PERFORMANCE EVALUATION OF TWO HIGH PROFILE SEGMENTATION ALGORITHMS IN IRIS RECOGNITION SYSTEM

By

ADEPOJU, SUNDAY FEMI

DEPARTMENT OF MATHEMATICS,
FACULTY OF SCIENCE,
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

NOVEMBER, 2014.

PERFORMANCE EVALUATION OF TWO HIGH PROFILE SEGMENTATION ALGORITHMS IN IRIS RECOGNITION SYSTEM

By

ADEPOJU, SUNDAY FEMI (B.SC., UNILORIN)
M.SC/SCIE/0159/2009-2010

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF M.SC. DEGREE IN COMPUTER SCIENCE

DEPARTMENT OF MATHEMATICS, FACULTY OF SCIENCE, AHMADU BELLO UNIVERSITY, ZARIA

NOVEMBER, 2014.

DECLARATION

I declare that the work in this project report entitled Performance Evaluation of Two High Profile Segmentation Algorithm in Iris Recognition System has been performed by me in the Department of Mathematics under the supervision of Dr. A.A, Obiniyi and Dr. M.B, Hammawa. The information derived from the literature has been duly acknowledged in the text and list of references provided. No part of this project report was previously presented for another degree or diploma at any university.

ADEPOJU SUNDAY FEMI		
Name of student	Signature	Date

CERTIFICATION

This thesis titled "PERFORMANCE EVALUATION OF TWO HIGH PROFILE SEGMENTATION ALGORITHM IN IRIS RECOGNITION SYSTEM" by Adepoju Sunday Femi (M.Sc./Sci./0159/2009-2010) meets the regulation governing the award of the degree of M.Sc. Computer Science of Ahmadu Bello University (ABU), Zaria, and it is approved for its contribution to knowledge and literary presentation.

…….	……	……
Chairman, Supervisory Committee	Signature	Date
…….	……	……
Member, Supervisory Committee	Signature	Date
…….	……	……
Member, Supervisory Committee	Signature	Date
…….	……	……
H. O. D. Mathematics	Signature	Date
…….	……	……
Dean, Post Graduate School	Signature	Date

DEDICATION

This research work is dedicated to God who has been the source of my wisdom and also to my father Late Raphael Femi Adepoju. Daddy millions of men cannot play your part neither could they build what you have built in me. Sleep on Dad.

ACKNOWLEDGEMENT

I wish to express my sincere gratitude to my supervisors Dr. A.A, Obiniyi and Dr. M. B, Hamawa whose instructions, leading, interest and mentoring accounted immensely for the progress and completion of this research work. Indeed their wealth of experience played a very important role in success of this research work and I am greatly indebted to them. Thanks to the Head of Department Dr.B. Sani for his fatherly role and good leadership style to all the staff and students of the Department.

Many thanks are given to Dr. Falohun A.S of the Department of Computer Science and Engineering, Ladoke Akintola University of Technology, Ogbomosho, Oyo State. His contribution to this work cannot be over emphasized. My immeasurable appreciation goes to my sweet, loving and caring mother Mrs. F.F Adepoju who is always striving to make sure I become a great man, may you live long ma. I am really blessed to have you and also to Dr. Mrs. Olubunmi Siyanbola who has shoulder the responsibility of taking care of me and see to my well being. Thank you so much ma, I am more than indebted to you, may God continue to lift you high.

I will like to express my gratitude to my friends: Miss. Ganiyat Alao, Miss. Chigozie Iro, Mrs. Ndadama Shabe, Mr. Shittu Abass, and Mr. Adelewa Williams, Mr. Okoji Anthony, Mr. Dada Olarewaju, Mr. Toluhi Seun, Mr. Bello Fatai, Mr. Johnson, Mr. Olarewaju, Mr. Olajide John, the HOD Aviation Security, Ilorin International Airport, Mr. Amoo. T.T and my entire colleagues in the Airport and all my friends who have contributed in what I call their widow's mirth to the success of this work, to you all I say thank you.

I thank my siblings: Mr & Mrs Ibrahim Oluwaseun, Mr & Mrs popuola Timileyin, Mr & Mrs Badiru Suraj, Mr & Mrs Yusuf Fatai, Miss Adepoju Adeola, Mr & Mrs Femi Atoyebi, Miss Remilekun Ayandiran and the Atanda's. Finally, I will want to appreciate someone so special to me Miss Bello Oladepe Esther who has always stood by me to her I say a big thank you. May God blessing be upon you all.

ABSTRACT

Iris is an effective biometric application of an individual for security-related applications. However, the iris segmentation process is challenging due to the presence of eye lashes that occlude the iris. Iris segmentation is an important phase in the whole iris recognition system, for it determines the accuracy of matching. To find a fast, effective and exact iris segmentation algorithm is the key step of iris recognition. This thesis compares the two high profile segmentation algorithms of Daugman (integro-differential) and Wildes (circular hough). Simulating the two algorithms with MATLAB 2012 and image datasets from Chinese Academy of Science Institute of Automation (CASIA) version 4, the evaluation of the algorithms was carried out using the performance metric False Acceptance Rate (FAR), False Rejection Rate (FRR) and Recognition Accuracy. The analysis of the result, indicated that the Circular Hough is more accurate than intego-differential as it shows higher recognition accuracy and lower error rate.

TABLES OF CONTENTS

COVER PAGE.....i

FLY LEAF.....ii

TITLE PAGE.....iii

DECLARATION iii

CERTIFICATION..... iv

DEDICATION v

ACKNOWLEDGEMENT vi

ABSTRACT.....viii

TABLES OF CONTENTS ix

LIST OF TABLES xi

LIST OF FIGURES..... xii

CHAPTER ONE 1

GENERAL INTRODUCTION..... 1

1.1 Introduction 1
1.2 Background to the Study 2
1.3 Problem Definition.....4
1.4 Motivation for the Thesis 5
1.5 Aim.....5
1.6 Objectives of the Research 5
1.7 Research Methodology.....6
1.8 Contribution to Knowledge 6
1.9 Organization of the Rest of the Thesis 7

CHAPTER TWO 8

LITERATURE REVIEW 8

2.1 Introduction 8
2.2 Related Works 9
2.2 Iris Localization and Segmentation 11
2.3 Biometrics Technology 24
2.4 Expectations from Biometrics Technology.....25

CHAPTER THREE..... 28

METHODOLOGY FOR SEGMENTATION COPMARISON 28

3.1 Introduction 28
3.2 Tools 28
3.3 System Architecture 28
3.4 Framework Data Flow 29
3.5 Intra and Inter Class Matching 36
3.6 False Acceptance Rate (FAR) and False Rejection Rate (FRR) 37
3.7 Threshold 38

CHAPTER FOUR 39

IMPLEMENTATION, RESULTS AND DISCUSSION 39

4.1 Implementation 39
4.2 Result and Discussion 45
4.3 Conclusion 51

CHAPTER FIVE 52

SUMMARY, CONCLUSION AND RECOMMENDATION 52

5.1 Summary 52
5.2 Conclusion 52
5.3 Recommendation 53

REFERENCES 54

APPENDIX A 57

LIST OF TABLES

Table 2.1 : Methods of Iris segmentation.....24
Table 4.1 FAR, FRR and RA (Integro-differential operator).....45
Table 4.2 FAR, FRR and RA (Circular Hough).....45

LIST OF FIGURES

Figure 2.1 Specular reflection removal 12
Figure 2.2 Image projecting right rigion 17
Figure2.3. Iris boundary localization 17
Figure 2.6 Specular removal 22
Figure 3.1 Iris recognition system architecture 29
Figure 3.2 Proposed framework data flow 30
Figure 3.3: Sample eyes image 31
Figure 4.1 General GUI for circular hough 40
Figure 4.2 GUI for loading an eye image 40
Figure 4.3 GUI for circular hough segmentation process 41
Figure 4.4 GUI for performing matching 41
Figure 4.5 General GUI for Integro-differential 42
Figure 4.6 GUI for loading an eye image 42
Figure 4.7 GUI for integro-differential segmentation process 43
Figure 4.8 GUI for integro-differential segmentation process 44
Figure 4.9 Integro-differential GUI for matching 44
Figure 4.10 intra class graph for integro-differential 46
Figure 4.11. Intra class graph for circular Hough 47
Figure 4.12 Inter class graph for circular hough 48
Figure 4.13 Inter class graph for integro-differential 48
Figure 4.14 FRR for Circular Hough and Integro-differential 49
Figure 4.15 Recognition accuracy for Circular Hough and Integro-differential 50

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Introduction

In today's information technology world, security of systems is becoming more and more important. The number of systems that have been compromised is ever increasing and authentication plays a major role as a first line of defense against intruders. The three main types of authentication are something you know (such as a password), something you have (such as a card or token), and something you are (biometric) (Penny, 2002). Passwords are notorious for being weak and easily crackable due to human nature and our tendency to make passwords easy to remember. Cards and tokens can be presented by anyone and although the token or card is recognizable, there is no way of knowing if the person presenting the card is the actual owner. Biometrics, on the other hand, provides a secure method of authentication and identification, as they are difficult to replicate, forge or steal (Penny, 2002)

Since authentication of users is essential and difficult to achieve in all systems. Shared secrets like Personal Identification Numbers (PIN) or Passwords and key devices such as Smart cards are not presently sufficient in few situations. The biometric improves the capability to recognize the person base on some characteristics possess by such individual. Biometrics is derived from a Greek word "bio" meaning life and "metrics" meaning measure to. In other word, biometrics means a measure to life.

A biometric identification system is an automatic recognition system that recognizes a person based on his or her physiological characteristic (for example, fingerprints, face,

retina, iris, and ear) or behavioral characteristic (for example, gait, signature, voice), (Radha and Kavitha, 2011).

Since biometric information is an integral part of an individual, the potential to misuse or abuse this information poses a serious threat to privacy (The Irish Council for Bioethics, 2009).

While the range of body features that can be used for biometric recognition has greatly expanded since this technology was first established, not all physiological or behavioral characteristics are suitable for biometric recognition since there are some criteria used for choosing a good biometric.

Based on evaluations, it is clear that there are strong and weak biometric, with the stronger biometrics meeting more of the said criteria. While no biometric modality fulfils all the criteria optimally, certain modalities satisfy more of the criteria than others (for example, fingerprint and iris would score better overall than dynamic signature and keystroke dynamics) and would, therefore, be deemed more reliable or "stronger" in terms of their suitability for recognition purposes.

1.2 Background to the Study

Biometrics is the science of automated recognition of persons based on one or multiple physical or behavioral characteristics. Among several biometrics, iris biometrics have gained lots of attention recently because it is known to be one of the best biometrics (Daugman, 1993) for recognition. The iris is visible, yet protected organ that remain unchanged throughout the life span of an individual. These features make it very desirable for use as a biometric for identifying individuals.

One of the most crucial steps in building an iris security system is iris segmentation in the presence of noises such as varying pupil sizes, shadows, specular reflections and highlights. The step definitely affects the performance of the iris recognition system since the iris code is generated from the iris pattern and the pattern is affected by iris segmentation. Thus, for a secure iris recognition system, robust iris segmentation is a prerequisite.

Iris segmentation is a crucial step in iris recognition since it severely affects the system's performance. This section of the algorithm consists in segmenting the specific iris region from an eye image by locating the exact iris boundary, the pupil region, and the upper and lower eyelids. In some cases, artifacts can be found in the resulting iris image which can be a combination of eyelash occlusion, eyelid occlusion and/or noise. Advanced algorithms are required for successful removal of these artifacts in order to generate a clean iris region for subsequent recognition. In fact, various methods have been proposed to identify and eliminate artifacts in iris images, particularly by detecting and removing eyelash occlusion and eliminating specular reflections. In general, most algorithms perform reasonably well except that they tend to overestimate eyelash occlusion (Xie ,2007).

However, it has been discovered that often the pupillary and limbic boundaries are not completely circular, which led Daugman to study alternative segmentation techniques for modeling the iris boundaries. His recent contributions to iris biometrics contains more methods to detect the iris inner and outer boundaries with active contours which leads to

more embedded coordinate systems and using Fourier-based methods in order to solve iris trigonometry and projective geometry for handling off-axis gaze by rotating the eye into orthographic perspective (Daugman, 2004).

1.3 Problem Definition

Just as in other areas of computer security, various segmentation algorithms are constantly emerging and promising near-perfect than its predecessors. Although prototype systems had been proposed earlier, it was not until the early nineties that Cambridge researcher, John Daugman, implemented a working automated iris recognition system (Daugman, 1993; Sanderson and Erbetta, 2000). Even though the Daugman system is the most successful and most well known, many other systems have been developed. The most notable include the systems of Wildes *et al*., 1994, Boles and Boashash (1998), Lim *et al.*, 2001, and Noh *et al*., 2002. The Daugman system has been tested under numerous studies, all reporting a zero failure rate. The Daugman system is claimed to be able to perfectly identify an individual, given millions of possibilities. The prototype system by Wildes *et al.*, 1994 also reports flawless performance with 520 iris images. These two most prominent approaches by Daugman and Wildes are contesting for superiority without basis.

Since, two most popular algorithms by Daugman and Wildes (Daugman, 1993; Wildes *et al.*, 1994) along with other algorithms are tested on their private database and under different conditions, making it hard to compare the performance among the algorithms. An evaluation of the two high profile segmentation algorithms to get a grip of the most accurate is of great importance.

1.4 Motivation for the Thesis

The issue of security of lives and properties has become a serious concern all around the globe today, this is because there is great threat to live and properties, nowadays. Advancement in technology is witnessing great changes in security techniques, ranging from the use of keys, specialized keys to special codes to lock and unlock doors to homes, organizations and places. The conventional technique of gaining access through what a person has (such as smart cards and I.D cards) have been beaten by impersonation while the one based on what a person knows (such as passwords and pin codes) has been overtaken by hacking. A most reliable technique that has remained unbeatable is the use of a life – measured security idea that is based on who one is (that is, Biometrics) that will serve as an infallible access control to resources and place one of which is the Iris Recognition System (Falohun *et al.*, 2012). This prompts the research into the most crucial stage of iris recognition system, called segmentation and an evaluation of the two prominent algorithms from where a grip of the most accurate of the two algorithms will be gotten.

1.5 Aim

The aim of this research work is to evaluate two of the most efficient segmentation algorithms techniques widely used for Iris segmentation process by Daugman's and Wildes.

1.6 Objectives of the Research

The objectives of the thesis are to:

a. Evaluate two of the most efficient segmentation techniques widely used for Iris segmentation process (Daugman, 2004 and Wildes, 1997)

b. Determine the percentage of errors in each method using the proposed framework and,

c. Establish from the results which one of the two algorithms as the highest recognition accuracy.

1.7 Research Methodology

a. An intensive study of iris recognition algorithms and segmentation algorithms were carried out.

b. The gap in evaluating iris segmentation algorithm was identified,

c. Due to the gap, a framework for evaluating segmentation algorithms was proposed

d. Simulation of the proposed framework using MATLAB and,

e. Performance evaluation of the algorithms will be carried out using the performance metrics false acceptance rate, false rejection rate and recognition accuracy.

1.8 Contribution to Knowledge

At the end of the research,

a. A framework was proposed for testing the accuracy of segmentation methods in iris recognition system.

b. Using the framework, it was observed that the integro-differential has a higher error rate when compared with circular hough

c. Using the proposed framework, it had been successfully proved that circular hough is more accurate than the integro-differential.

1.9 Organization of the Rest of the Thesis

The rest of the thesis is structured as follows: Chapter two discussed literature review, some segmentation algorithms, biometric technology, biometric technology expectation and literature in to detail. Chapter three present the proposed system methodology, and detailed the processes involved. In chapter four the system implementation, evaluation and analysis were presented. Chapter five, summarize, concludes and make some recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Individual identification and recognition is paramount to many processes. Contemporary societies give higher relevance to systems that contribute to the increase of security and reliability, basically due to terrorism and other extremism that has bedeviled the society. In this context, the use of biometric systems has been increasingly encouraged by public and private entities in order to replace or improve traditional security systems. Basically, the aim is to establish an identity based on who the person is, rather than what the person possesses or what the person remembers.

Biometrics can be regarded as the automated measurement and enumeration of biological characteristics, in order to obtain a plausible quantitative value that, with high confidence, can distinguish between individuals. This process has been used for centuries. In the 14^{th} century, the Portuguese writer Jaoa de Barros reported its first known application (Aleksandra, 2012). The writer wrote that Chinese merchants stamped children's palm print and footprints on paper for identification purposes. In the western world, until the late 1800s the automatic recognition of individuals was largely done using "photographic memory". In 1883, the French police and anthropologist Alphonse Bertillon developed an anthropometric system, known as Bertillonage (Jain *et al*. 1999), to fix the problem of identification of convicted criminals.

According to the proposal of Jain *et al.*, (1999), biometric systems can be evaluated regarding seven parameters: uniqueness: it must be sufficient to distinguish between two individuals, universality: all individuals should have that characteristic, permanence:

must remain unchanged throughout the individual life time, collectability: easy to collect and use for recognition, performance: the level of accuracy and speed , acceptability: individual's willingness to accept the use of the characteristic for recognition purpose and resistance to circumvention: the degree of difficulty required to defeat or bypass the system.

Among the biometric technologies, iris recognition has attracted lots of attention because it satisfied most of the parameters for evaluation and due to its long time stability. Iris recognition involves four stages: segmentation, normalization, feature extraction and matching. One of the most important stages in the use of iris recognition system is the segmentation, where iris localization takes place.

2.2 Related Works

Segmentation is a process of partitioning the iris image in order to acquire information from the iris. The information of the eye is focused on iris part and the other part is ignored. The information from the iris image is more meaningful to authenticate each user because the image was partition into a multiple segment. Many researchers have worked and are still working in this direction.

Jillela *et al*.,(2013) in their work, an evaluation of iris segmentation algorithm in challenging periocular images, evaluated Wide's circular hough and Daugman's integro-differential based their result on the number of eye images that were properly segmented and they claimed circular hough had higher accuracy over integro-differential.

Hiral and Mehta (2010) in their work compared Daugman's and Wilde's based on the segmentation time of which they deduced that the integro-differential method by Daugman has less segmentation time.

Zainal *et al.*,(2012) in their work, iris segmentation algorithm using integro-differential and circular hough in biometric system focused on the number of well segmented eye images from where they deduce that the circular hough have a higher accuracy than the integro-differential.

Zyad and Mutasem, (2013), in their work, iris recognition using robust algorithm for eyelid, eyelash and shadow avoiding, proposed three models for segmention namely, pupil detection, limbic boundary localization and eyelid/eyelash detection. Their result was compared to that of Jaehan and Govindaraju, (2010), who also does not established basis of his comparison. Ifeanyi and Ghazali, (2012) in their work, an enhanced iris segmentation algorithm using circle hough, which the Authors claimed was better compared with the results of Seyyed *et al.*(2010) and Screecholpech and Thainimit (2009) respectively. However, from the publications, it cannot judge whether actual comparison was carried out by these Authors. Nakissa and Shahram, (2009) proposed an approached using an area preserving level set approach for his segmentation approach, however, his comparison was based on an existing data which the Author acknowledge that he adopted from Proenca and Alexandre, (2006). The Author claimed to have 99% accuracy over Daugman's algorithm with 96% but was silent on the framework used. Surjeet and kulbir (2011), claimed to have compare Wildes and Daugman's approach in their work, but it could not be ascertain under which frame work the evaluation was carried out. Gunjan *et al.*, (2012) Proposed in their work Recognition of Human Iris Patterns, claim that their enhancement is better than that of intego-differential but were also silent on the framework they use. Zhaofeng *et al.* (2009) proposed iris localization using pull and push method, which works on the principle of Hooke's law of elasticity,

though still in experimental stage. Zhaofeng *et al*. (2009) compared the result obtained from their method with Daugman's integro- differential algorithm, they only succeeded in outlining his method but were silent on the framework used.

Since most of the researchers basis are on circular hough and Daugman's Integro-diffential technique to segment the iris. Thus, the experiment is implemented in analyzing the performance of both techniques.

2.2 Iris Localization and Segmentation

Iris localization and segmentation is a crucial step in iris recognition since it severely affects the system's performance. Segmentation means segmenting the specific iris region from an eye image by locating the exact iris boundary that is the pupil region, and the upper and lower eyelids. In some cases, artifacts can be found in the resulting iris image which can be a combination of eyelash occlusion, eyelid occlusion and/or noise. Advanced algorithms are required for successful removal of these artifacts in order to generate a clean iris region for subsequent recognition. In fact, various methods have been proposed to identify and eliminate artifacts in iris images, particularly by detecting and removing eyelash occlusion and eliminating specular reflections. The following section describes few iris-pupil segmentation techniques widely used in some iris recognition systems.

2.2.1 Specular Reflection Removal Using Bilinear Interpolation

In order to get proper illumination, most iris cameras use infrared illuminators, which introduce specular reflections in the iris images, as shown in Figure 2.1.These specular reflections will inevitably destroy the structure of the iris. To address this problem, a novel reflection removal method is proposed.

Most iris databases have specular reflection in the image. To perform robust iris segmentation, it is important to mitigate the effect of these reflections present on the segmentation process, since it will be more harmful if it is present on the pupil area and iris region (Annapoorani *et al.* 2010).



Figure (a) Figure (b) Figure (c)

Figure 2.1 Specular reflection removal
Source: Annapoorani *et al*. 2010.

The titles of the label are:

(a) An original iris image occluded by reflections. (b) The reflection map and the envelop points respectively. (c) The results of reflection removal.

In order to reduce reflection noise, the original image $I(x, y)$ is divided into 8 x 8 blocks . The average of each block is computed. Then the average of first five highest averages of the image is taken as adaptive threshold Tref. The original image $I(x, y)$ is binarized using Tref to calculate a binary "reflection" map $R(x, y)$ of $I(x, y)$, as shown in Figure2.1b.

In order to interpolate the reflection point $P_o(x_o, y_o)$, four envelop points $\{P_l, P_r, P_t, P_d\}$ are defined. These envelop points are the surrounding pixels of the reflected area. In the $R(x, y)$, the algorithm iterates through the image until it finds a white pixel (x, y), then it establishes four envelop points defined as:

$P_t = (x, y-3)$

$P_l = (x-3, y)$

$P_r = (x+3, y)$

$P_d = (x, y+3)$

For each row, this method interpolates the area formed by the envelop points, the interpolation pixel $I(P^o)$ is defined as follows:

$$I(P^o) = \frac{I(P^i)(x_r - x_0) + I(P^r)(x_0 - x_l)}{2(x_r - x_i)} + \frac{I(P^t)(y_d - y_0) + I(P^d)(y_0 - y_t)}{2(y_d - y_t)} \qquad 2.1$$

2.2.2 Pupil and Iris Localization Using Discrete Circular Active Contour Model

The discrete circular active contour (DCAC) model can also be used to locate the pupil and iris boundaries in the iris image (Ritter and Owens, 1999). First, in order to localize the pupil region in the iris image, the variance image must be computed from the original image and then, an active contour model with a starting point in the center of the pupil, is initiated and moved within the iris image under the influence of so called "internal and external forces". Along the active contour, the vertex v moves from time to time according to: (eqn 2.2) which represents the position of the vertex at a specific time t to time $t+1$ according to:

$$v_i(t+1) = v_i(t) + F_i + G_i(t) \qquad 2.2$$

Where v_i represents the position of the vertex at a specific time F_i, and $G_i(t)$ represent the internal and external forces, respectively. The internal force is characterized by the continuity, and other prior knowledge about the iris (i.e. circular contour) while the external force is directly related to the gray-scale intensity values within and outside the vertex, which also includes the iris region. Finally, the iris contour is segmented after an

extensive iterative contour searching operation which ends when equilibrium with minimum energy or minimum mean variance of the annulus is attained. The discrete circular active contour (DCAC) has shown good results but do suffer from few limitations such that the performance of this method greatly depends on the iris image quality. For instance, if the image contains severe noise, specular reflections or distortions, the method will fail in locating the proper boundaries (Ritter and Cooper, 2003).

2.2.3 Pupil boundary localization By Using Edge Detection And Distance Measurement

The iris is the annular part between the pupil (inner boundary) and the sclera (outer boundary) both can be taken approximately as non-concentric circles, pupil finding is an important step because the iris is localized based on the pupil. The pupil has an important feature, it is darker than the rest of the eye, even in brown or dark eyes. Based on this heuristic a simple but effective method to find the pupil is used. In order to perform edge detection on the image canny edge detector is used due to the fact that it gives excellent results. It has very low error rate and there is almost zero response to non-edges when giving an appropriate threshold. This algorithm uses horizontal and vertical gradients in order to deduce edges in the image. After running the canny edge detection on the image a circle is clearly present along the pupil boundary. Next euclidean distance is computed from any non-zero point to the nearest zero valued point an overall spectrum can be found. This spectrum shows the largest filled circle that can be formed within a set of pixels. Since the pupil is the largest filled circle in the image the overall intensity of this spectrum will peak in it. In the pupil circle the exact center will have the highest value.

This is due to the simple fact that the center is the one point inside the circle that is farthest from the edges of the circle. Thus the maximum value must correspond to the pupil center, and furthermore the value at that maximum (distance from that point to nearest non-zero) must be equal to the pupil radius. With the center and radius circular hough is applied. Circular hough transform is a high cost method to find circles in an image, it would be prohibitive to perform Hough transform in the entire image, pupil center and radius are provided to Hough transform to dramatically reduce the computational cost. From the center, a region of 5 x 5 pixels is established where Hough transform will look for circle center. This is done because pupil is not always a perfect circle and sometimes the estimated center is not the exact center. The last thing to do is to draw the boundary based on the center and radius found in Hough transform, the drawing is done in the original image using midpoint circle drawing technique. (Annapoorani *et al*. 2010)

2.2.4 Pupil and Iris Localization Using Integro-differential Operator

The integro-differential operator, proposed by Daugman (2004), locates the pupil, the iris inner and outer boundaries as well as the upper and lower eyelid boundaries using the eqn 2.3 and 2.4.

$$Max_{(r,x_0,y_0)}\left|G_0(r)*\frac{\partial}{\partial x}\oint_{r,x_0,y_0}\frac{I(x,y)ds}{2\pi r}\right| \tag{2.3}$$

$$G_0(r)=\frac{1}{\sqrt{2\pi\sigma}}e^{\frac{-(r-r_0)^2}{2\sigma^2}} \tag{2.4}$$

Where $I(x,y)$ represents the eye image (r,x_0,y_0) are parameters that correspond to a circle of radius r and center coordinates (x_0,y_0) respectively, $G_0(r)$ is a radial smoothing

Gaussian function with center r and standard deviation σ. One application of this function is that it searches the entire eye image for integrations along different circular contours with center coordinates (x_0, y_0) and an increasing radius r. The maximum contour integral derivative found will then be classified as the most likely circle tracing the iris. In a similar manner, the circular boundaries for the pupil and iris regions are localized by searching through the entire iris image for the maximum integration along various circular contours. In addition, Daugman approximates the upper and lower eyelids with two open curves that are part of two different circles. Finally, the iris region surrounded by the upper and lower eyelids as well as the extracted circular pupil and iris boundaries are used for further feature extraction in the iris recognition process (Daugman, 2004)

2.2.5 Iris boundary localization By Selecting The Largest Graidient Change To The Left And Right Boundaries Of The Pupil

The next step in the process is to segment the iris outer boundary; this is a more complicated task than the pupil segmentation. Since the top and bottom part of the iris are often covered by eyelashes, the boundary of the iris is sought after along the horizontal line starting from the pupil iris boundary. Starting from the pupil center (c_1, c_2)two regions to look for jumps in gray scale level are defined as:

$$W_r = W_1, W_2 \qquad 2.5$$

$$W_l = W_1, W_2 \qquad 2.6$$

W_r and W_l are rectangle based on the two coordinates in the original image. As shown in figure 2.2, the region represents the pupil-iris and iris-sclera gradient change but iris pattern introduces some noise to confuse the gradients location.

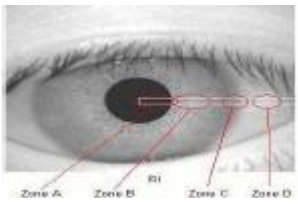


Figure 2.2 Image projecting right rigion
Source: Annapoorani et al. 2010

Zone A represents pupil area with a dramatic change of gradient (pupil – iris gradient), Zone B represents the clearer pixels in the iris pattern Zone C, represents the gradient change between iris and sclera followed by much whiter pixels of the sclera in Zone D.



Figure a Figure b

Figure2.3. Iris boundary localization

Source: Annapoorani *et al*. 2010

The titles of the label are:

(a) sample CASIA image (b) iris and pupil boundary

Based on the heuristic that there will be only two important gradients in the region (pupil – iris, iris – sclera) and pupil pixels will be the darkest, iris pixels will be intermediate and sclera pixels will be whiter, this way can be looked into for the second gradient and it can be taken as iris estimated radius. The left and right boundaries of the iris are found by selecting the largest gradient change to the left and right of the pupil. With iris radius estimation Hough transform is performed inside the pupillary area in order to reduce the number of pixels which are allowed to vote for iris boundary. Figure 2.3 shows the iris boundary localization.

2.2.6 Circular Hough Transform

The circular Hough transform is a standard technique used in the machine vision field to locate the circular contours in images. The Hough transform is applied directly on an intensity gradient edge map usually obtained through a gradient-based edge detector (Wildes, 1997). The latter method is used in many iris recognition algorithms such as the Wildes system (Wildes, 1997). First, the entire iris image $I(x, y)$ is smoothed with a Gaussian filter $G(x, y)$ with centers (x_0, y_o) and a standard deviation σ of ¾ (equation 2.7). Then, the intensity gradient image map $M(x, y)$ is generated from the smoothed Image $F(x, y)$ as shown in equation (2.8) using the gradient operation defined in (2.9). Subsequently, the binary edge map is generated by setting a threshold on the intensity gradient image $M(x, y)$. The threshold is usually selected based on experimental data and depending on the application. Finally, using the binary image map, the Hough transform is performed to locate a circle with the largest number of edge points and with circular parameters (x_0, y_o, r) which is denoted by equation (2.10). (x_0, y_o, r) represents a circle to be located within the iris image such that the circle is characterized by a radius, and center coordinates (x_0, y_o) with possible edge point (x, y) (Richard, 2011)

$$f(x, y) = G(x, y) * I(x, y) \qquad 2.7$$

$$G_0(r) = \frac{1}{2\pi\sigma^2} e^{\frac{-(x-x_0)^2+(y-y_o)}{2\sigma^2}} \qquad 2.8$$

$$M(x, y) = |\Delta f(x, y)| \qquad 2.9$$

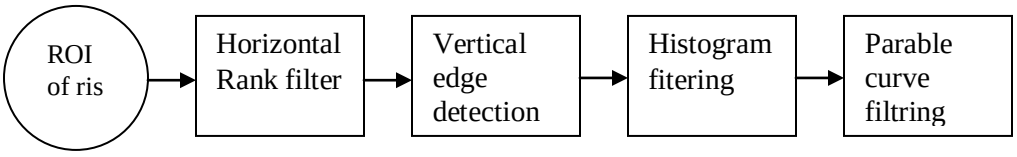
$$\Delta = (\frac{\partial}{\partial x}, \frac{\partial}{\partial y}) \quad 2.10$$

$$r^2 = (x_i - x_0)^2 + (y_i - y_0) \quad 2.11$$

From this, the Hough transform is then performed through the entire collection of the edge points. Whenever equation (2.8) is satisfied, it means that the circular contour goes through (r, x_0, y_0) and one extra vote is added to the histogram count for possible circular contours. Once the entire image is scanned for all possible contours, the contour that obtained the highest amount of votes represents the most likely circle in the edge map (Wildes, 1997).

2.2.7 Eyelash removal and Eyelid localization Using Rank Filter and Histogram Filter

An even harder problem involved in iris segmentation is to locate the upper and lower eyelids. The shape of eyelids is so irregular that it is impossible to fit them with simple shape assumptions. In addition, the upper eyelid tends to be partially covered with eyelashes, making the localization more difficult. Fortunately, these problems can be solved by 1D rank filter and a histogram filter. The 1D rank filter removes the eyelashes, while the histogram filter addresses the shape irregularity. The steps involved in eyelid localization method is depicted in Figure2.4.



.

Figure 2. 4 The steps involved in localization.

Source: *Annapoorani* et al. 2010

Region of interest of the original iris image (IROI) is filtered with a 1D horizontal rank filter and with the observation that the eyelashes are mostly vertical thin and dark lines, IROI is horizontally filtered with a 1D rank filter. A rank (or order-statistic) filter is a nonlinear filter whose response is based on ranking (ordering) the pixels contained in the image area encompassed by the filter. For example, the rank-p filter will replace the value of a pixel by the pth gray level in the neighborhood of that pixel encompassed by the rank filter. After horizontal rank filtering, most eyelashes will be weakened or even eliminated in the resultant image (Iranked) depending on their width, leading to a clearer eyelid boundary. A raw eyelid edge map is calculated. Edge detection is then performed on the upper region of Iranked along the vertical direction, resulting in a raw eyelid edge map Eraw. Only one edge point is reserved along each column so that most noisy edges are avoided. The eyelid is fitted with a parabola curve. The exact shape of the eyelid is obtained by parabolic curve fitting. A similar approach is repeated to locate the lower eyelid (Annapoorani *et al*. 2010)

2.2.8 Specular Reflection Removal Using Bilinear Interpolation

Usually, specular reflections appear as the brightest points in the iris image $I(x, y)$ and the bilinear interpolation method is used to fill the reflections. The method is illustrated in Figure 2.5. First, an adaptive threshold Tref is used to calculate a binary "reflection" map $R(x, y)$ of $I(x, y)$, as shown in Figure 2.7b.

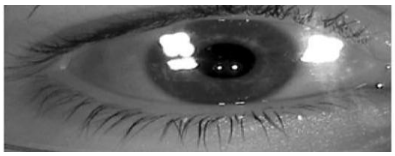
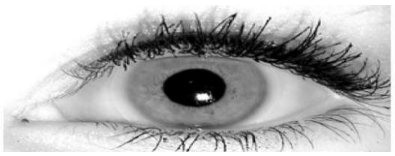
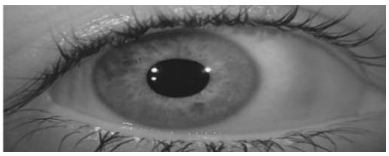




Figure a Figure b Figure c

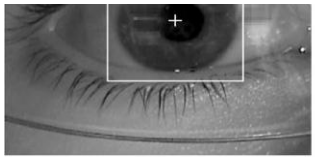
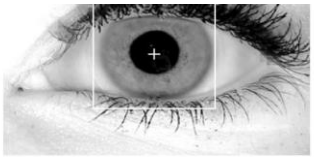
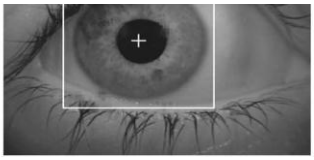
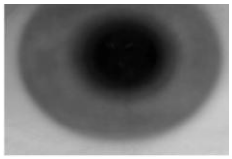





Figure (d) Figure (e) Figure (f) Figure (g)

Figure 2.5 reflection detection and removal

Source: ICE v1.0 iris image database after reflection removal.

Note that (a)-(c) means three original iris images with different specular reflections. (d)-(f) The results of reflection removal and iris detection of (a)-(c), where the reticule denotes the rough position of the iris center, and the square is an indicator of the size of the iris.

In order to interpolate the reflection point $P_o(x_o, y_o)$, four envelop points $\{P_{left}(x_l, y_0)$, $P_{right}(x_r, y_0)$, $P_{top}(x_0, y_t)$, $P_{down}(x_0, y_d);\}$ are defined and calculated as follows:

$$X_l = \max_x \{\sum_{i=0}^{L-1} R_{(x+i,y_0)} = 0, R_{(x+L,y_0)} = 1, x < x_0\} \quad 2.6$$

$$X_r = \min_x \{\sum_{i=0}^{L-1} R_{(x-i,y_0)} = 0, R_{(x-L,y_0)} = 1, x < x_0\} \quad 2.7$$

$$Y_t = \max_y \{\sum_{i=0}^{L-1} R_{(x_0,y+i)} = 0, R_{(x_0,y+L)} = 1, y < y_0\} \quad 2.8$$

$$Y_d = \max_y \{\sum_{i=0}^{L-1} R_{(x_0,y-i)} = 0, R_{(x_0,y-L)} = 1, y < y_0\} \quad 2.9$$

where L controls the necessary separation between the reflection points and their envelop points. L is set within a certain range. Obviously, all of the neighbor points

lying in the same line share the same P_l and P_r, while all of the neighbor points lying in the same column share the same P_t and Pd P_d, as shown in Figure 2.5b.

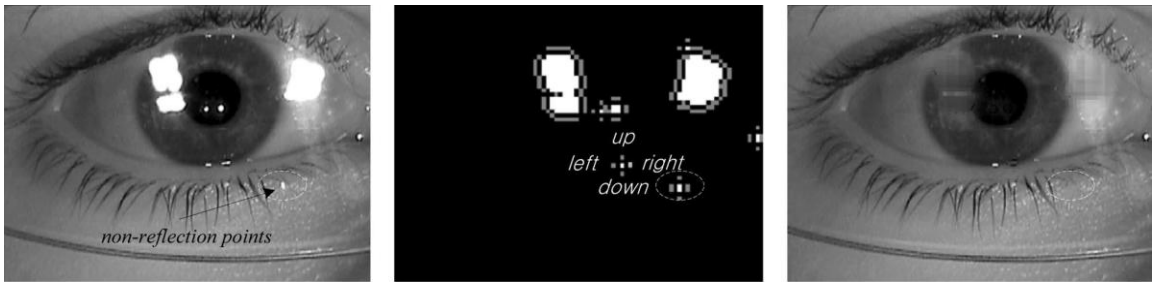


Figure a Figure b Figure c

Figure 2.6 Specular removal
Source: Zhaofeg *et a.l* 2009

2.2.9 Pulling and Pushing

The inspiration of pulling and pushing stems from the Hooke's law (Young and Roger, 2003) the restoring force of a spring is directly proportional to its deformation, namely $F = k * x$, where x measures the displacement of the spring from its equilibrium position, k is the spring constant, the negative sign means the restoring force opposes the deformation. In pull and push method, the inner and outer boundaries of the iris are modeled as two non-concentric circles, represented by six independent parameters: the pupil center $O_p(x_{p,}y_p)$ and pupil radius R_p, the iris center O_i $(x_i y_i)$ and iris radius R_i. The iris localization of the inner boundary as assumed to have a rough location of the pupil center $O^{'}(x_{p,}y_p)$ as well as a set of uniformly sampled edge points in the inner circle $P_{i,i=1,2,\ldots,N}$ are available. Join each edge point P_i and the center point O' with an imaginary spring-like line then, we get a set of identical 'springs' attached in a circle and jointed at O'. The equilibrium length R of these 'springs' is set to

$$R = \frac{1}{N}\sum_{i=0}^{N} O' p_i$$

spring constant is set to $K = \frac{1}{N}$. Hence, each 'spring' produces a restoring force to resist the introduced deformation, pulling or pushing the current center O' with a displacement d_i along each radial direction given as.

$$d_i = -k(R - r_i)e_i \quad i = 0,1,\ldots,N$$

The resultant displacement is obtained as

$$D = \sum_{i=0}^{N} d_i$$

and the center is then moved to $O(x_p, y_p)$. If the edge points and the spring constant of these 'springs' are generated accurately enough, then $O_p = O$ and $R_p = R$. However, such is not always the case, so a second pulling and pushing round is performed with the newly estimated center $O(x_p, y_p)$, providing a set of regenerated edge points. This process is repeated until O_p and R_p converge to the genuine position (Zhaofeg *et al.* 2009).

All the aforementioned techniques of segmentation process are actually built on two most popular methods of segmentations, (Daugman, 1993 and Wildes, 1994), though there appear to be a new approach that is still at experimental stages (Pulling and pushing elastic mode). Table 2.1 list the segmentation approaches.

Table 2.1 : Methods of Iris segmentation

Authors	**Segmentation Technique**
Daugmann (1994)	Integro-differetial operator
Wildes (1997)	Edge detection and Hough transform
He *et al.*(2009)	Pulling and pushing elastic mode

Source : Samir Shah and Arun Ross, 2009

2.3 Biometrics Technology

A biometric system provides automatic recognition of an individual based on some sort of unique feature or characteristic possessed by the individual. Biometric systems have been developed based on fingerprints, facial features, voice, hand geometry, handwriting, the retina, and the one presented in this thesis, the iris. Biometric systems work by first capturing a sample of the feature, such as recording a digital sound signal for voice recognition, or taking a digital color image for face recognition. The sample is then transformed using some sort of mathematical function into a biometric template (Libor, 2003). The biometric template will provide a normalized, efficient and highly discriminating representation of the feature, which can then be used in order to verify the identity of that individual in a population. The main advantages of biometrics over other standard security systems are that biometric traits cannot be forgotten or lost, they are difficult to copy and share, they require the person to be present at the time of authentication. In most applications, a biometric system is a real-time identification system which requires the measurement of unique information (that is, features) characterizing the individual being enrolled or tested and later comparing these samples against a database containing several candidates (Richard, 2008)

Most biometric systems allow two modes of operation. An enrolment mode for adding templates to a database, and an identification mode, where a template is created for an individual and then a match is searched for in the database of pre-enrolled templates.

A good biometric is characterized by use of a feature that is highly unique so that the chance of any two people having the same characteristic will be minimal, stable so that the feature does not change over time, and be easily captured in order to provide convenience to the user and prevent misrepresentation of the feature (Libor, 2003).

Biometric recognition is based on two fundamental premises about body traits which are: *distinctiveness* and *permanence*. The applicability and identification accuracy of a specific biometric trait essentially depends to what extent these two premises hold true for the population at hand. Fingerprints, face, and iris are amongst the most popular physiological characteristics used in commercial biometric systems which is considered in this thesis. (Anil and Ajay, 2010)

2.4 Expectations from Biometrics Technology

Increasing requirements for security in many sectors of our society have generated a tremendous interest in biometrics. This has also raised expectations from biometric technologies. These expectations can be summarized into four categories: performance, cost, user convenience and interoperability (Anil and Ajay, 2010).

2.4.1 **Performance:** The recognition performance achievable from a biometric system is of utmost interest in the deployment of biometric systems. A biometric system is prone to two major errors namely; false accept rate (FAR), and false reject rate (FRR). The system performance is further characterized in terms of transaction time or throughput. The accuracy of a biometric system is not static, but it is data dependent and influenced

by several factors such as: size of database, biometric quality and robustness of employed algorithm.

2.4.2 **Cost:** The cost of deploying a biometric system is often estimated from its direct and indirect components. The direct component includes hardware components and the software modules. The sensor should be low cost and it should be easy to embed it in the existing security infrastructure. There are multifaceted components that constitute the indirect cost in the usage of biometric system. These include system installation, training/maintenance requirements, and most importantly, user acceptance.

2.4.3 **Interoperability:** As biometrics systems are being increasingly deployed in a wide range of applications, it is necessary that the system be interoperable among different biometrics technologies. A biometric system can no longer operate under the assumption that the same sensor, same algorithms, or same operating conditions will always be available during its lifetime. The biometric system should be highly interoperable to authenticate individuals using sensors from different vendors and on varying hardware/software platforms. The system should employ usage/development/deployment of common data exchange facilities and the formats to exchange the biometric data/features between different vendors, from different geographical locations. This would significantly reduce the need for additional software development and bring all the associated advantages that is cost savings and efficiency.

2.4.4 **User Convenience:** A biometrics system should be user friendly. Therefore, the health or hygienic concerns with the continuous usage of biometric sensors can influence user acceptance. Hygiene as well as security has been one of the motivations for developing touchless sensors. Some biometric modalities are easier to acquire than others

and require less user cooperation during data acquisition. Human factors and ergonomic issues will continue to play a major role in widespread deployment of biometric systems.

CHAPTER THREE

METHODOLOGY FOR SEGMENTATION COMPARISON

3.1 Introduction

This Chapter gives the details of the proposed work, it detailed the methodology used, which was programmed MATLAB 2012 and which was used to evaluate the Daugman (integro-differential) and Wildes (Circular Hough) respectively. The stages involved in the methodology were also enumerated and discussed in detail.

3.2 Tools

a. MATLAB 2012 was used to develop a simulated program for the proposed framework. The MATLAB is gotten from an open source.

b. To test the developed system, some set of iris data set from the Chinese Academy of Sciences - Institute of Automation (CASIA) eye image database were used. The CASIA image dataset used contains 120 subjects and 6 (six) different images of a unique eye.

3.3 System Architecture

The diagram in figure 3.1 represent the general architecture of an iris recognition system, outlining the stages involved for an iris of a user to be accepted or rejected.

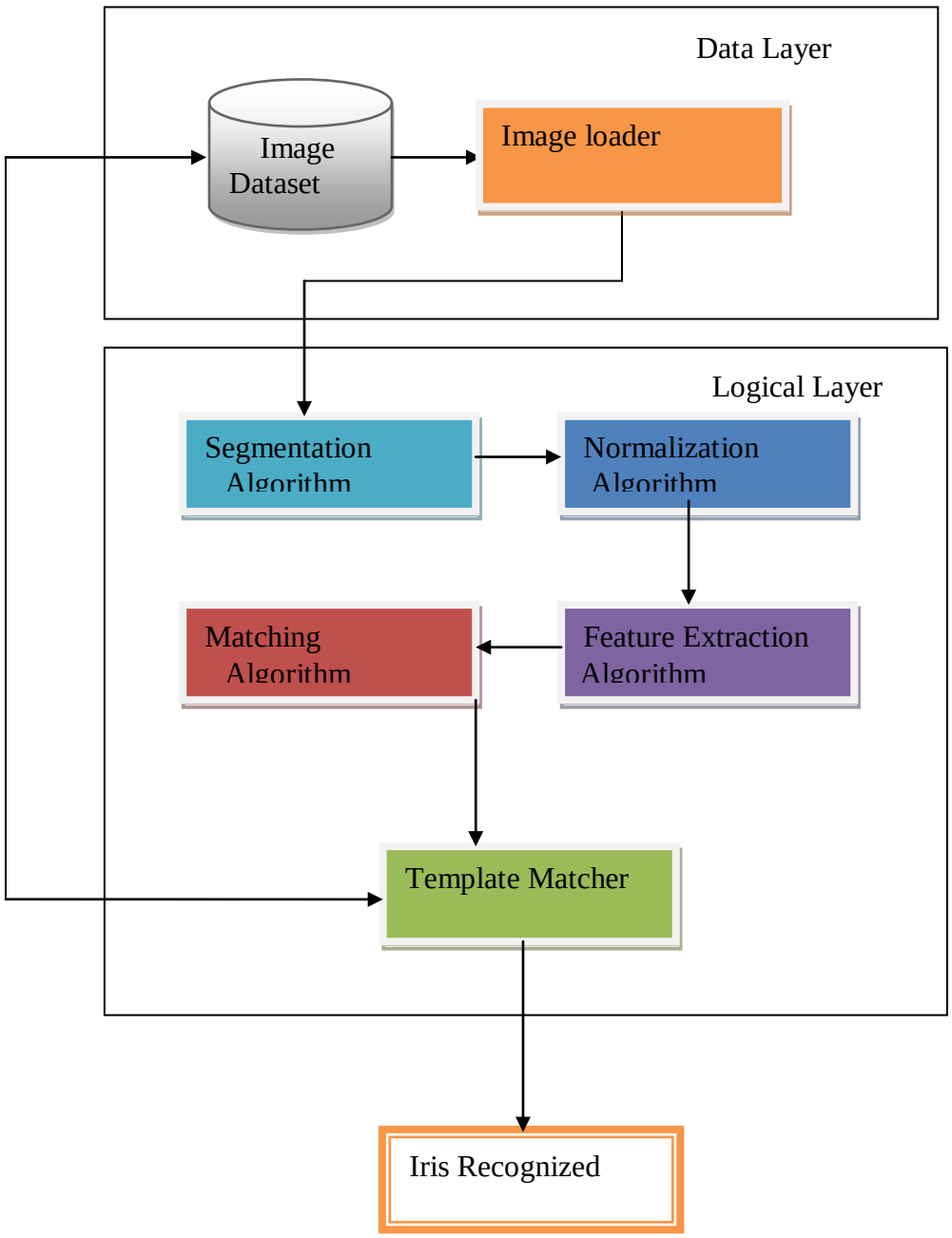


Figure 3.1 Iris recognition system architecture

3.4 Framework Data Flow

The proposed framework involves some steps, which are outlined in a form of data flow in figure 3.1. The framework data flow consists of different components or stages, which was outlined on how it was implemented in this proposed framework. The framework

data flow consists of the following: Database, load image, segmentation algorithm, normalization algorithm, feature extraction algorithm and matching algorithm. Each of these will be explained in this section.

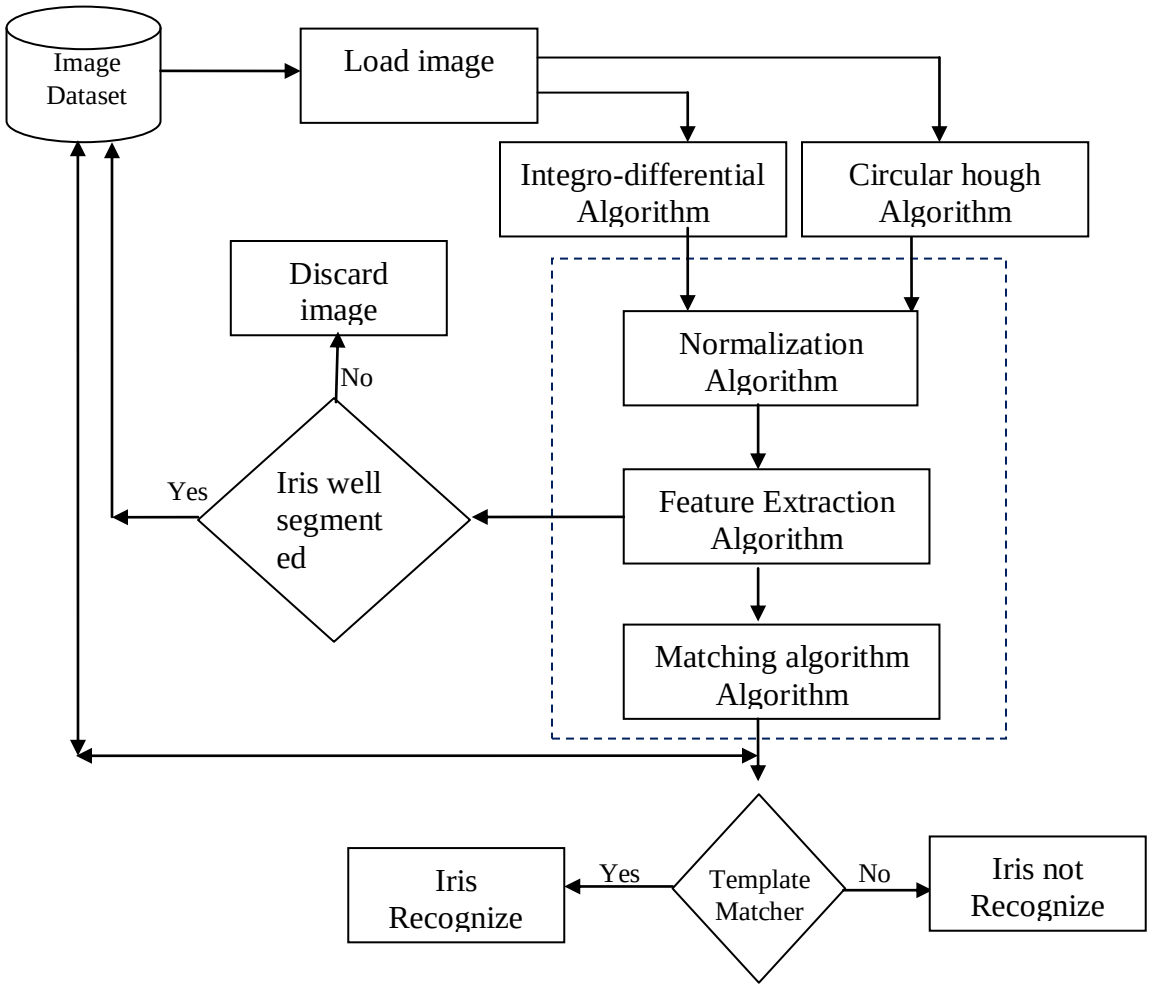


Figure 3.2 Proposed framework data flow

3.4.1 Image dataset: the database represents the eye images obtained from CASIA database which were captured using iris camera and are taken under favorable condition. The CASIA contain white eye images from where the eye images to be used for our evaluation were stored, for the sake of this research, 120 images were used. Figure 3.3, shows the sample images from the CASIA data set.

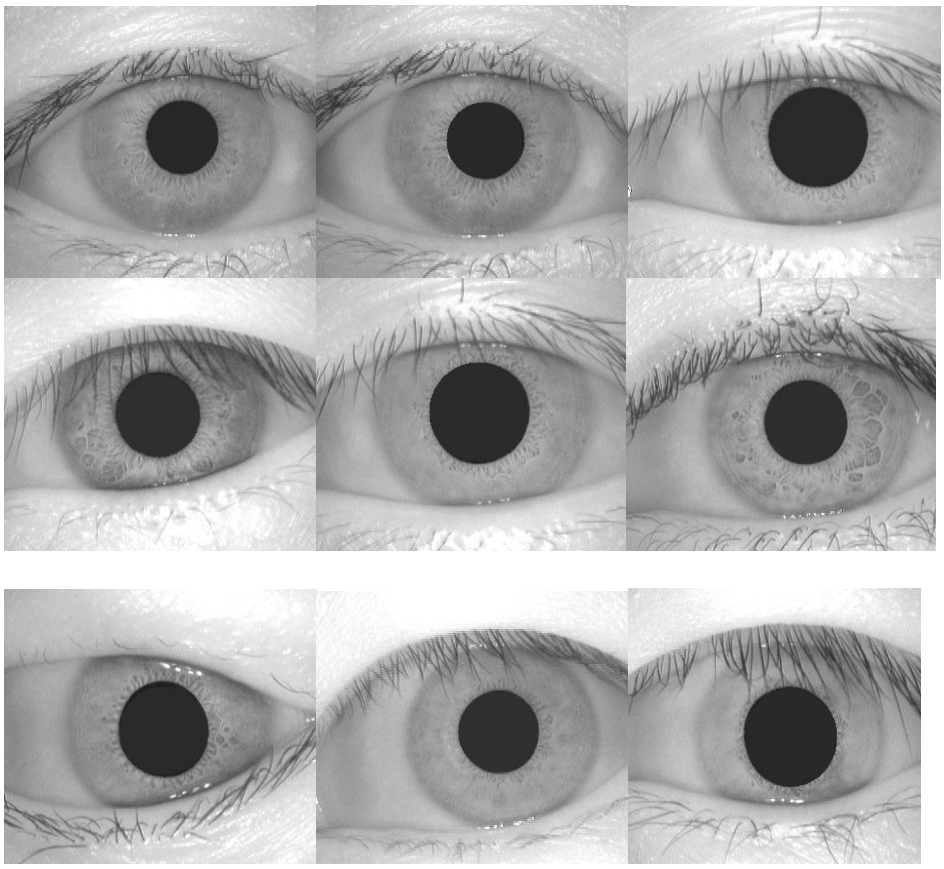


Figure 3.3: Sample eyes image
Source: CASIA Database

3.4.2 Load image: Since the image location is different, for every evaluation that the system need to performed, it is necessary to load an image, on which iris segmentation process will be perform, the load image part of the flow chart was implemented using the MATLAB, that will be initiated each time an evaluation is needed to be performed. The user initiated this action by clicking on the GUI on the user interface.

3.4.3 Segmentation Algorithm: Image segmentation is the process of dividing an image into multiple parts. This is typically used to identify objects or other relevant information in digital images. The image segmentation segment performs the localization of the iris in the image and removes the areas corresponding to eyelids, eyelashes, reflections, and shadows; all these are carried out to ensure the accuracy of the

resulting image. Basically, the iris segmentation is the most time-consuming step in the entire process and its effectiveness is relevant because it strongly influences the accuracy of the result of biometric system. An incorrectly segmented iris can result in errors of the matching module. Since, the aim of the study is to compare the two commonly used techniques, their segmentation algorithms were adopted and the segmentation phase will vary depending on which algorithm, the system is testing, Thus, if the system is running the Daugman method, the Daugman algorithm of segmentation will be loaded and vice versa.

Daugman (1994) applies an integro-differential algorithm to isolate the boundaries, while Wildes (1997) proposed another called circular Hough transform. Wildes approach is divided into two steps; first is the conversion of the image into binary edge map using a gradient-based edge detector then applies the Hough transform to detect the boundaries. For this research, MATLAB software was used to implement the two approaches for experimental purpose. The algorithm used to describe the steps involved in each algorithm is depicted as:

Segmentation Algorithm

Segmentation (image, method)

If method = integro-differential {

Max iris ⟵ compute max of iris using integro- differential

Max pupil ⟵ compute max of pupil using integro- differential

X ⟵ return (max iris – max pupil)

}

Else if (Method = circular hough)

Trace contour of iris

Trace contour of pupil

X ⟵ largest point of contour

Return X}

}

3.4.4 Normalization: The Pupil size of the stored image varies with dependence on the quantity of light that comes into it, which in turn also affects the shrinkage and stretching of the elastic surface of iris. This may affect the comparison of two irises of the same eye, therefore the system have to convert the area of iris to a fixed size, technically called normalization. Performing normalization in this work, the Daugman's rubber sheet was adopted which convert the area of iris to a fixed two-dimensional space that enables the system to compare two irises.

The rubber sheet model devised by Daugman remaps each point within the iris region to a pair of polar coordinates where the radius r is on the interval [0,1], and the angle is on the interval $[0,2\pi]$. Then the normalized iris region is unwrapped into a rectangular region. The various steps involved in normalization are outlined using algorithm as:

Normalization (X) {

P = rectangle

R = radius (X)

Θ = angle (X)

P. length = θ

P. breath = r

Return P

}

3.4.5 Feature Extraction: After the iris image had been normalized, it is necessary to extract features from it. Selection of features from polar normalized iris image is carried out with the transformation of the image with Log Gabor, which converts the normalized iris into bits of '0's and '1's called binary image, from where a template which is used for comparison is formed. The stepwise approach of feature extraction is given in form of an algorithm as:

Feature extraction (p) {

Bit_string = ""

For each pixel of a rectangle {

If pixel = point {

Bit string = concatenate (bit string, 1)

Bit string = concatenate (bit string, 0)}

} }

The feature extraction stage performs two tasks namely updating the feature extracted into the image dataset for subsequent use during matching while the second task extract the features and is directly sent for matching where the comparison will be made with the stored feature.

3.4.6 Matching: After being able to generate the iris code of the image, there is need to compare this template and see if any matching occurs. Due to the processing of the image from image acquisition to image localization and then generating the binary code, slight errors may come up therefore, a threshold is needed. A threshold of 0.4 is set as a

benchmark in this work. The matching value is computed as the Hamming distance between shifted templates. The HD (Hamming Distance) is denoted by the algorithm:

```
Matching (string_bit) {
Store_bit = bit of image in the dataset
X ⟵ compute hamming distance (stored_bit, string_bit)
    If X > 0.4
    Return 0
    Else
    Return 1
}
```

The overall algorithm of an iris recognition system is denoted by:

```
Main computation (image) {
X ⟵ segmentation (image, method)
Rectangle ⟵ normalize (X)
String_Bit = feature extraction (rectangle)
Value = match (string_ Bit)
Return (value)
```

The implementation code that was used to call each algorithm function is presented in appendix A.

From the flowchart, some results that were obtained based on the number of iris images that were rejected or accepted when an inter class and intra class matching was carried out, these results will be used for our evaluation. The output results are presented in a

tabular form showing the output results for each segmentation methods, from where the percentage of errors in the said segmentation algorithms will be taken and subsequently used to calculate the accuracy of the segmentation method.

In order to determine how well the images were segmented, a one to one matching of the of the irises were carried from where all images matches its equivalent in the image dataset

3.5 Intra and Inter Class Matching

In any biometric system, the individuals required to use the system need to be enrolled. The iris image has been collected using a sensor to produce a digital representation of the real image. The system performs feature extraction from the digital representation and these features are used to generate a template, which is then linked to the iris identity and stored in the system. The system is tested using a sample template that is acquired and is compared to the stored template using a mathematical algorithm. One feature that is common to all biometric systems is that no two samples of the same biometric from the same person are ever absolutely identical. This phenomenon is known as intra-class variation and it can be caused by imperfect imaging conditions, changes in the user's biometric characteristic or in the user's interaction with the sensor. The higher the matching score the more certain the system is that the two templates belong to the same person. The final decision is regulated by a threshold, which determines the margin of error allowed by the algorithm; therefore, the matching score needs to be above the designated threshold. In this work, a threshold of 0.40 which is the standard for iris recognition system was used, decreasing it makes the system more tolerant to user variations, whereas increasing it makes the system more secure. The inter and intra class

matching was performed to determine the false acceptance rate or false rejection rate by the two algorithms under consideration.

3.6 False Acceptance Rate (FAR) and False Rejection Rate (FRR)

Iris recognition is a statistical process, which is affected by intra-class variations between enrolment and subsequent acquisitions. It is unlike password or PIN -based systems, which are either correct or not, there is no biometric recognition system that is 100 per cent accurate and all biometric systems are susceptible to a number of different errors. For the purpose of this study, two like errors are compared, false acceptance error and false rejection error. A *false acceptance error* occurs when an acquired template from one individual, who is not in the system, is mistakenly matched to an enrolled template from another individual. False acceptance errors can compromise the security and integrity of the system. A *false rejection error* occurs when an acquired template from one individual does not match the enrolled template for that individual. Force rejection errors are inconvenient to legitimate users of the system, who have to re-attempt the recognition process again or have to be authorized through an alternative mechanism, for example, through human intervention. The FAR and FRR are influenced directly by the decision threshold of the system, which itself is a function of a particular application.

Therefore, there needs to be some trade-off between the two error rates for each application. For example, for high security applications a low FAR is required therefore, the decision threshold would be set quite high and, as a consequence of the stringent system requirements, the FRR increases. The point where FAR and FRR are equal is known as the equal error rate (EER). These FAR and FRR error rates are tested to

evaluate overall performance and accuracy and the results are used as benchmark to promote either of the algorithms under investigation.

3.7 Threshold

Since matching is a statistical process, with certain algorithm providing a score of the degree of similarity between the iris templates being compared, the higher the matching score the more certain the system is that the two iris templates belong to the same class. This decision is controlled by enforcing a certain threshold, which determines the margin of error allowed by the algorithm; thus , the matching score needs to be below the designated threshold before the system accept that certain iris are in the same class. In this work, a threshold of 0.40 which is the standard for iris recognition system was used. The threshold level can also be adjusted by the system operator to meet the needs of a specific application. However, it was observed during implementation that decreasing it makes the system more tolerant to user variations, whereas increasing it makes the system more secure.

CHAPTER FOUR

IMPLEMENTATION, RESULTS AND DISCUSSION

4.1 Implementation

MATLAB 2012 was used to develop a simulated program for our proposed method. The said MATLAB is gotten from an open source. The software was installed on an HP laptop with the following configuration: 4.0GB RAM, 350GB Hardisk and 2.00GHz processor speed.

To test the developed system, some set of iris data set from the Chinese Academy of Sciences - Institute of Automation (CASIA) eye image database were used. The CASIA data set used contains 120 eye images with 20 subjects and 6 (six) different images of each unique eye. Examples of some of the dataset were shown in figure 3.3 in chapter three.

Each eye image to be tested was selected and run through the simulated program where the analysis of different processes involved in iris segmentation process were carried out. The intra and inter class matching were carried out and recorded in a tabular form, from where further analysis were carried out. Figure 4.1 to 4.11, displayed the screen shot of the interfaces of the application that perform the recognition process for each algorithm on the selected eye image.

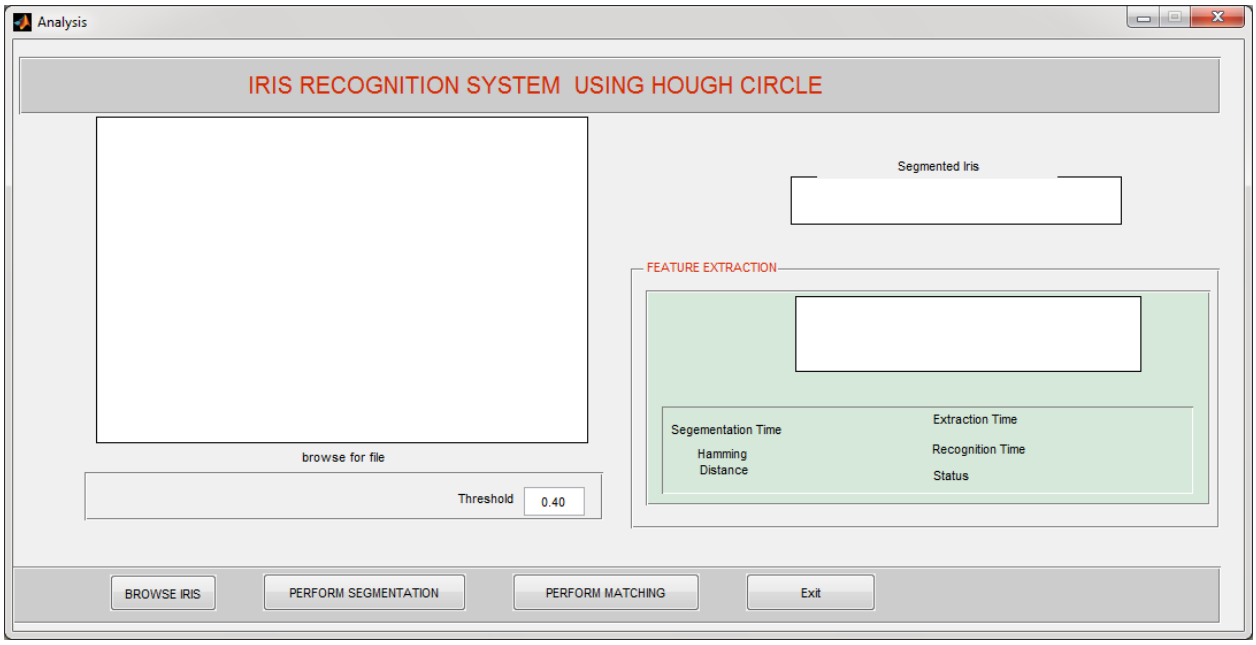


Figure 4.1 General GUI for circular hough

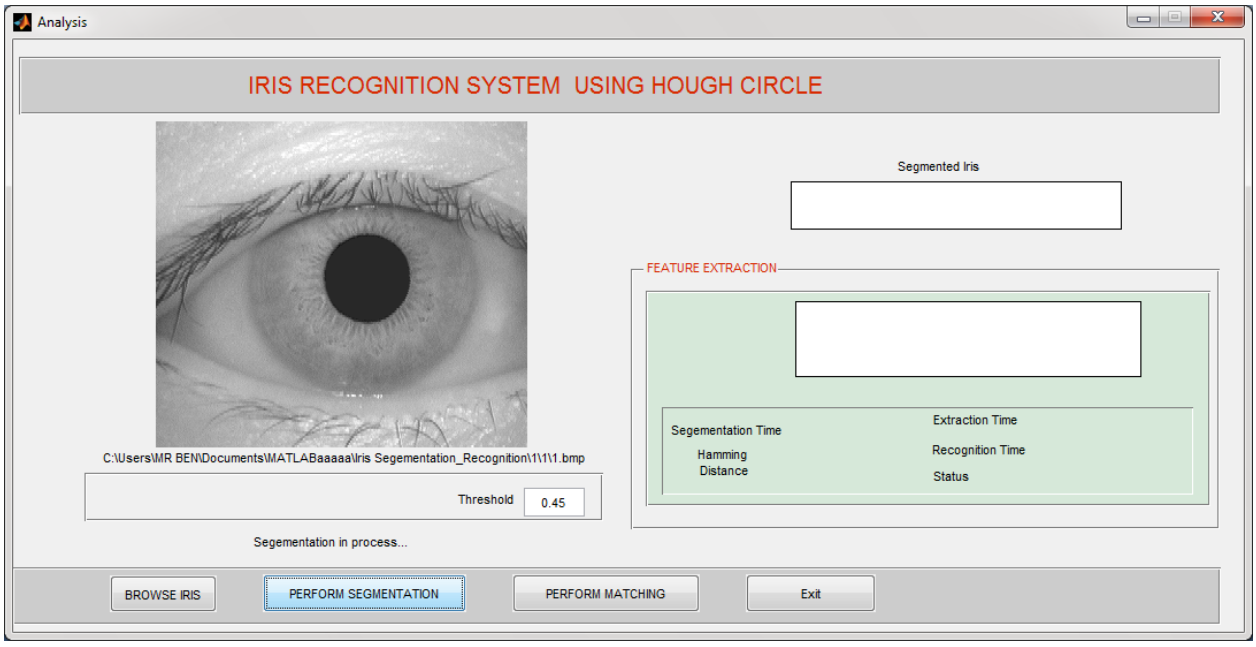


Figure 4.2 GUI for loading an eye image

To select an image as presented in figure 4.2, the user will click on load iris from where an image will be selected from the image dataset.

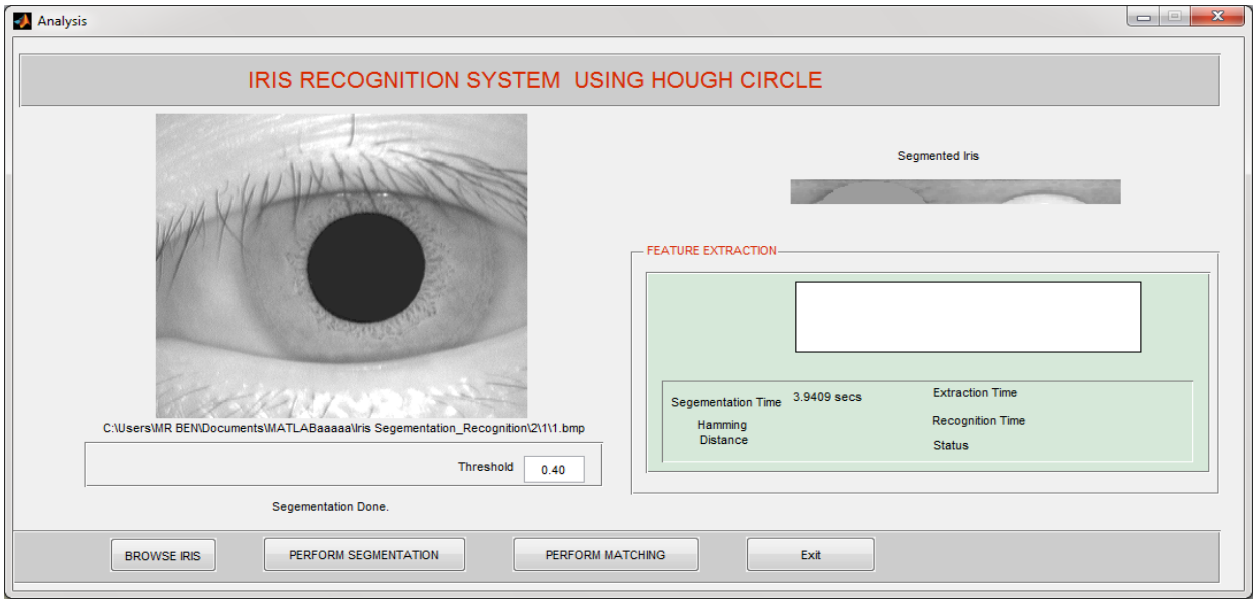


Figure 4.3 GUI for circular hough segmentation process

After loading an image, the perform segmentation button will be click which perform the segmentation of the selected eye image using circular hough algorithm. After segmentation, the program will also perform the normalization and feature extraction on the iris image using Daugman's rubber sheet and log gabor algorithm.

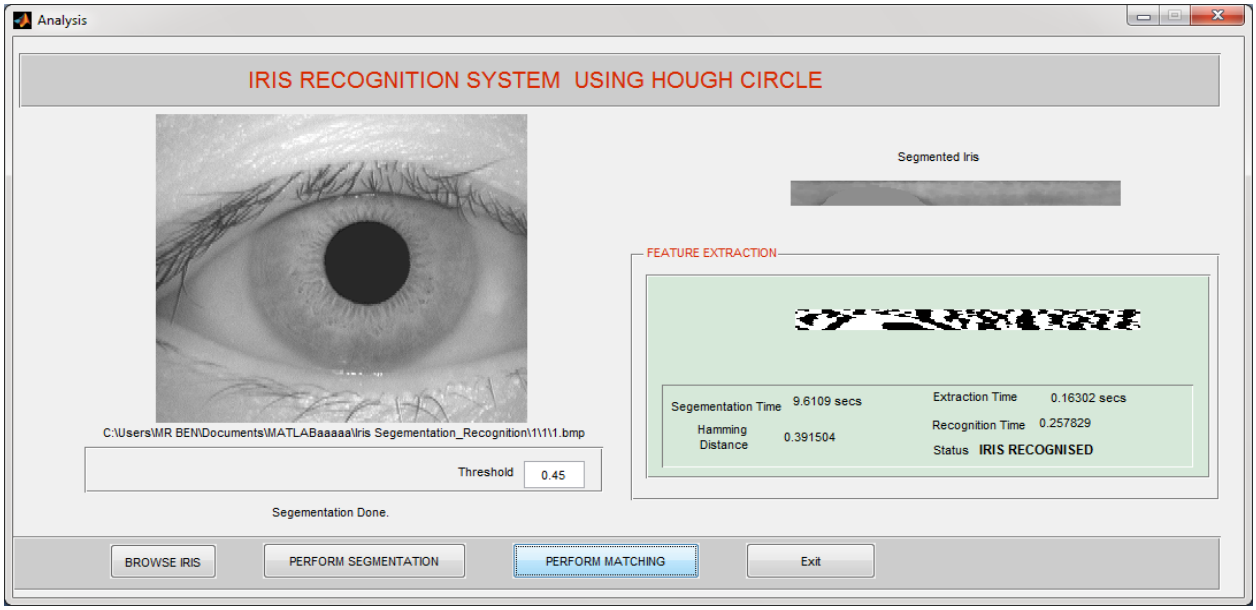


Figure 4.4 GUI for performing matching

Figure 4.4 present the result of a successful segmented iris that has been matched and recognized by clicking on perform matching button.

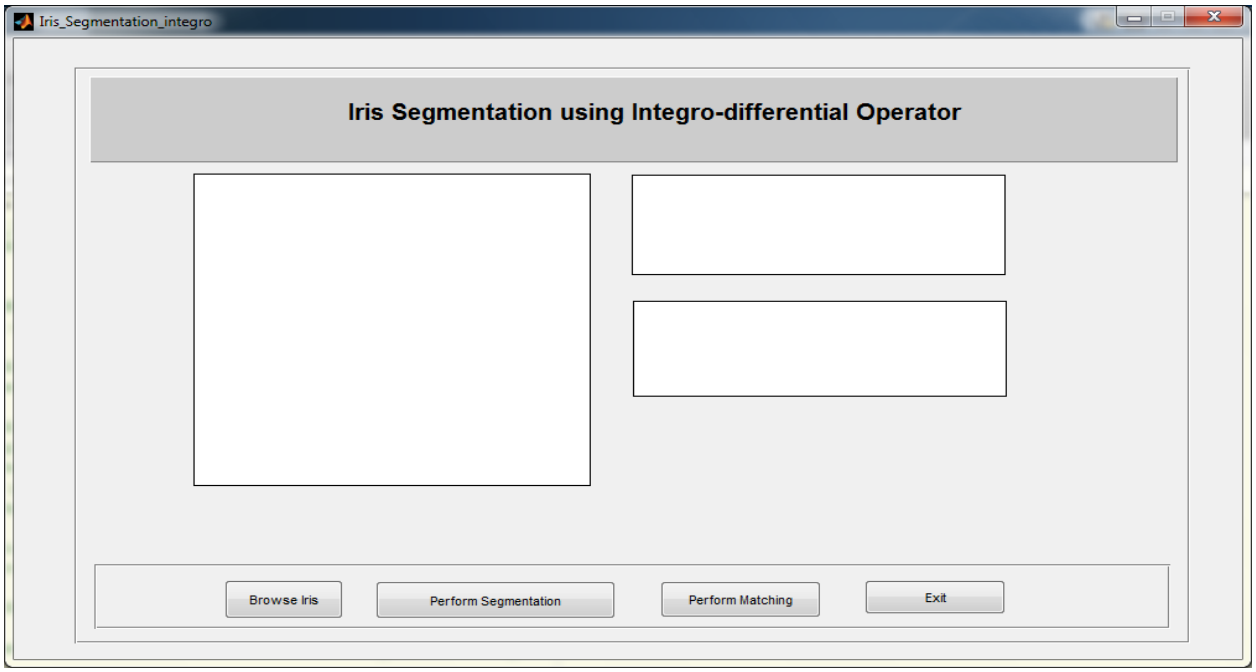


Figure 4.5 General GUI for Integro-differential

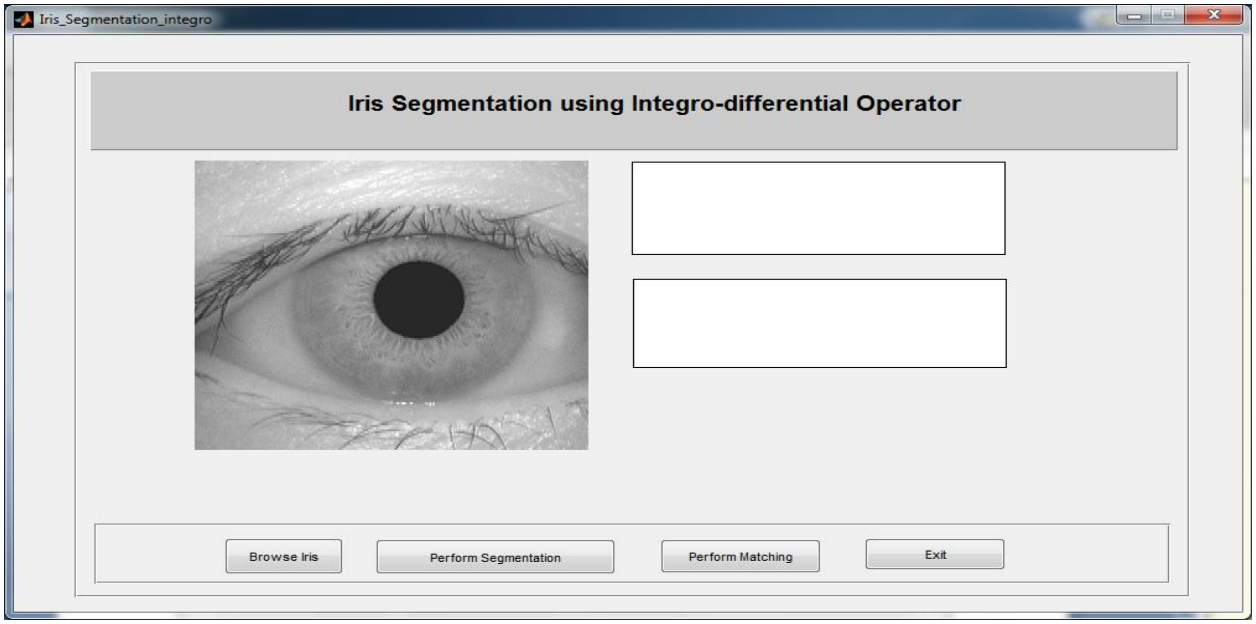


Figure 4.6 GUI for loading an eye image

To select an image as presented in figure 4.2, the user will click on browse iris from where an image will be selected from the image dataset.

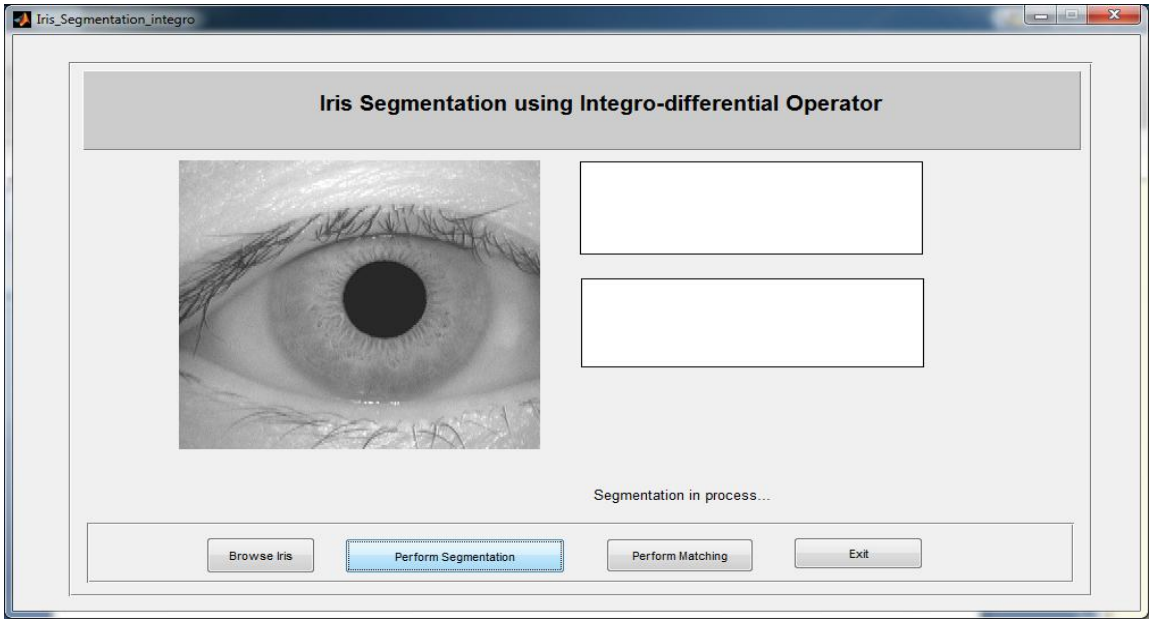


Figure 4.7 GUI for integro-differential segmentation process

After loading an image, the perform segmentation button will be click which will initiate the process of integro-differntial segmentation method on the selected eye image.

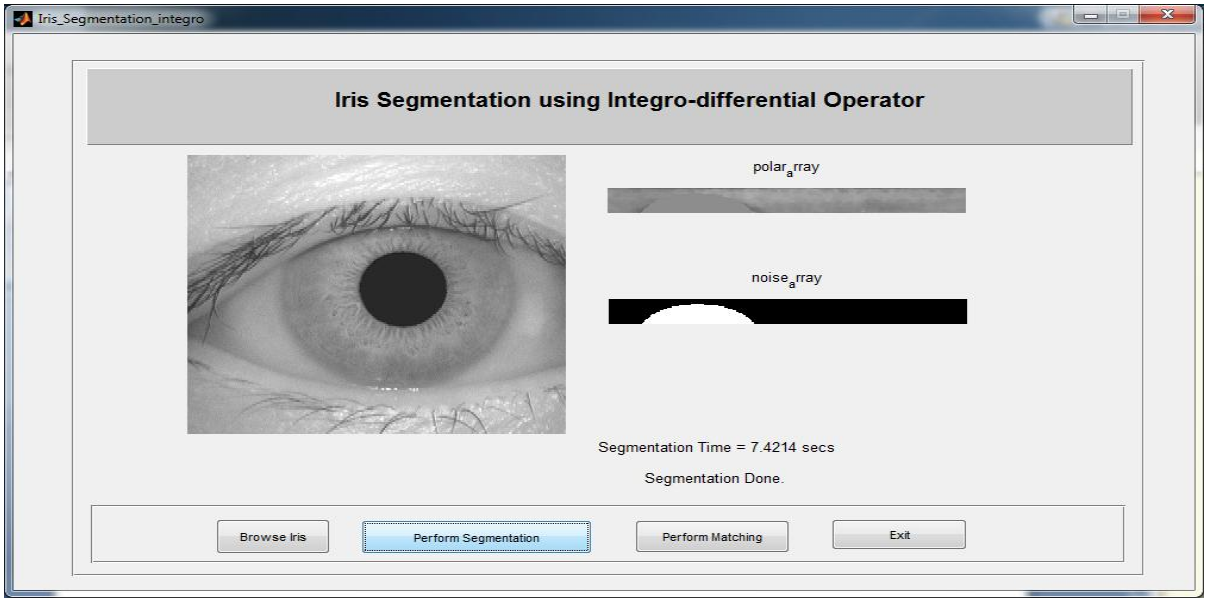


Figure 4.8 GUI for integro-differential segmentation process

After loading an image, the perform segmentation button will be click which perform the segmentation of the selected eye image using integro-differential algorithm. After segmentation, the program will also perform the normalization and feature extraction on the iris image using Daugman's rubber sheet and log gabor algorithm.

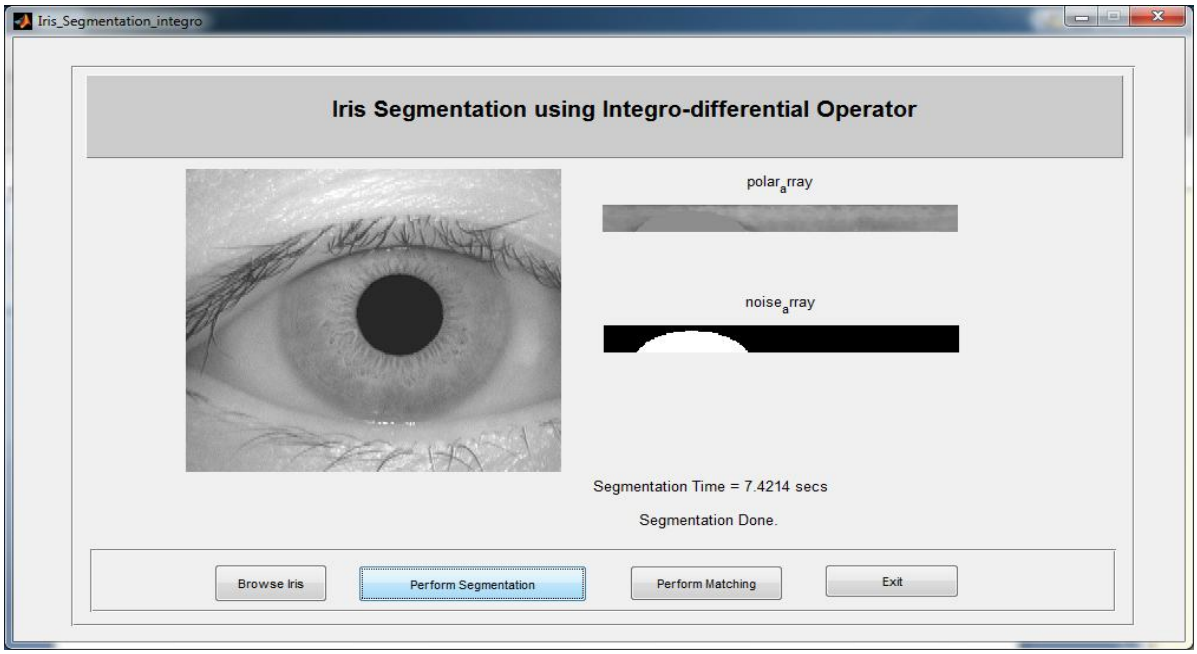


Figure 4.9 Integro-differential GUI for matching

Figure 4.9 present the result of a successful segmented iris that has been matched and recognized by clicking on perform matching button.

4.2 Result and Discussion

Table 4.1 FAR, FRR and RA (Integro-differential operator)

S/NO	NOS OF FAR	FAR (%)	NOS OF FAR	FRR (%)	Recognition Accuracy (100-FRR)%
01	0	0	10	8.3333	91.6667
02	0	0	10	8.3333	91.6667
03	0	0	12	10.0000	90.0000
04	0	0	12	10.0000	90.0000
05	0	0	7	5.8333	94.1667
06	0	0	11	9.1667	90.8333

Table 4.2 FAR, FRR and RA (Circular Hough)

S/NO	NOS OF FAR	FAR (%)	NOS OF FRR	FRR (%)	Recognition Accuracy (100-FRR)%
01	0	0	9	7.5000	92.5000
02	0	0	9	7.5000	92.5000
03	0	0	7	5.8333	94.1667
04	0	0	10	8.3333	91.6670
05	0	0	6	5.0000	95.0000
06	0	0	9	7.5000	92.5000

Table 4.1, display the intra class matching based on integro-differential, eye image one and two of each class an error of 8.3% was recorded, on eye image of class three an error of 10% was recorded, on eye image of class four an error of 10% was recorded, on eye image of class five an error of 5.2% was recorded and on eye image of class six an error of 9.2% was recorded while from table 4.2 when the intra class matching was carried out on circular Hough, eye image one and two of each class an error an error of 7.5% was recorded, on eye image of class three an error of 5.8% was recorded, on eye image of class four an error of 8.3% was recorded, on eye image of class five an error of 5% was recorded and on eye image of class six an error of 7.5% was recorded. Running the intra class for each method shows zero percent error rate that is no FAR was recorded. This shows the near perfection of the CAISA database. The graph of the FAR FRR are shown in figure 4.10 to 4.13 respectively.

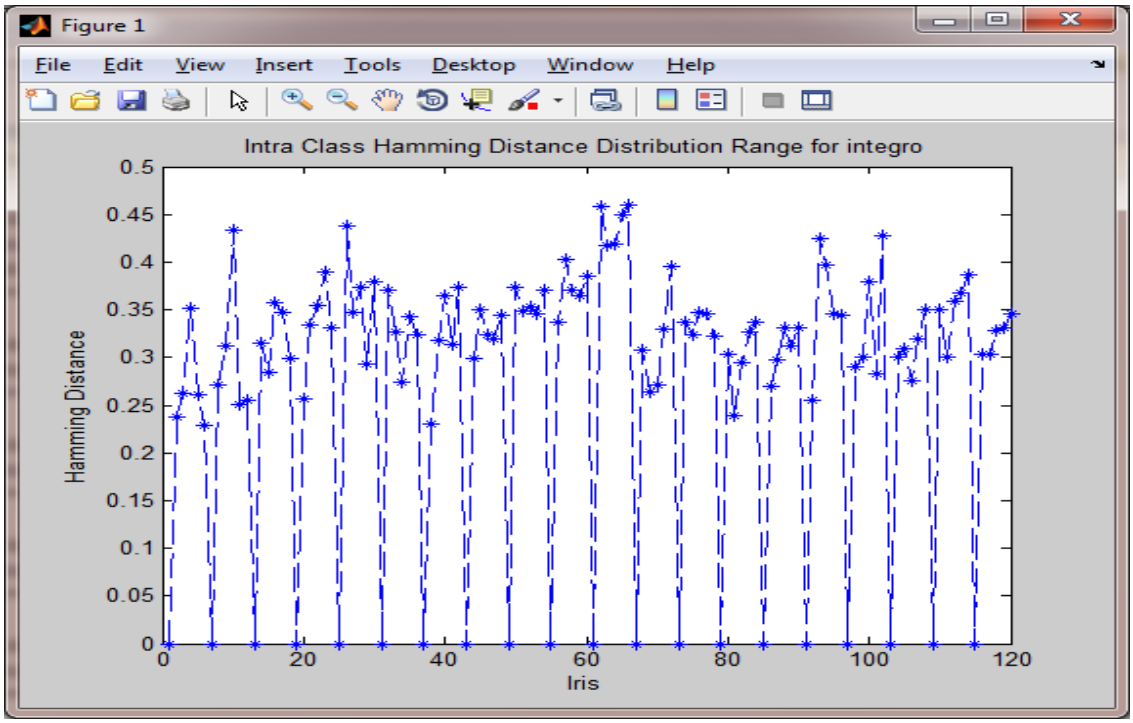


Figure 4.10 intra class graph for integro-differential

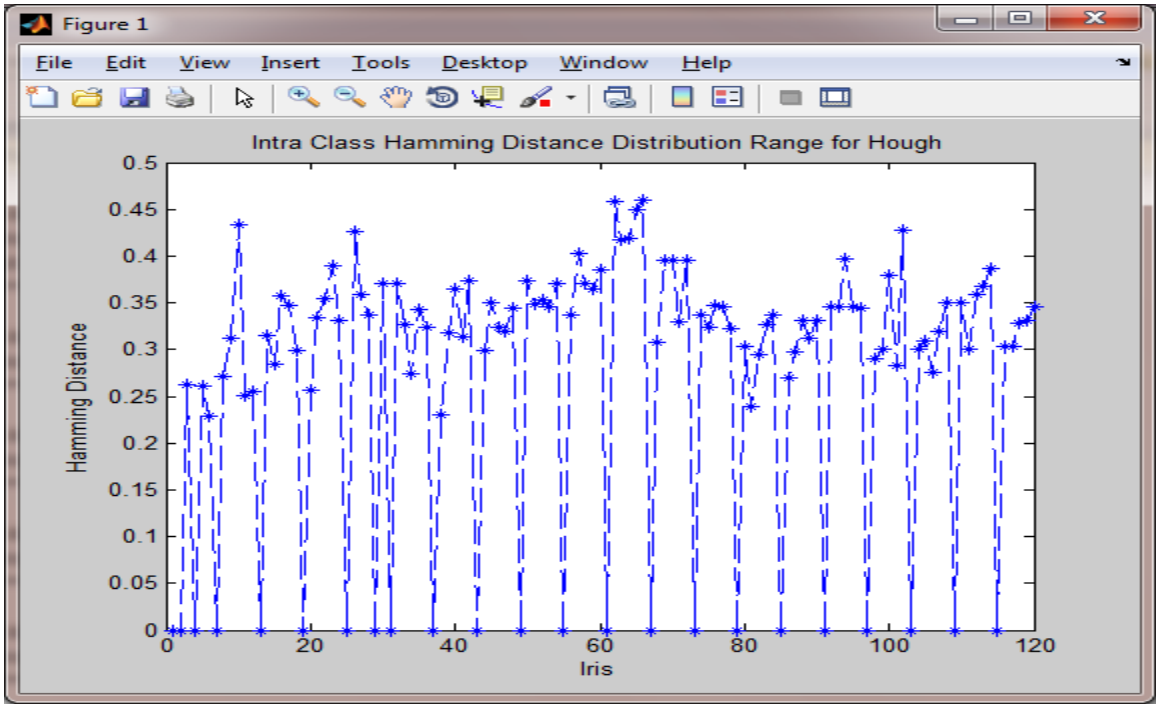


Figure 4.11. Intra class graph for circular Hough

Figure4.10 and 4.11 shows an intra class graph for integro-differential and circular Hough respectively showing some of the eye images that are FR since they fall above the threshold value of 0.4. Though the eye images belong to the same class of images that are accepted, they are rejected due to some errors from any of the stages of iris biometric recognition earlier mention. The system is reliable since FR error is acceptable in any working system.

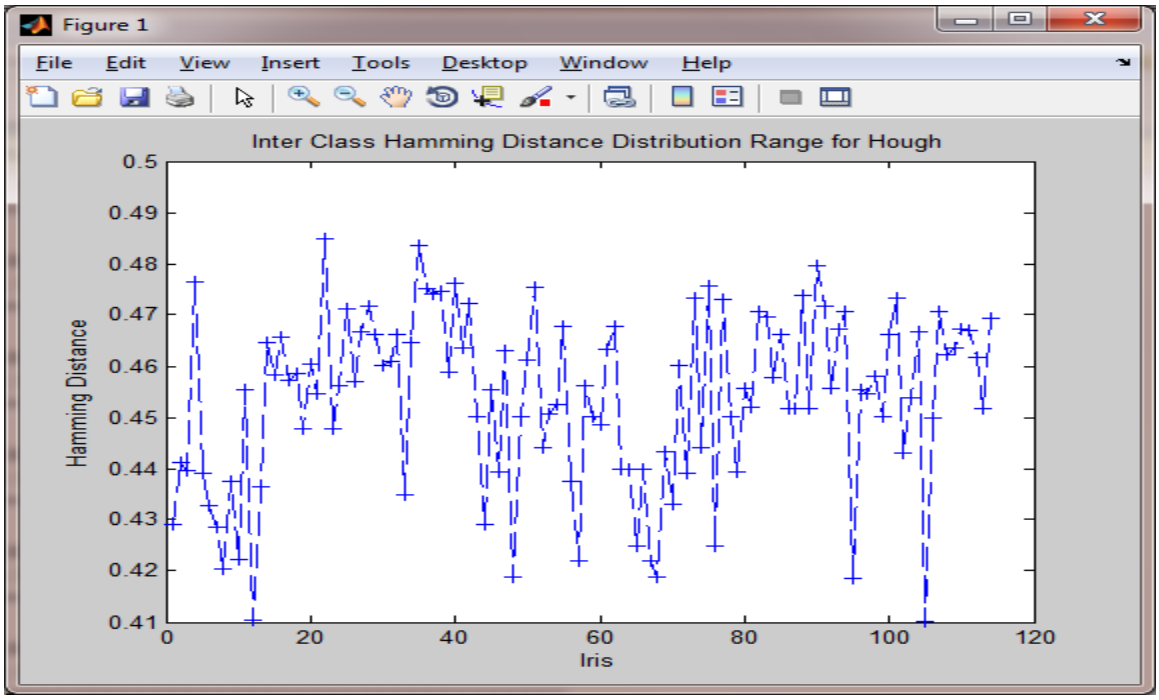


Figure 4.12 Inter class graph for circular hough

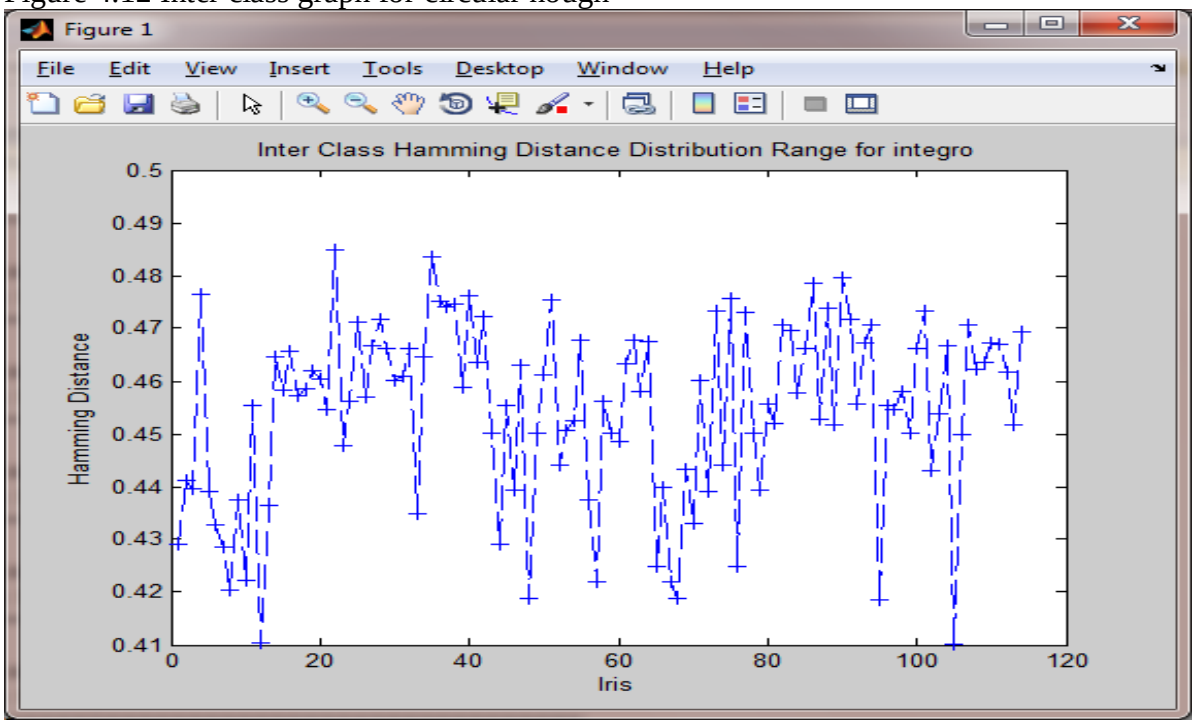


Figure 4.13 Inter class graph for integro-differential

Figure 4.12 and 4.13 show an inter class graph for integro-differential and circular Hough respectively. From the graph, the eye images were rejected since they fall above the

threshold value of 0.4. Since, the eye images were run on class that was different from its class for the images to be rejected shows that the threshold set for the application well chosen. It also shows that the system is reliable since false acceptance error which is disastrous if it accepts an imposter hence, this shows the accuracy of the CASIA dataset used.

From each run of the intra class and inter class matching, numbers of FRR and FAR and the percentage of error for each run were taken. In addition, the percentage accuracy for each method is calculated. To calculate the value for the percentage recognition accuracy, the value of the FRR and the FAR was subtracted from 100 which is called the recognition accuracy (RA) in a tabular form represented in table tables 4. 1 and 4.2 respectively

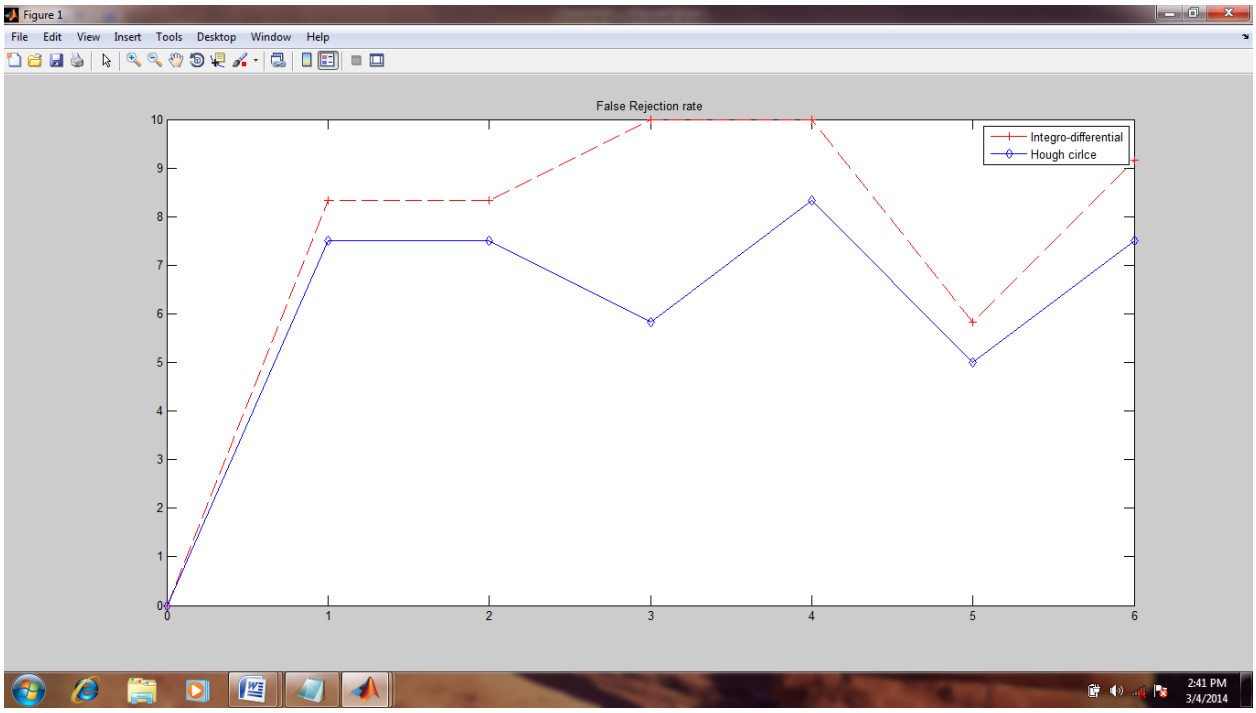


Figure 4.14 FRR for Circular Hough and Integro-differential

From figure 4.14, it can be observed that the error rate of Integro-Differential is higher than that of the Circular Hough since its curve is higher than that of the Circular Hough.

From table 4.1 and 4.2, MATLAB was used to plot a comparison graphs which combines the graph of FFR of circular Hough and the recognition accuray for integro-differential and circular hough from where analysis can was carried out is shown in figure 4.14 and 4.15 respectively.

The figures 4.15 below shows the graphical interpretation of the of the combine recognition accuracy for both the Integro- differition and Circular Hough respectively.

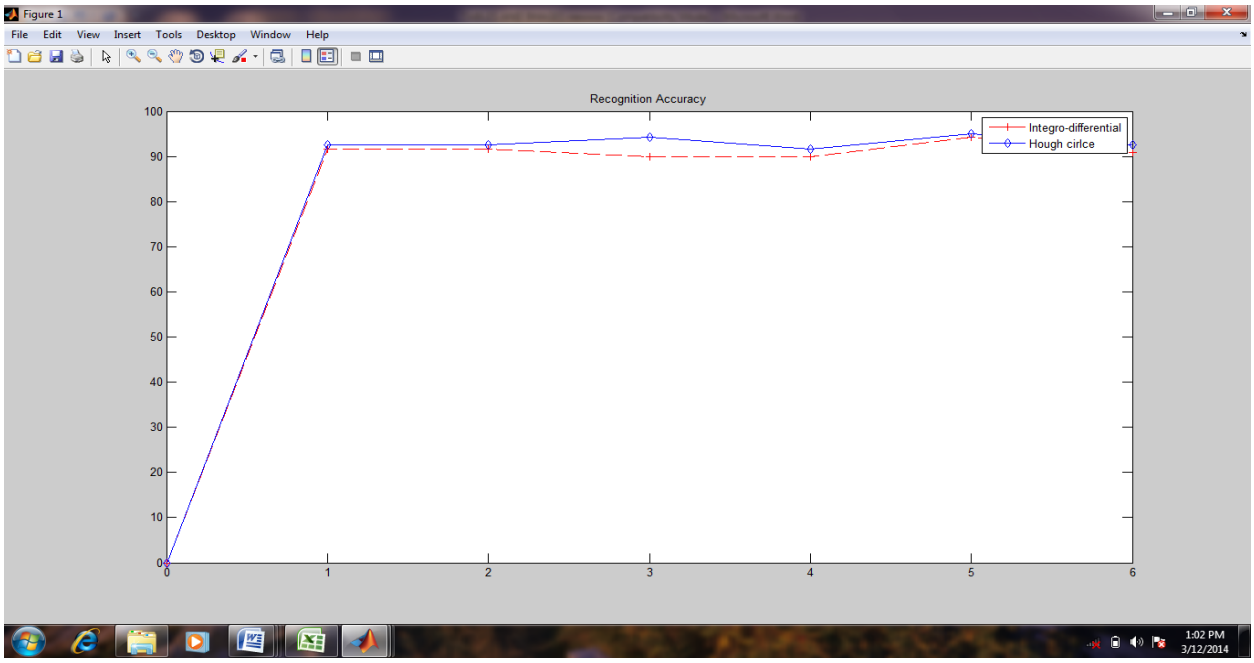


Figure 4.15 Recognition accuracy for Circular Hough and Integro-differential

From the graph in figure 4.15, it was observed that the curve of Circular Hough is higher than that of the Integro-differential which implies that the Circular Hough degree of accuracy is higher than that of the Integro-differential, since, the accuracy of the system is determined by the degree of error of FAR and FRR and the FAR is equal zero (0) these shows that the circular hough is more accurate than the integro-differential.

4.3 Conclusion

In conclusion, this thesis has proved that under the same condition, Wildes algorithm performs better than Daugman's algorithm because the FRR curve of Circular Hough was lower compare to that of Integro-differential algorithm. Also, the comparison of accuracy graph of the two algorithms depicts higher accuracy for Wildes over Daugman. These features are essential in any biometry system. Hence, there is basis that Circular Hough proposed by Wildes has a better performance than integro deferential algorithm proposed by Daugman.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

Iris segmentation is one of the crucial steps in building an iris recognition system, since it affects the accuracy of the matching. This segmentation should be accurately extract the iris region, despite the lots of research on the two most common segmentation algorithms, there is little or no attempt to compare the performance of these algorithms under the same condition and on the same data set. Considering this gap, this thesis proposed a framework for evaluating the performance of the algorithms under the same conditions using the same data set. The performance evaluation result on 120 images from CASIA iris image database shows that Wilde's algorithm performs segmentation accurately than Daugman's algorithm.

5.2 Conclusion

Iris recognition system is a reliable and an accurate biometric system. Segmentation of the iris borders in an eye image can be considered as a vital step in the iris recognition process. There exist two most common algorithms used in many commercial iris biometric systems to segment the iris. The aim of this thesis is to implement these algorithms using MATLAB programming environment, in order to compare them under the same condition. The implemented algorithm was tested on the eye images taken from CAISA database. The performance evaluation of the results demonstrated that the Wildes algorithm has a lower FRR than the Daugman's. Hence, the performance

evaluation of both algorithms using the same framework under the same conditions has established a basis that effort should be made to better enhanced Wilde's algorithm.

5.3 Recommendation

Based on the findings from this thesis, the following recommendations were made:

a. This thesis uses dataset from CAISA that consist of white iris, further research should make effort to use a black dataset of iris.
b. During the evaluation, it was observed that the Integro-differential performs segmentation faster than the Circular Hough. Hence, further work is needed to speed up the segmentation time for Circular Hough
c. Finally, the research is carried out using one out of different type of Normalization, Feature Extraction and matching Technique. Hence, further work can be carried out varying different type of Normalization, Feature Extraction and matching Technique, to allow room for a better conclusion on their performance.

REFERENCES

Aleksandra B. (2012) Biometric Authentication. Types of biometric identifiers. M.Sc Thesis Haaga-Helia University of Applied Science. Pp.2-3

Anil K. J and Ajay.K (2010). Biometrics of Next Generation: An Overview. Second generation biometrics springer, Verlag London Limited. pp. 2-9

Annapoorani G., Krishnamoorthi R., Gifty jeya P and Petchiammal S. (2010). Accurate and Fast Iris Segmentation. International Journal of Engineering Science and Technology 2(6), pp.1492-1499.

Boles W. and Boashash B. (1998). A human identification technique using images of the iris and wavelet transform. *IEEE Transactions on Signal Processing*, 46(4).

Daugman J. (1993). High confidence visual recognition of persons by a test of statistical independence. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 15(11).

Daugman J. (1994). Biometric personal identification system based on iris analysis. United States Patent, Patent Number: 5, pp. 291-560.

Daugman J. (2002). How iris recognition works. Proceedings of 2002 International Conference on Image Processing. 1(1), pp 120-140

Daugman J. (2004). How Iris Recognition Works. IEEE Trans. Circuits and Systems for Video Technology. 14(1), pp. 21-30

Falohun A.S., Omidiora, Olabiyi. E.O, Fenwa O.D. and Adedeji O.T. (2012). Development of a Web-Based Iris Recognition System.First International Conference on Engineering and Technology Research. Las palmas de Gran, Canaria, pp 32-43

Ifeanyi U. and Ghazali B. (2012). An Enhanced Iris Segmentation Algorithm Using Circle Hough Transform. Faculty of Computer Science and Information System, University of technology. Malaysia. pp. 4-6

Gunjan S, Sharma R. and Puja N. (2012). Recognition of Human Iris Patterns International Journal of Electrical Electronic and Communication Engineering. VSRD-IJEECE, 2 (6), pp. 353-358

Hiral R. and Mehta .G.(2010). Comparing the techniques for iris Localization. Journal of information, knowledge and research in Electronics and communication engineering. 2(2), pp. 666

Jain A. K., Bolle R., and Pankanti S. (1999). Personal Identification in networked society. 2nd edition. Kluwer Academic Publisher, E.U.A.

Jaehan, K. and Govindaraju, V. (2010). A Robust Iris Localization Method Using an Active Contour Model and Hough Transform. Pattern Recognition (ICPR), 20th International Conference.

Jillela R., Arun R., Vishnu N., Vijaya K., Xiaofei H., Robert P.and Paul P. Lane.(2013). An Evaluation of Iris Segmentation Algorithms in Challenging Periocular Images. Department of Computer Science and Electrical Engineering, West Virginia University. Pp.5-9

Lim S., Lee K., Byeon O. and T. Kim. (2001) Efficient iris recognition through improvement of feature vector and classifier. *ETRI Journal*, 23(2).

Libor M. (2003). Recognition of Human Iris Patterns for Biometric Identification. A thesis submitted to the School of Computer Science and Software Engineering, The University of Western Australia. pp. 1

Nakissa B. and Shahram M. (2009). A New User Dependent Iris Recognition System Based on an Area Preserving Pointwise Level Set Segmentation Approach. Journal on Advances in Signal Processing, 13(2), pp. 1-7

Noh S., Pae K., Lee C. and Kim J. (2002). Multiresolution independent component analysis for iris identification. Paper presented at 2002 International Technical Conference on Circuits/Systems, Computers and Communications.

Penny K. (2002). Iris Recognition Technology for Improved Authentication. SANS Security Essentials (GSEC) Practical Assignment. Foundation of Computer Science, New York, USA. 10(39), pp. 4-5

Radha N. and Kavitha N. (2011). Rank Level Fusion using Finger Print and Iris Biometrics. Indian Journal of Computer Science and Engineering (IJCSE). pp.105-119

Proenca H. and Alexandre L. (2006), "Iris segmentation methodology for non-cooperative recognition," *IEE Proceedings: Vision, Image and Signal Processing*, 153(2), pp. 199–205.

Richard Y. (2011). Algorithms to process and measure biometric information content in low quality face and iris images. Ph.D Thesis, School of Information Technology, Faculty of Graduate and Postdoctoral Studies, University of Ottawa. pp.57-74.

Ritter, N. and Owens, R. (1999). Location of the Pupil-Iris Border in Slit-Lamp Images of the Cornea. International Conference on Image Analysis and Proceedings, pp. 740-745.

Ritter, N., Cooper, J.R. (2003). Locating the iris: A first step to registration and identification. In Proc. 9th IASTED *International Conference on Signal and Image Processing*. Pp. 507-512.

Sanderson S. and Erbetta J. (2000). Authentication for secure environments based on iris scanning technology. *IEE Colloquium on Visual Biometric*s, Foundation of Computer Science, New York. 90(13), 778-789

Samir S. and Arun R. (2009). Iris Segmentation Using Geodesic Active Contours. IEEE Transactions on Information Forensics and Security. 4(4), pp.824-827

Seyyed M, Ahmad A, and Seyyed S. (2010). A Novel Iris Segmentation Method based on Balloon Active Contour. Machine Vision and Image Processing (MVIP), 6th edition. Pp 1-5

Sreecholpech C. and Thainimit S. (2009). A Robust Model-based Iris Segmentation. International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS). pp 599-602

Surjeet S. and Kulbir S. (2011). Segmentation Techniques for Iris Recognition System. International Journal of Scientific & Engineering Research 2(4), pp. 6.

The Irish Council for Bioethics. (2009). Biometrics: Enhancing Security or Invading Privacy. Published by The Iris council for Biomtric, Dublin. pp.1-30

Wildes R., Asmuth J., Green G., Hsu S., Kolczynski R., Matey J., McBride S. (1994). A system for automated iris recognition. *Proceedings IEEE Workshop on Applications of Computer Vision*, Sarasota, pp. 121-128.

Wildes R. (1997). Iris Recognition: An Emerging Biometric Technology. *Proceedings* IEEE, 85(9), pp. 1348-1365.

Xie, L. (2007). Algorithms for Recognition of Low Quality Iris Images. Master's thesis, Carleton University, Ottawa, Canada.

Young, H.D., and Roger A. F. (2004) University *Physics with Modern Physics*. 11th ed. San Francisco, CA: Addison Wesley. http://www.amazon.com/University-Physics-Freedman-Francis-Weston

Young H. and Freedman R. (2003). University Physics with Modern Physics. Addison-Wesley

Zainal A., Manaf M., Shibghatullah A., Mohd Y., Anawar S., Ayop Z.(2012). Iris Segmentation Analysis using Integro-Differential Operator and Hough Transform in Biometric System. Journal of Telecommunication, Electronic and Computer Engineering. 4(2), pp. 42-47

Zhaofeng H., Tieniu T., Fellow, Zhenan S. and Xianchao Qiu. (2009). Toward Accurate and Fast Iris Segmentation for Iris Biometrics.Transactions on Pattern Analysis and Machine Intelligence. 31(9), pp. 1670-1676

Zyad T. and Mutasem A. (2013). Iris Recognition Using Robust Algorithm for Eyelid, Eyelash and Shadow Avoiding. World Applied Sciences Journal 25 (6), pp. 858-865

Young H. and Freedman R. (2003). University Physics with Modern Physics. Addison-Wesley

APPENDIX A

```
% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @Iris_Segmentation_integro_OpeningFcn, ...
                   'gui_OutputFcn',  @Iris_Segmentation_integro_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT


% --- Executes just before Iris_Segmentation_integro is made visible.
function Iris_Segmentation_integro_OpeningFcn(hObject, eventdata, handles, varargin)
% This function has no output args, see OutputFcn.
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% varargin   command line arguments to Iris_Segmentation_integro (see VARARGIN)

% Choose default command line output for Iris_Segmentation_integro
handles.output = hObject;

% Update handles structure
guidata(hObject, handles);

% UIWAIT makes Iris_Segmentation_integro wait for user response (see UIRESUME)
% uiwait(handles.figure1);


% --- Outputs from this function are returned to the command line.
function varargout = Iris_Segmentation_integro_OutputFcn(hObject, eventdata, handles)
```

```
% varargout  cell array for returning output args (see VARARGOUT);




% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Get default command line output from handles structure
varargout{1} = handles.output;

% --- Executes on button press in pushbutton1.
function pushbutton1_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global PathName FileName
[FileName,PathName] = uigetfile('*.bmp','Select the iris image');
fullname = [PathName FileName];
%set(handles.text2,'string',fullname)
axes(handles.axes1)
imshow(fullname)

% --- Executes on button press in pushbutton2.
function pushbutton2_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global PathName FileName
 w = cd;
    set(handles.text1,'string','Segmentation in process...')
    pause(0.5)
    segstr = strcat(w,'\segmentation');
    cd(segstr)
    tic
    I = imread([PathName,FileName]);
    [polar_array noise_array] = morphop(I);
    eElapsed=toc;
   axes(handles.axes2)
   imshow(polar_array)
    title('polar_array')
   axes(handles.axes3)
   imshow(noise_array)
   title('noise_array')
```

```
set(hObject,'userdata', polar_array)
  set(handles.pushbutton3, 'userdata', noise_array)
  set(handles.text1,'string','Segementation Done.')
  cd(w)
  set(handles.text3,'string',['Segementation Time = ',num2str(eElapsed),' secs'])
% --- Executes on button press in pushbutton3.
function pushbutton3_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
%% extracting features
ui = get(handles.pushbutton2,'userdata');
%     figure(12)
%     imshow(ui)
   ui = ui';
   dim = [256 16];
   ui = resize_uint8_ui(ui, dim);
   iristemp = lgfilter(ui);
   iristemp = iristemp';
%%
global PathName FileName
w=cd;
tic
extract_temp=getimage(handles.axes2);
extract=imresize(extract_temp,[20 480]);
%imwrite(extract,'nww.bmp','bmp')
template1=extract;%imread('nww.bmp');
if FileName=='1.bmp';
dir2=strcat(PathName,'\a1.bmp');
mask=strcat(PathName,'\b1.bmp');
elseif FileName=='2.bmp';
   dir2=strcat(PathName,'\a2.bmp');
   mask=strcat(PathName,'\b2.bmp');
elseif FileName=='3.bmp';
   dir2=strcat(PathName,'\a3.bmp');
   mask=strcat(PathName,'\b3.bmp');
end
mask=imread(mask);
template2=imread(dir2);
hammiDistance=gethammingdistance(template1,mask,template2,mask);
%set(handles.text11,'string',hammiDistance)
Eelapsed=toc;
%set(handles.txtrectime,'string',Eelapsed)
%threshold=str2double(get(handles.editthreshold,'string'));
if hammiDistance<=0.50
```

```
   set(handles.text1,'string',['IRIS RECOGNISED.  ', 'Harming Distance
=',num2str(hammiDistance)])
else
   set(handles.text16,'string','IRIS NOT RECOGNISED')
end

 % --- Executes on button press in pushbutton3.
function pushbutton5_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% --- Executes on button press in pushbutton6.
function pushbutton6_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton6 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
close(gcf)

w=cd;
clc
% INTER-CLASS MATCHING ALGORITHM
disp('Performs Iris Inter class Matching')
disp('++++++++++++++++++++++++++++++++++++++++++++++++++++++++')
ExtractDatabase=strcat(w,'\LogGabor Extract\');

cd(strcat(ExtractDatabase,'1'))
cd(w)
disp('Supply the Iris to use[1-6]')
xx=input('Input your option:  ');
%
iris1=strcat('C:\newprojects\IrisRecog_Quadtree\TemplateDatabase\1\',num2str(xx),'.bm
p');
% testiris=iris1;
%PathName1=strcat('C:\newprojects\IrisRecog_Quadtree\TemplateDatabase\',num2str(N
oId),'\1\');
nscales=1;
FAR=0;
tic
template1=imread(strcat(ExtractDatabase,'1\',num2str(xx),'.bmp'));
Threshold=0.40;%hamming distance
%mask1=imread(strcat(ExtractDatabase,'1',num2str(xx),'.bmp'));
kk=1;
for NoId=2:1:20
    PathName1=strcat(strcat(ExtractDatabase,num2str(NoId)));
   for iris2=1:6;
      cd(PathName1)
```

```
    template2=imread(strcat(num2str(iris2),'.bmp'));
   % mask2=imread(strcat('b',num2str(iris2),'.bmp'));
    cd(w)
    c = gethammingdistance2(template1,template2,nscales);
    if c<=Threshold
        disp('*******************************************')
        disp(['Iris ',num2str(iris2)])
        disp(strcat('Hamming distance is=  ',num2str(c)))
        disp('Iris Recognized')
        inthd1{NoId}=c;
        FAR=FAR+1;

    else
        disp('*******************************************')
        disp(['Iris ',num2str(iris2)])
        disp(strcat('Hamming distance is=  ',num2str(c)))
        disp('Iris not Recognised')
        inthd1{NoId}=c;
    end
     HammingArray(kk)=c;
    kk=kk+1;
    end

    %%

end
Elapsed=toc;
FAR=(FAR/114)*100;
disp(['False Acceptance rate is= ',num2str(FAR),'%'])
figure(1)
plot(HammingArray(1:100),'--r+');
title('Inter Class Hamming Distance Distribution Range for integro')
xlabel('Iris');
ylabel('Hamming Distance');

w=cd;
clc
% INTRA-CLASS MATCHING ALGORITHM
disp('Performs Iris Intra class Matching')
% cd('C:\newprojects\IrisRecog_Quadtree\TemplateDatabase')
% cd(w)
ExtractDatabase=[w,'\LogGabor Extract\'];

disp('Supply the Iris to use[1-6]')
xx=input('Input your option:  ');
```

```
FRR=0;%initialising
kk=1;
for NoId=1:1:20
%
iris1=strcat('C:\newprojects\IrisRecog_Quadtree\TemplateDatabase\',num2str(NoId),'\',nu
m2str(xx),'.bmp');
% testiris=iris1;
%PathName1=strcat('C:\newprojects\IrisRecog_Quadtree\TemplateDatabase\',num2str(N
oId),'\1\');
nscales=1;
Threshold=0.40;%hamming distance
disp(['Threshold = ',num2str(Threshold)])
template1=imread(strcat(ExtractDatabase,num2str(NoId),'\',num2str(xx),'.bmp'));
%mask1=imread(strcat(ExtractDatabase,'1\','b',num2str(xx),'.bmp'));

    PathName1=strcat(ExtractDatabase,num2str(NoId));
   for iris2=1:6;
      cd(PathName1)

   template2=imread(strcat(num2str(iris2),'.bmp'));
   %mask2=imread(strcat('b',num2str(iris2),'.bmp'));
   cd(w)
   c = gethammingdistance2(template1,template2,nscales);
   if c<= Threshold
      disp('*********************************************')
      disp(['Iris ',num2str(iris2)])
      disp(strcat('Hamming distance is=  ',num2str(c)))
      disp('Iris Recognized')
      inthd1{NoId}=c;


   else
      disp('*********************************************')
      disp(['Iris ',num2str(iris2)])
      disp(strcat('Hamming distance is=  ',num2str(c)))
      disp('Iris not Recognised')
      inthd1{NoId}=c;
      FRR=FRR+1;
   end
    HammingArray(kk)=c;
   kk=kk+1;
   end
   %%
end
disp(['No of falsely rejected Iris is = ',num2str(FRR)])
FRR=(FRR/120)*100;
```

```
disp(['False Rejection rate is= ',num2str(FRR),'%'])
figure(1)
plot(HammingArray(1:100),'--b*');
title('Intra Class Hamming Distance Distribution Range for integro')
xlabel('Iris');
ylabel('Hamming Distance')
```