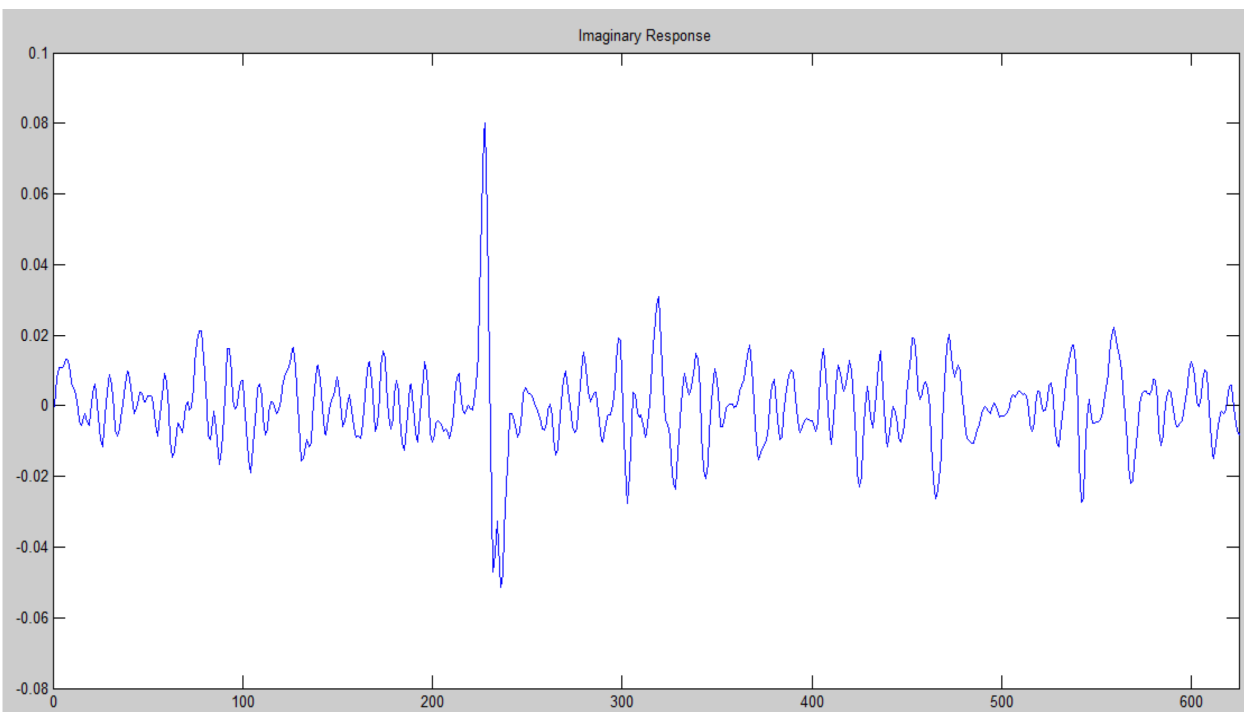


Real Response of the normalized image

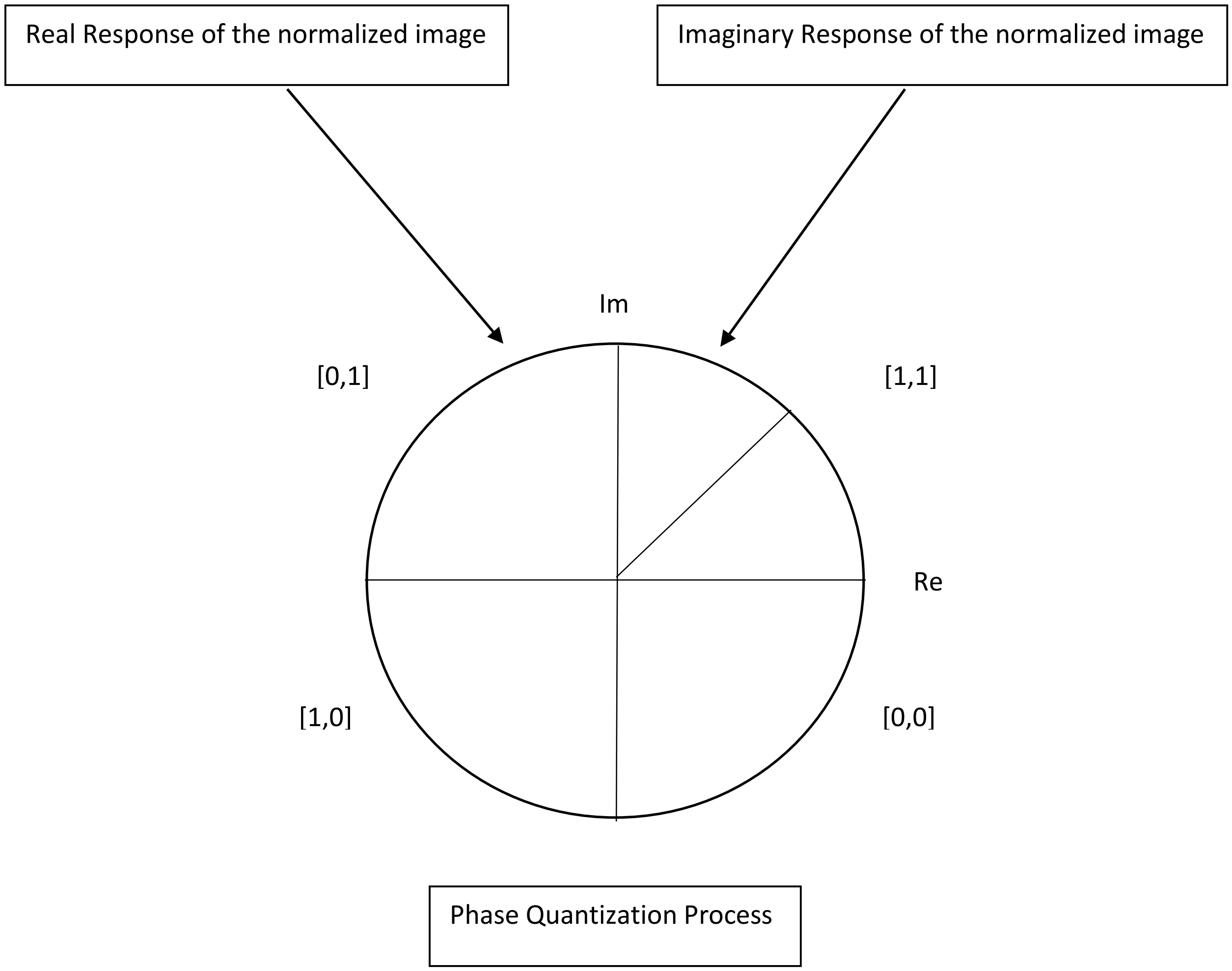
4.5.2 Getting Imaginary Response

The normalized Image

1D Log-Gabor Filter



Imaginary Response of the normalized image



Template example

0111111101100011001001110111111110010000011001110100010
1100100010110011110110110111110000010001011010110100010

4.6 Matching

It is very important to present the obtained vector in a binary code because it is easier to determine the difference between two binary code-words rather than between two number vectors. In fact, Boolean vectors are easier to compare and to manipulate.

We have an applied a Hamming Distance matching algorithm for the recognition of two samples. It is basically an exclusive-OR (XOR) function between two templates. Hamming distance is a measure, which detect the differences of iris code. Every bit presents in the new iris template will be matched against every bit of reference template. From the XOR truth table,

x	y	x XOR y
0	0	0
0	1	1
1	0	1
1	1	0

Figure 10: XOR truth table.

From the figure, if the two bits from two patterns match our hamming distance will be 0 and otherwise it will be 0.

$$\text{Ratio} = \left(\frac{T_z}{T_b}\right) \times 100 .$$

5. Experiment result

5.1 Segmentation Result

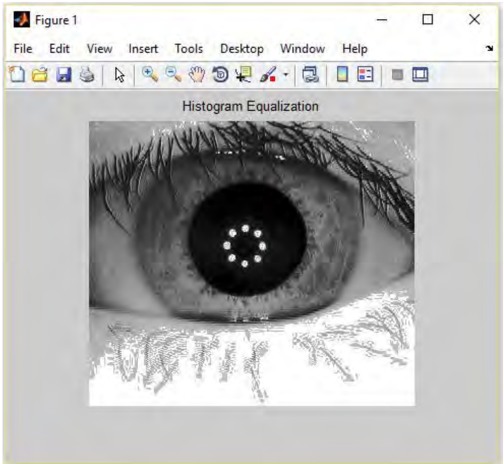
The segmentation process demonstrated in this paper worked very well. A table containing the record of segmentation process is given below:

Number of person	Eye Position	Number of eye images	Number of segmented eye	Error in Segmentation
1	L	10	10	0
	R	10	10	0
2	L	10	10	0
	R	10	10	0
3	L	10	10	0
	R	10	10	0
4	L	10	10	0
	R	10	10	0
5	L	10	10	0
	R	10	10	0
6	L	10	10	0
	R	10	10	0
7	L	10	10	0
	R	10	10	0
8	L	10	10	0
	R	10	10	0
9	L	10	10	0
	R	10	10	0
10	L	10	10	0
	R	10	10	0

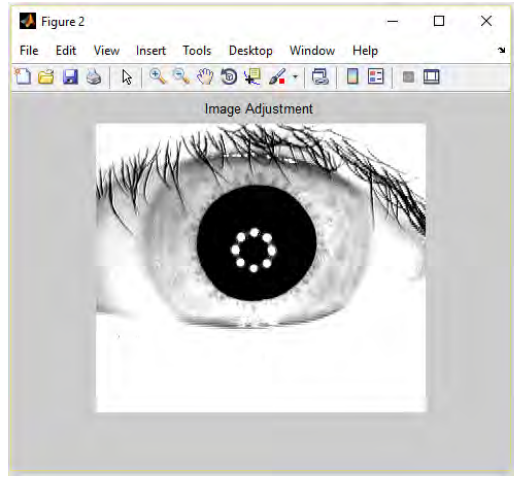
Table 1: Segmentation Record

A total number of 200 eye images were taken from CASIA v3 database and our segmentation is applied among. A matter of proud for us that the segmentation process has worked well with all of those eye images. Our automated segmentation process has zero failure rate.

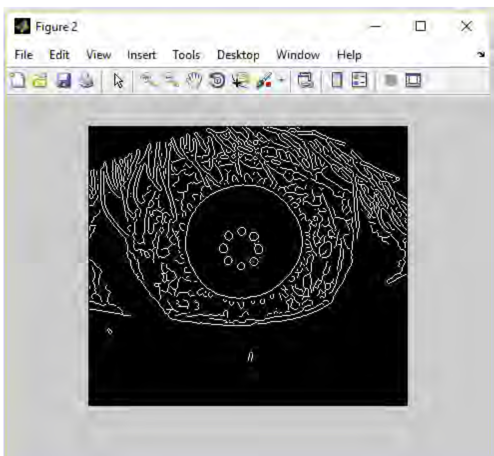
Person 1 Left Eye:



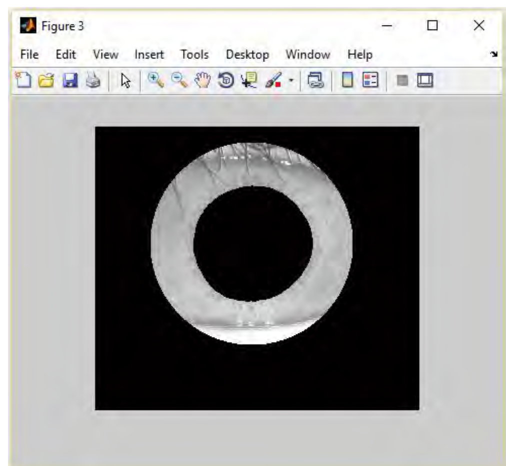
(a)



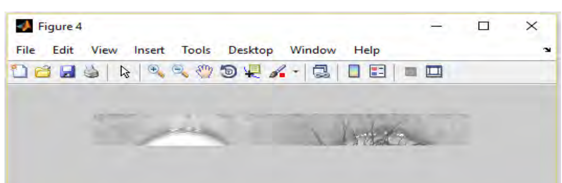
(b)



(c)



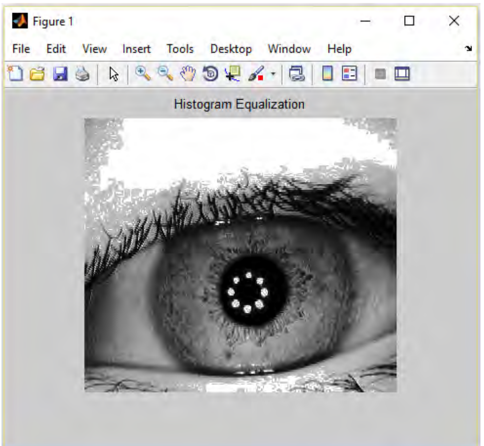
(d)



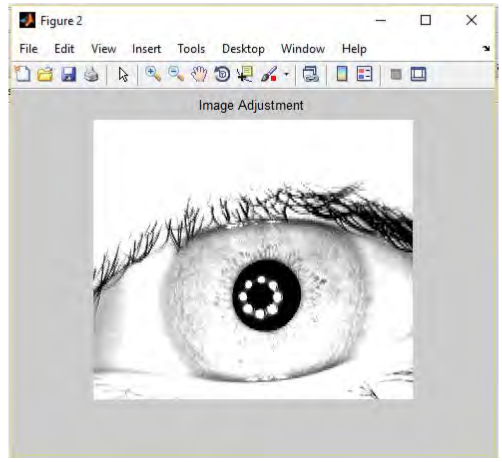
(e)

Figure 8: (a) Histogram Equalization on the input image, (b) Image adjustment to the equalized image for better edge detection, (c) Canny edge detector operator is used on the adjusted image, (d) Hough transformation and Mid-point circle drawing algorithm is applied and (d) Normalized iris region based on Daugman's Rubber sheet Model

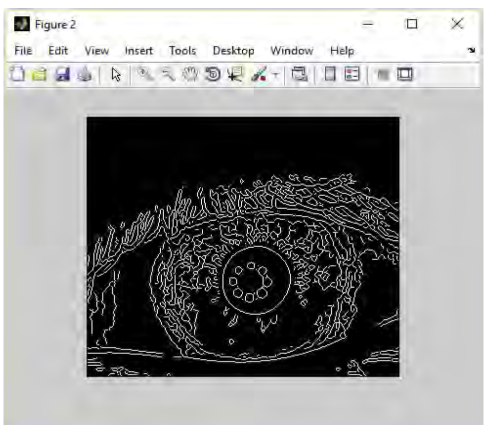
Person 2 right eye:



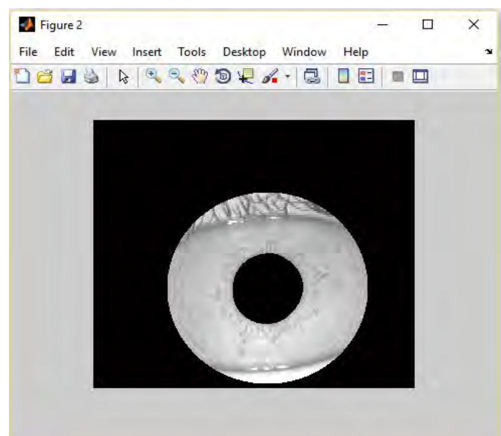
(a)



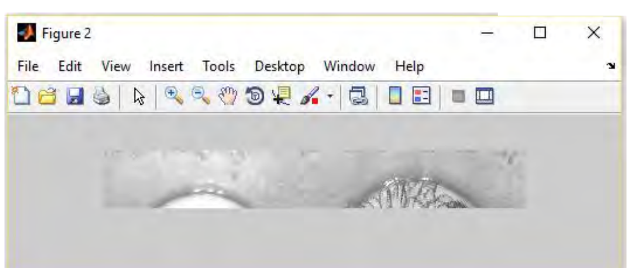
(b)



(c)



(d)



(e)

Figure 9: This eye has lower radius for pupil but nonetheless our automated segmentation worked perfectly. (a) Histogram Equalization on the input image, (b) Image adjustment to the equalized image for better edge detection, (c) Canny edge detector operator is used on the adjusted image, (d) Hough transformation and Mid-point circle drawing algorithm is applied and (d) Normalized iris region based on Daugman's Rubber sheet Model

5.2 Feature Extraction Constant value

The most distinguishable features were extracted from the iris region by using Log-Gabor algorithm. The below mentioned constant values were used in the system:

σ / f_0 = 0.5 (Found from the experiment described in [1])

f_0 = 18 (All the experiment were done under this initial frequency)

5.3 Matching Result

In this thesis, the uniqueness of the human iris is tested. Testing the uniqueness of iris patterns is important, since recognition relies on iris patterns from different eyes being entirely independent. Uniqueness was determined by comparing templates generated from different eyes to each other, and examining the distribution of Hamming distance values produced. The sample test result is given below.

Number of person	Eye Position	Reference eye images	Matched Eye images	Successfully recognized	Error in matching
1	L	1	9	9	0
	R	1	9	9	0
2	L	1	9	8	1
	R	1	9	9	0
3	L	1	9	9	0
	R	1	9	9	0
4	L	1	9	8	1
	R	1	9	8	1
5	L	1	9	9	0
	R	1	9	9	0
6	L	1	9	9	0
	R	1	9	9	0
7	L	1	9	8	1
	R	1	9	9	0
8	L	1	9	9	0
	R	1	9	9	0
9	L	1	9	9	0
	R	1	9	9	0
10	L	1	9	9	0
	R	1	9	9	0

Table: Matching Record

The rate of successful matching rate = $\frac{\boldsymbol{Number\ of\ succession}}{\boldsymbol{Total\ Number\ of\ Images}} \times \mathbf{100}$

$$=\frac{\mathbf{176}}{\mathbf{180}} \times \mathbf{100} = \mathbf{97.78}\%$$

6. Conclusion and Future work

Human eye is protected and yet remains stable throughout the adult life. These characteristic of human eye makes it attractive as a biometric system sample.

Nowadays, Iris recognition system is considered the most reliable biometric system as most of the iris recognition system that exist provides zero failure rate. This thesis represents an automatic iris recognition system. This thesis also provides new way of iris segmentation based on the classic mid-point circle drawing algorithm. Log-Gabor filter is also used instead of traditional Gabor filter since it has non-zero DC component advantage.

Though, the traditional systems including the system presented in this thesis have to go through a several process after normalization. However, it may become possible to reduce the workload by SVM (Support Vector Machine) algorithm to match the two normalized iris region. I would like to try this in future.

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