Performance Analysis of Feature Extraction Techniques for Iris Recognition System

By

Amina Atia Abdo

Supervisor

Dr. Ahmed Lawgali

This Thesis was Submitted in Partial Fulfillment of the Requirements for Master's Degree in Computer Science

University of Benghazi
Faculty of Information Technology
Department of Computer Sciences

2020

Dedication

This thesis is dedicated to my parents, for their love, kindness, devotion, endless support, and for their encouragement.

Amina A. Abdo

Publications

ICEEIT2020 Paper: (Accepted)

Amina A. Abdo., Ahmed Lawgali., and Ahmed K. Zohdy. "Iris Recognition based on Histogram Equalization and Discrete Cosine Transform". In International Conference on Electrical Engineering and Information Technology (ICEEIT2020). March, 2020, Benghazi-Libya.

Acknowledgments

First and foremost, I am deeply grateful and thankful to God who inspired me to accomplish this work.

My special thanks to Dr. Ahmed Lawgali my research supervisor, for his patience and enthusiasm. His guidance criticisms aided the writing of this work and his support was greatly needed and deeply appreciated.

I would like to thank my parents and all my family for providing me with support and continuous encouragement throughout my years of study. I would also like to thank Dr. Wafa El-Tarhouni, Dr. Aeiman Gadafi and my friends for helpful suggestions.

Last but not least, I would like to extend my thanks to the administration at the Martyr Mohammed Al-Durra Institute, and I am grateful for the support that I have received throughout my study.

TABLE OF CONTENTS

Contents	Page No.

LIST OF TABLES

LIST OF FIGURES

Figure	Page No.

LIST OF ALGORITHMS

LIST OF ABBREVIATION

Abbreviation	Meaning
DWT	**D**iscrete **W**avelet **T**ransform
DCT	**D**iscrete **C**osine **T**ransform
LBP	**L**ocal **B**inary **P**attern
SVM	**S**upport **V**ector **M**achine
CASIA	**C**hinese **A**cademy of **S**ciences' **I**nstitute of **A**utomation database
MMU	**M**ulti**M**edia **U**niversity
UPOL	**U**niversity of **P**alackeho and **Ol**omouc
CNN	**C**onvolutional **N**eural **N**etworks
GLCM	**G**ray **L**evel **C**o-occurrence **M**atrix
GLRLM	**G**ray-**L**evel **R**un **L**ength **M**atrix
TCM	**T**exture **C**ode **M**atrix
BoF	**B**ag **o**f **F**eature
PWT	**P**yramid structure **W**avelet **T**ransform
TWT	**T**ree structure **W**avelet **T**ransform
OPDF	**O**rientation **P**robability **D**istribution **F**unction
MPDF	**M**agnitude **P**robability **D**istribution **F**unction
ANN	**A**rtificial **N**eural **N**etworks
RBF	**R**adial **B**asis **F**unction
CHT	**C**ircular **H**ough **T**ransform
ERNN\LMA	**E**lman **R**ecurrent **N**eural **N**etwork/Levenberg-**M**arquardt **A**lgorithm
PCA	**P**rincipal **C**omponent Analysis
HE	**H**istogram **E**qualization
AHE	**A**daptive **H**istogram **E**qualization
RBNN	**R**adial **B**asis **N**eural **N**etwork
PNN	**P**robabilistic **N**eural **N**etwork(PNN)
WT	**W**avelet **T**ransform
GF	**G**abor **F**ilter
KNN	**K**-**N**earest **N**eighbor
HD	**H**amming **D**istance
NBP	**N**eighborhood - based **B**inary **P**attern
ZMs	**Z**ernike **M**oment
FRR	**F**alse **R**eject **R**ate
ED	**E**uclidean **D**istance
BPSO	**B**inary **P**article **S**warm **O**ptimization
RT	**R**adon **T**ransform
FDs	**F**ourier **D**escriptors
RF	**R**andom **F**orest
DST	**D**iscrete **S**ine **T**ransform
FWHT	**F**ast **W**avelet **H**adamard **T**ransform

Performance Analysis of Feature Extraction Techniques for Iris Recognition System

By

Amina Atia Abdo

Supervisor

Dr. Ahmed Lawgali

ABSTRACT

Biometric systems are widely used by governments, businesses and organizations to identify people based to their biological characters. The main purpose to use such systems is to improve the security of systems, but they could also be used to get more information about individuals. Some biometric traits are used to authenticate a person's identity such as face, fingerprint, handwriting, signature, voice, DNA, and ear. One of the most prompting and evolving methods in biometric identification is the iris recognition as the human iris has a unique texture which includes a veriety of details. Iris recognition has gained a challenge for many researchers. Many of the challenges occur due to the errors in the method of capturing images, poor illumination, image dimensions, off-angle iris, etc. The various methods have been adopted by researchers in order to enhance and increase the performance of iris recognition.

Most of the iris recognition systems incorporate processes before the features extraction stage; first, the pre-processing stage which is done to enhance only the region of interests. This stage includes segmentation and normalization. Segmentation is used for the localization of the correct iris region by using the Circular Hough Transform technique (CHT). In the normalization stage, it converts the iris region to a suitable shape with specific dimensions. The Daugman’s Rubber Sheet Model has been used to remaps each point within the iris region to a pair of polar coordinates. Finally, to improve the normalized iris image, the Histogram Equalization (HE) technique has been implemented to facilitate the application of the feature extraction step.

In this research, we are interested to achieve high the accuracy of human iris recognition system. We presented an approach of combining (HE) and Discrete Cosine Transform (DCT) techniques for enhancing and extracting features with Support Vector Machine (SVM) as a classifier. Then, evaluate this against Local Binary Pattern (LBP) and Discrete Wavelet Transform (DWT) with SVM. To validate our approach, we used a free public iris database (CASIA interval-v4). The approach is implemented by using MATLAB version R2014a. The experiments on CASIA interval-v4 show that the performance of our approach better than DWT and LBP with SVM.

CHAPTER 1
Introduction

1.1. Overview

The word biometrics is derived from the incorporation of two Greek words, metrics and bio, which mean measure and life. Biometric is the science of establishing the identity of an individual based on the physical, chemical or behavioral attributes of the person. (Jain, 2007). In the same context, a biometric system is a pattern recognition system that is used to recognize the identity of an individual. The aim is to capture an item of biometric data from a person. It can be a photo of their iris, face, fingerprint, or an image of their hand geometry. After that, this data is compared to other data kept in a database.

Biometric system is important for many applications that are related to security such as passenger control in airports, access control in restricted areas, database access, and financial services.

In most cases, common identification tools such as ID Cards or passwords are possible to lose or forget easily with or without the knowledge of the owner. This can not occur by using biometric traits. The biometric has unique, and stable information about a person (Rai and Yadav., 2014).

The biometrics are divided into two basic parts as illustrated in Figure 1.1. The first part is physiological biometric which related to the shape of the body such as face, hand geometry, fingerprint, ear, and iris. The second part is behavioral biometric traits include signature, handwriting and the voice. Biometrics should meet the specified recognition accuracy, speed, and should consist of unique information (Pato and Millett, 2010). Moreover, the chance of any two people having the same characteristic will be minimal and stable so that the feature does not change over time.

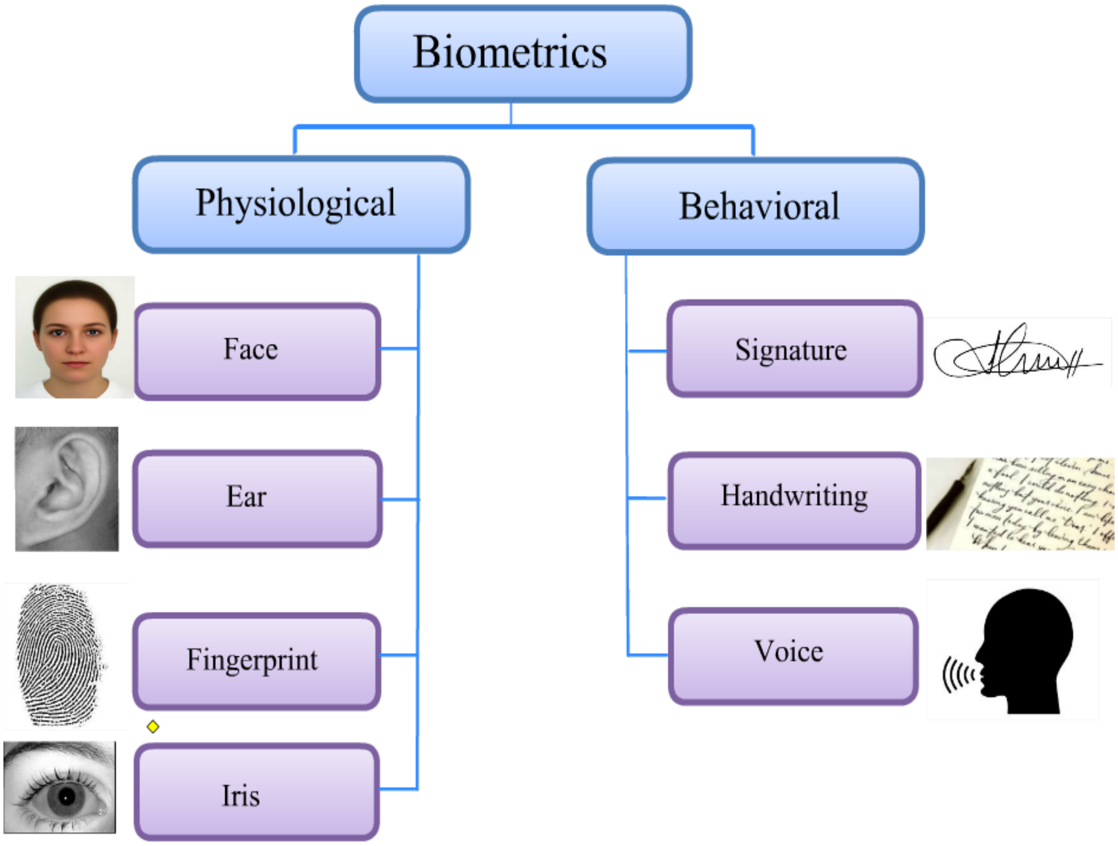


Figure 1.1: Biometric classification

The most important factors for the success of any biometric recognition system are uniqueness, stability, accuracy, availability, cost, and usability (Jain et al., 2007). In fact, each biometric trait has its strengths and weaknesses, and the choice of a specific trait depends upon the requirements of the application (Pato and Millett, 2010). For example, the iris area has rich and unique information. It can be used to identify individuals, iris images can even be captured from a distance which could be used for recognition purposes.

The history of using iris as an identity of individual goes back to mid-19th when the French physician, Alphonse Bertillon, studied the use of eye color as an identifier (Jain et al., 2002). The iris is one of the most reliable methods used to identify individuals because it is fixed and does not change throughout life and it is unique to each person. In fact, the iris pattern is characterized by a high level of stability and distinctiveness (Senior, 2010).

1.2. Research motivation

Since iris is a robust and unique biometric data, researchers have developed many techniques to deploy its uniqueness to generate a biometric system. In fact, the iris recognition system has become one of the best authentication systems (Chai et al., 2017). Nowadays, iris recognition is important for many applications such as the fight against crime, and security measures in airports. Iris recognition is an important and challenging problem in secure authentication and in a noisy imaging environment. The purpose of this work is to implement system that is able to recognize human iris patterns by applying different techniques. Then evaluate the results of these techniques. This work is related to an approach to address the sub problem of iris feature extraction, which deals with extracting the distinguished pattern of the iris to produce data, which can be used in the subsequent steps of iris recognition.

1.3. Problem statement

In this research, the problem of recognition of iris is addressed. This recognition is needed for secure methods of authentication of identification of individuals that are becoming increasingly important. Many algorithms of iris recognition systems have been applied to achieve excellent performance. However, these techniques still represent challenges in iris recognition. Many of the negative results occur because of errors in the method of capturing images, poor illumination, image dimensions, off-angle iris, eyes color, in addition to contact eyeglasses or contact lenses in the eyes, etc. (Gnana et al., 2018). All of these characteristics may lead to incorrect classification, and thus negative results will be obtained. Image quality affects the feature extraction process.

In this work, the main challenge is to achieve high accuracy of recognizing the human iris. It is by carrying out Circular Hough Transform for the localization of the correct iris region, and Daugman rubber sheet model for normalization. After this, HE for enhancing segmented iris image and DCT for extracting the feature with SVM as a classifier has been applied. And then, evaluate this against LBP and DWT with SVM.

1.4. Research aims and objectives

The selection of the methods for feature extraction and classification remain the most important step in achieving high recognition accuracy. The aim of this work is to evaluate and compare the effectiveness of three separate techniques in capturing discriminative features of iris in order to achieve high accuracy in recognizing human iris. In this research, the main objectives are as follows:

- A survey of iris recognition systems.
- To apply the HE and DCT on segmented iris image for enhancing and extracting features using SVM as a classifier.

- To implement a technique for iris recognition based on DWT, and LBP using SVM.
- To evaluate the results of the above techniques against DCT with SVM .
- To evaluate and compare the results with existing works.

1.5. Research methodology

1.5.1. Literature review

The sources from which data will be collected in this study are from reliable digital libraries such as, IEEE Xplore, ACM, Springer, and Elsevier. Moreover, the captured images are selected from CASIA iris database. The collected studies related to iris recognition will be analyzed to help narrowing down the research effort to focus on feature extraction and classification methods for iris recognition system.

1.5.2. Problem definition and analysis

The quality of the image captured by the sensor greatly affects the performance of the iris recognition system. If in an iris recognition system the image captured is of low quality, then the performance of the iris recognition based biometric system is influenced by a great amount. Therefore, exploratory research will be carried out in this work to provide more insights into the problem in order to propose a solution that might overcome the issue being investigated.

1.5.3. Research Design

The design of the work consists of the following steps:

- Reviewing previous studies related to the topic.
- Analysis of collected data to narrow down the research problem.
- Providing a clear and concise definition of the problem.
- Planning a solution to the problem by introducing and implementing the proposed solution.
- Evaluating the proposed solution by comparing the obtained results from the proposed solution with results from two techniques that have been used and compared in terms of the information content of features extracted from the segmented iris image.

1.6. Scope of the research

This work will focus on iris recognition as a biometric technology because everyone has an iris pattern that is distinct. The feature extraction methods have an important role for high accuracy of iris recognition system. The overall aim of this work is to investigate biometric systems able to recognize people using their iris. The work investigates the theoretical concepts behind iris recognition and proposes approach to extract features for the iris recognition system.

1.6. Significance of the study

The presented work try as much as possible to provide the best techniques that could be used for the iris recognition, according to the results that will be obtained to find out which techniques are suitable for some of them. This work produced a research paper entitled "Iris Recognition based on Histogram Equalization and Discrete Cosine Transform" and it was accepted at International Conference on Electrical Engineering and Information Technology (ICEEIT2020).

1.7. Thesis organization

This thesis comprises of six chapters. The first chapter includes introduction and briefly discusses the overviews about the research, aims and objectives, problem statements, and research motivation of this research.

The rest of the research is organized as follows:

- Chapter 2 discusses an overview of the iris recognition system and presents the challenge in iris recognition. The chapter also introduces brief explanations about the feature extraction techniques, which will be utilized in the study. These techniques are DCT, DWT, and LBP. Furthermore, the classifier SVM that is used to classify features obtained from iris are explained in details.
- Chapter 3 comprises of literature review and the results which obtained in each study are reviewed and presented in a table. In addition, the common public and freely available iris image databases are described.
- Chapter 4 explains the major methodology that has been used in this study. Firstly, a general overview of the database that is used in this research is given. Then, a detailed explanation of the most important stages of the iris recognition system is provided. These stages are, preprocessing (segmentation and normalization) , and finally, classification.
- Chapter 5 accompanies the result and discussion. The most important results obtained from the experiments and the steps that have accompanied the

implementation of these experiments are discussed. Moreover, observations of the obtained results are presented.

- Finally, Chapter 6 displays conclusion and future work. The conclusion describes the task that has been done during this research. The future works are added to give an opinion and also an improvement of how the future works should have done.

CHAPTER 2

Background and overview of iris recognition system

2.1. Introduction

In this chapter, some problems related to iris recognition in the attention of artificial intelligence research will be presented. This chapter is organized as follows: Section 2.2 provides eye anatomy. Section 2.3 is dedicated to present an overview of iris recognition. Section 2.4 addresses the challenges in iris recognition, while section 2.5 provides the iris recognition system. Moreover, this chapter describes the techniques that will be used in this work; Circular Hough Transform, Daugman Rubber Sheet Model, Histogram Equalization, DCT, DWT, LBP, and SVM.

2.2. Eye Anatomy

The most visible eye structures are the pupil, iris, and sclera, which can be seen easily by looking at the person. The iris is a thin, colored ring around the pupil. It contains the inner and outer circles, the inner circle locates between the iris and pupil boundary, the outer circle locates between the sclera and iris boundary. The function of the iris is to control the amount of light entering through the pupil (Masek, 2003). Figure 2.1 shows images of irises.

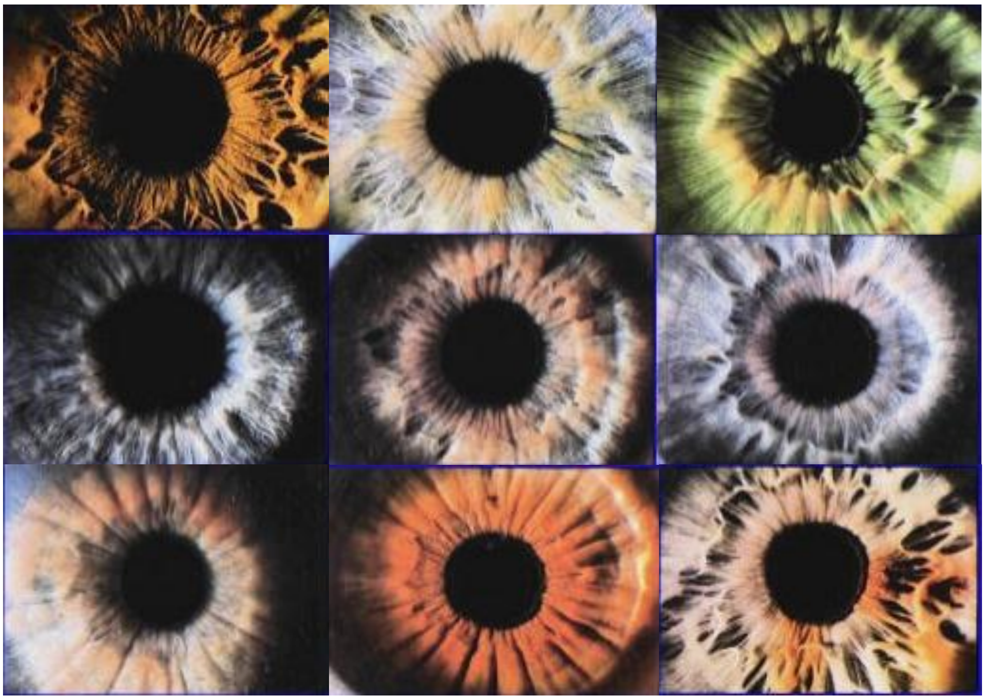


Figure 2.1: Images of Irises

The iris is a complex pattern which contains many distinctive features such as arching ligaments, furrows, ridges, crypts, rings, corona, freckles, and a zigzag collarette. The iris consists of a number of layers (Daugman, 2009). The epithelium layer contains dense pigmentation cells. The stromal layer lies above the epithelium layer and contains blood vessels, pigment cells, and the two iris muscles. The density of stromal pigmentation determines the color of the iris. The externally visible surface of the multi-layered iris contains two zones, which often differ in color. An outer ciliary zone and an inner pupillary zone, and these two zones are divided by the collarette which appears as a zigzag pattern as illustrated in Figure 2.2. Formation of the iris begins during the third month of embryonic life (Daugman, 2009). The unique pattern on the surface of the iris is formed during the first year of life, and pigmentation of the stroma takes place for the first few years. The two eyes of an individual contain completely independent iris patterns, and identical twins possess uncorrelated iris patterns.

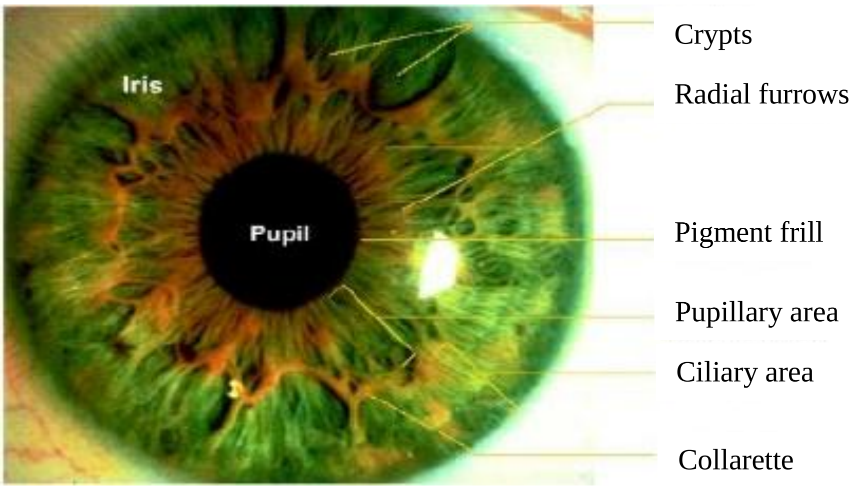


Figure 2.2: The structure of iris (Saminathan et at., 2015)

2.3. Iris recognition overview

The iris is an externally visible organ. Moreover, its unique features do not change throughout the life of the individual (Senior, 2010). These characteristics make it very attractive for use as a biometric for identifying individuals. To extract the distinguished pattern of the iris, the image processing technique can be utilized. Then, encoded the unique iris pattern into a biometric template, which can be stored in a database. This biometric template contains an objective mathematical representation of the unique information stored in the iris and allows comparisons to be made between templates (Masek, 2003).

Iris recognition is a biometric technique to identify a person due to its unique pattern contained in each iris. Nowadays, the use of iris recognition is increasing and it has become one of the most reliable and accurate techniques for biometric authentication. First iris recognition system was proposed in 1939 by Dr. Frank, and it was implemented in 1990 by Dr. Daugman (Daugman, 2009). 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, 1994), Boles and Boashash (Boles and Boashash, 1998), and Lim et al. (Lim et al., 2001). Most studies have shown that the Daugman system is able to perfectly identify an individual.

2.4. Challenges in iris recognition

Extraction of the discriminative features of the iris image depends on the quality of the image, which affects the performance of an iris localization and segmentation algorithms. When an iris image is acquired under non-ideal conditions then localization and segmentation become a challenging task (Dhage et al., 2015). Therefore, iris recognition is a challenging task in a noisy imaging environment. This fact inevitably qualifies iris recognition as an interesting subject of artificial intelligence. The following below are some difficult issues related to image acquisition.

2.4.1. Occlusion by eyelids

The eye is protected using eyelid. However, normal human eye typically occluded by the eyelid respectively. In such cases, the boundary of the eye is not in a circular shape as shown in Figure 2.3.

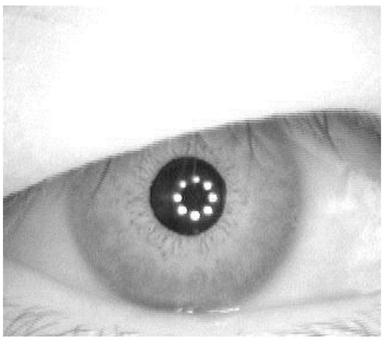


Figure 2.3: Occlusion by eyelids

2.4.2. Occlusion by eyelashes

Occlusions by eyelashes are caused by the hairs that are located nearer to the eyelids (see figure 2.4). However, in the existence of eyelashes boundary detection process is affected.

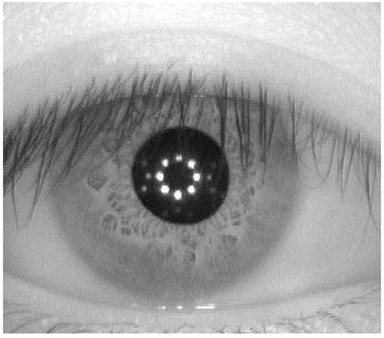


Figure 2.4: Occlusion by eyelashes

2.4.3. Specular reflections

Occur due to improper focus of light source. The segmentation accuracy is affected by specular reflection because the iris boundaries segmentation becomes difficult. (see figure 2.5)

Figure 2.5: Specular reflections

2.4.4. Motion blur

It occurs in iris due to the moment of camera, fluctuation of camera and moving object while image acquisition. It results in false identification of the region of interest in the segmentation process as illustrated in Figure 2.6.

Figure 2.6: Motion blur

2.4.5. Off-angle iris

The off-angled iris images are caused when angle of orientation of sensor used for acquiring iris is improper as illustrated in Figure 2.7.

Figure 2.7: Off-angle iris

2.4.6. Eyeglasses or contact lenses

The more noisy artifacts are added, when the acquired iris images consist of contact lens. (see figure 2.8).

Figure 2.8: Eyeglasses or contact lenses

2.4.7. Poor illumination

The less information is captured due to poor illumination, the boundaries are difficult to identify and texture features may not be highlighted as shown in Figure 2.9.

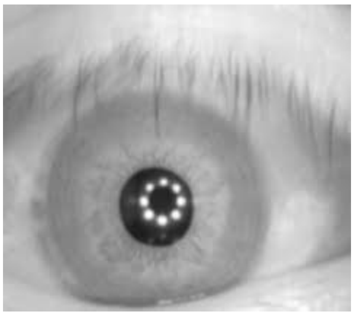


Figure 2.9: Poor illumination

2.4.8. Person with Spec

The acquired iris image with spec causes problems on localizing the boundaries. The detected iris boundaries are not circular as shown in Figure 2.10.

Figure 2.10: Person with Spec

From the previous studies, it can be observed that most of the researchers are not able to find a complete and reliable solution to all the challenges discussed above (Luhadiya and Khedkar, 2016). Moreover, there is still a scope of improvement in existing approaches dealing with the noisy environment (Rai and Yadav, 2014).

2.5. Iris recognition system

In general, the iris recognition system is defined as the following, image acquisition, preprocessing, feature extraction, and iris matching. Figure 2.11 shows the iris recognition system process.

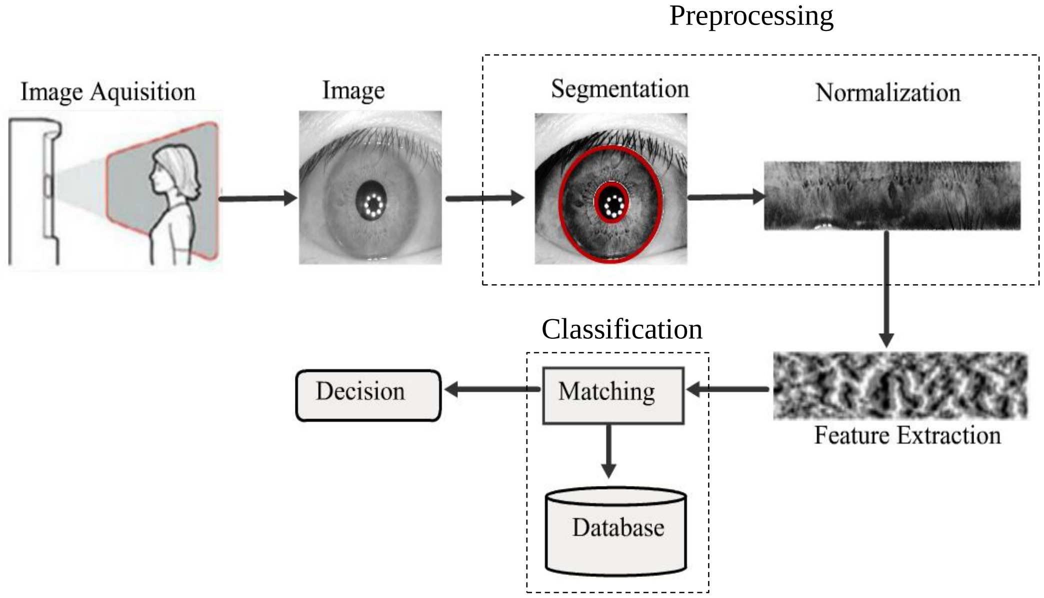


Figure 2.11: stages of the iris recognition system

2.5.1. Image acquisition

The first step is image acquisition. Since iris is small in size and dark in color, it is difficult to acquire good images for analysis using the standard camera and ordinary lighting. It is done by standard iris camera operated invisible infrared light band. The camera can be positioned between three and a half inches and one meter to capture the image (Daugman, 2009).

2.5.2. Preprocessing

It is done to enhance only the region of interests and it includes segmentation and normalization. The images in the database may have low contrast because of non-uniform illumination caused by the position of light sources. To achieve uniform illumination with high contrast, image characteristics must be enhanced (Gnana et al., 2018).

A. Segmentation

Segmentation is used for the localization of the correct iris region. Iris can be approximated by two circles (Daugman, 2009). One for iris outer, it is between iris and sclera boundary. The other circle is for inner boundaries, it is between iris and pupil boundary. Also, the segmentation is used for the localization of boundaries between iris and eyelids.

B. Normalization

The segmented iris part is converted in the Cartesian coordinate system to a fixed length from the polar coordinate system. The iris region is transformed so that it has fixed dimensions in order to allow compression. The dimensional differences between eye images are mainly due to the stretching of the iris caused by pupil dilation from varying levels of illumination (Shaik, 2018). The normalization process will produce iris regions, which have the same constant dimensions so that two photographs of the same iris under different conditions will have characteristic features at the same spatial location (Daugman, 2009).

2.5.3. Feature extraction

Feature extraction converts the image into a set of vectors to be passed onto the matcher to assist in the classification process. Feature extraction techniques differ from one application to another. Techniques that succeed in one application may not be successful for other applications. The iris consists of many irregular shapes, such as freckles, coronas, stripes, furrows, and crypts. In this step, extracting the most discriminating information that presents in the iris pattern will be done.

2.5.4. Classification

The aim of this step is to measure the similarity and dissimilarity between two iris templates.

2.6. Technique used for localization: Circular Hough Transform

The subproblem of iris localization is a step involved in iris recognition. Since images having more irrelevant information imposes problems and gives inaccurate results while iris localization. So, it is important to apply an efficient technique of iris localization which gives accurate results.

The Hough Transform algorithm is widely used in digital image processing, computer vision and image analysis for isolating features of lines, circles, ellipses etc. (Duan et al., 2010). Even arbitrary shapes can be isolated using the generalized form of the Hough transform. Hough transform determines instances of objects within a set of shape parameters by a voting procedure carried out in a parameter space called the "accumulator" space. Accumulator is generated by the algorithm chosen for the transform wherein the object instances/ candidates are acquired as local maxima. The Hough transform is very useful in determining the parameters of a curve with given edge description. The edges can be located through pre-processing by either using a Canny, Sobel, Robert Cross edge detectors or any separability filter (Gnana et al., 2018).

A Circular Hough Transform pertains to detecting circular shaped objects or features in an image. For spheroid detection in 2D images, we look for circular shapes and then set a threshold parameter that separates a well-formed circular shape from the malformed one. A circle can be represented by the following equations, where equation (2.1) relates to Cartesian space while equation (2.2) and equation (2.3) to Parametric space.

$$(x-m)^2 + (y-n)^2 = R^2 \qquad (2.1)$$

$$x = m + Rcos\emptyset \qquad (2.2)$$

$$y = n + Rsin\emptyset \qquad (2.3)$$

Where *m, n* are the coordinates of the center of the circle of radius *R*, in *x* and *y* directions respectively. Thus the parameter space for a circle will have three parameters namely, *R*, *m* and *n* which means that the accumulator space will be of the order 3 as shown in Figure 2.12. For simplicity, the radius can be treated as a constant, and transforms can be performed for various values of radii.

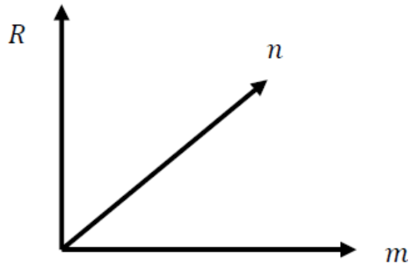


Figure 2.12: Parameter space for a circle

2.6.1. Algorithm of Circular Hough Transform

The brief of the algorithm of Circular Hough Transform (Pedersen, 2007) is:

1. Read an image file.
2. // Hough Begin
3. Find edges in the image.
4. Define a range of radius to be used. (Initialize pupil radius =28 and iris radius =75 for CASIA database.)
5. For each edge point:
    a. Draw a circle with that edge point as the center and a radius r and increment the number of votes by 1 for all the coordinates that coincide with the circumference of the circle drawn, in the accumulator space.
    b. Find circles for an edge point for all the radius in the range.
6. Find the maximum number of in the accumulator space.
7. //Hough End
8. Plot the circle with parameters (r, a, b) corresponding to the maximum in the accumulator space.
9. The circle obtained is the desired circle with (r, a, b) as the radius and center of circle respectively.

2.7. Technique used for normalization: Daugman's Rubber Sheet Model

The Daugman's rubber sheet model devised by Daugman (Daugman, 2009) remaps each point within the iris region to a pair of polar coordinates (r, θ) where r is the radial distance and θ is the rotated angle at the corresponding radius, θ is angle [0,2π]. (See Figure 2.13)

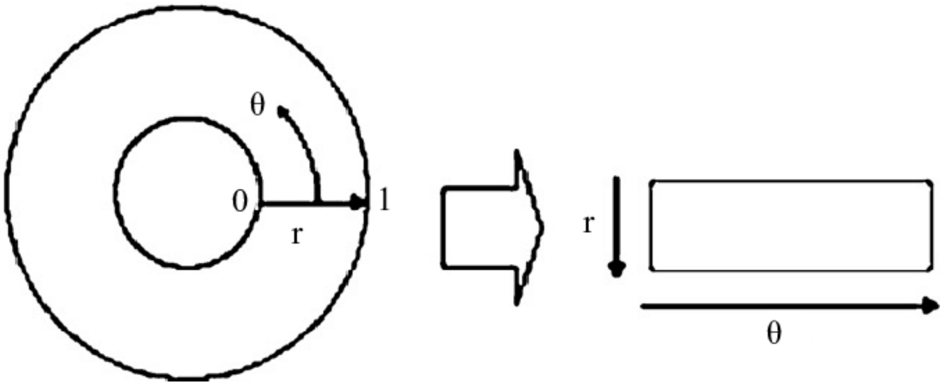


Figure 2.13: Daugman's Rubber Sheet Model (Gnana et al., 2018).

To transform the annular region of iris into polar equivalent the following set of equations are used:

$$I(x(r,\theta), y(r,\theta)) \rightarrow I(r,\theta) \qquad (2.4)$$

Where:

I(x,y) corresponds to the iris region, (x,y) and (r, θ) are the Cartesian and normalized polar coordinates. θ ranges from 0 to 2π.

2.8. Technique used for image enhancement (Histogram Equalization)

In most time, the normalized iris images are not having a natural look (Savithiri and Murugan, 2011). For this reason, many methods are introduced to enhance images. HE is the method in which, the histograms of the input images are altered to obtain the enhanced images. The produced image by this method has a uniform distribution that yields better contrast than the original image. The image can be altered so that all the available pixel intensities are used. The intensity of a pixel is represented by the formula below (Srivastava and Rawat, 2013):

$$s = T(r) = \int_0^{\omega} p_r(r) d\omega = CDF_i \qquad (2.4)$$

Where,

- r, s are the intensity values of the input image and output image respectively.
- $p_r(r)$ is the probability distribution function of the original image that comes after normalizing the histogram of the original image such that the area is equal to 1.

- CDF_i is the cumulative distribution function of the input image because transformation to achieve histogram equalization is actually CDF of the original image

2.9. Techniques used for feature extraction

Different techniques have been used for extracting the most important pattern for iris such as DCT, DWT, and LBP. These techniques were designed by specialists using their knowledge and expertise.

2.9.1. Discrete Cosine Transform (DCT)

The DCT algorithm is well known and commonly used for image compression. DCT is widely used tool in digital signal processing, especially the two-dimensional (2-D) DCT (Rabie et al., 2016).

DCT converts the pixels of an image, into sets of spatial frequencies and it can be used in the area of digital processing for the purposes of pattern recognition. During a step called Quantization, where parts of compression actually occur, the less important frequencies are discarded. Then the most important frequencies that remain are used to retrieve the image in decomposition process (Gupta et al., 2012) (Nigam et al., 2015).

A. The DCT equation and coding

In DCT need low processing power but it has blocks artifacts means loss of some information (Britanak et al., 2010). The 2-dimensional DCT (2D-DCT) is a widely used image transformation, extended from the 1D-DCT, to compress digital images using the Joint Photographic Experts Group (JPEG) compression standard. The DCT coefficients $f(u,v)$ of $f(x,y)$ are computed by (Rabie et al., 2016):

$$f(u,v) = C(u)C(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)\cos\left[\frac{(2x+1)\pi u}{2N}\right]\cos\left[\frac{(2y+1)\pi v}{2N}\right] \quad (2.5)$$

Where,

$$C(u) = C(v) = \begin{cases} \frac{1}{\sqrt{N}}, & for\ u,v = 0 \\ \sqrt{\frac{2}{N}}, & for\ u,v \neq 0 \end{cases} \quad (2.6)$$

f(x, y) is the image intensity function and f(u, v) is a 2D matrix of DCT coefficients. The higher value DCT coefficients are then extracted in a zigzag fashion and stored in a vector sequence as shown in Figure 2.14.

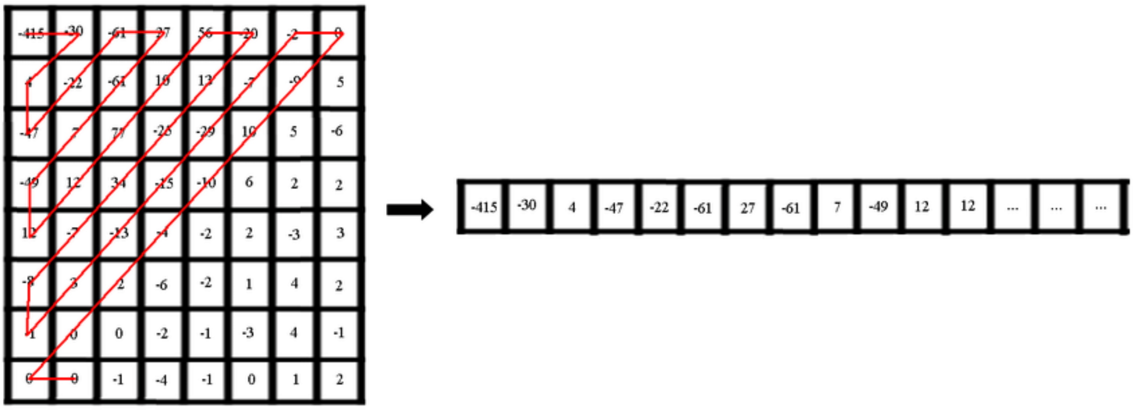
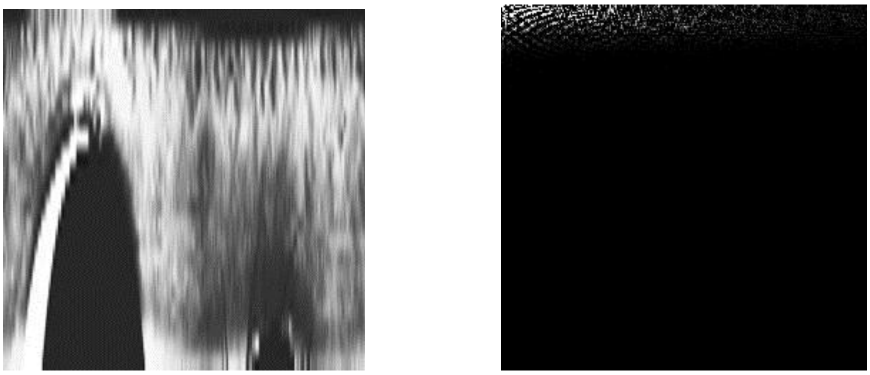


Figure 2.14: Rearranging DCT coefficients from zigzag order into one vector (Lawgali et al. 2011)

Figure 2.15 shows an example of an image and its DCT. The energy of the image is packed into the low-frequency top-left region of its DCT.



(a) (b)

Figure 2.15: Example of DCT. (a) The input image. (b) The its DCT

B. The process of DCT

DCT is applied on the normalized image in this thesis. After that, for reducing the storage space DCT coefficients are quantized through dividing by some value or by a quantization matrix. So that large value becomes small and it needs small size of space. This step is lossy step (Gupta et al., 2012). A summary of the most important steps of the DCT technique is shown below:

1. The DCT works by separating images into parts of different frequencies
2. During a step called quantization, where part of compression actually occurs, the less important frequencies are discarded, hence the use of term " lossy".
3. Only the most important frequencies that remain are used to retrieve the image in the decompression process

C. Advantages of DCT (Britanak et al., 2010)

1. It has been implemented in single integrated circuit.
2. It has the ability to pack most information in fewest coefficients.
3. It has a strong energy compaction.

2.9.2. Discrete Wavelet Transform (DWT)

DWT is the most popular transformation technique adopted for image compression. Wavelets can be used to remove noise in an image (Rani and Bishnoi, 2014). Wavelets are mathematical functions that can be used to transform one function representation into another. Rather than calculate the wavelet coefficients at every point, the DWT uses only a subset of positions and scales. The DWT plays a major role in the JPEG-2000 image and it has been applied in many image compression techniques. Wavelet transform divides the information of an image into approximation and details sub-signals (Xiaoyin, 2010). The approximation sub-signals show the general trend of pixel values and other three detail sub-signals show the vertical, horizontal and diagonal details or changes in the images. The two-dimensional (2-D) DWT has been applied in many image compression techniques. There are a number of wavelet families from which a mother wavelet may be chosen including the Haar, Daubechies, Coiflets, Symlets and Meyer wavelet families.

A. Haar Wavelet

Haar functions have been used from 1910 when they were introduced by the Hungarian mathematician Alfred Haar (Stanković and Falkowski, 2003). A Haar wavelet is the simplest type of wavelet. In discrete form, Haar wavelets are related to a mathematical operation called the Haar transform. The Haar transform serves as a prototype for all other wavelet transforms. As all wavelet transforms, the Haar transform decomposes a discrete signal into two sub-signals of half its length. One sub-signal is a running average or trend; the other sub-signal is a running difference or fluctuation. Haar wavelet represents the same wavelet as Daubechies db1. Haar used these functions to give an example of an orthonormal system for the space of square-integrable function on the unit interval [0, 1].

B. Daubechies Transform

The Daubechies wavelet transforms are defined in the same way as Haar wavelet transform by computing the running average and differences via scalar products with scaling signals wavelets. The only difference between them consists in how these scaling signals and wavelets are defined. The names of the Daubechies family wavelets are written dbN, where N is the order, and db the surname of the wavelet. The db1 wavelet, as mentioned above, is the same as Haar wavelet (Gupta and Choubey, 2015).

C. The process of DWT

The DWT (Kumar et al., 2011) converts the image into four different frequency sub band to decompose into one low frequency sub-band LL and three high frequency sub-bands (LH, HL, HH). Figure 2.16 shows wavelet filter decomposition with one level. The image can be decomposed on more than one level. The sub-bands are labeled by using the following notations (Baviskar et al.,2016):

- LL1 represents the approximation image at the first level of decomposition, resulting from low-pass filtering in the vertical and horizontal both directions.
- LH1 represents the horizontal details at the first level of decomposition and obtained from horizontal low-pass filtering and vertical high-pass filtering.
- HL1 represents the extracted vertical details/edges, at first level of decomposition and obtained from vertical low-pass filtering and horizontal high-pass filtering.
- HH1 represents the diagonal details at the first level of decomposition and obtained from high pass filtering in both directions.

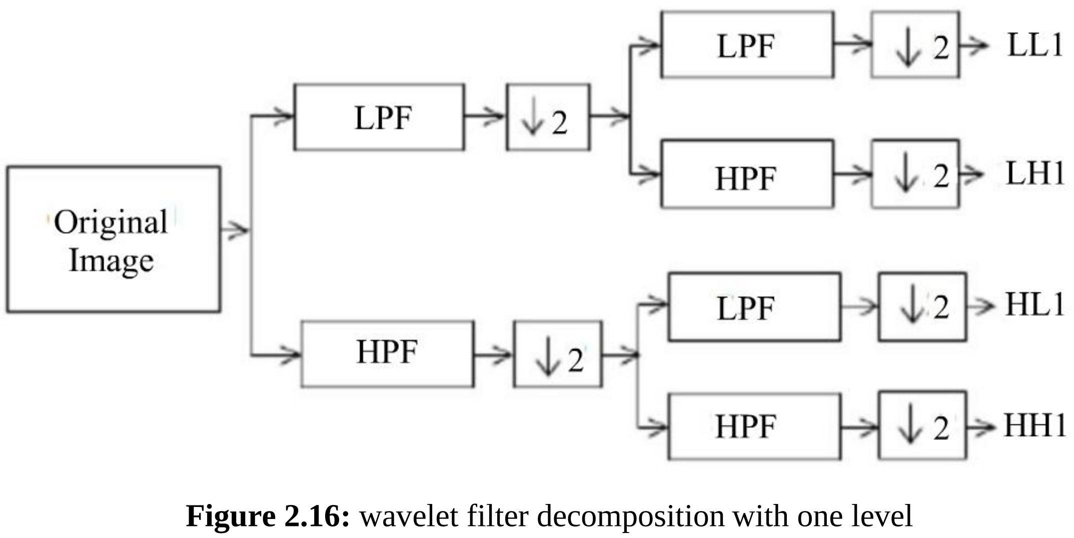


Figure 2.16: wavelet filter decomposition with one level

The six steps below is summarizing of the process for compressing an image with Discrete Wavelet Transform:

1. First original image has been passed through high pass filter and low pass filter by applying the filter on each row.
2. Now output of both image l1 and h1 are combined into T1= [l1 h1].
3. T1 is down sampled by 2.
4. Now, again T1 has been passed through high pass filter and low filter by applying on each column.
5. The output of the step4 is supposed l2 and h2. Then l2 and h2 are combined into t3= $\binom{l2}{h2}$.
6. Now down sampled t3 by 2.

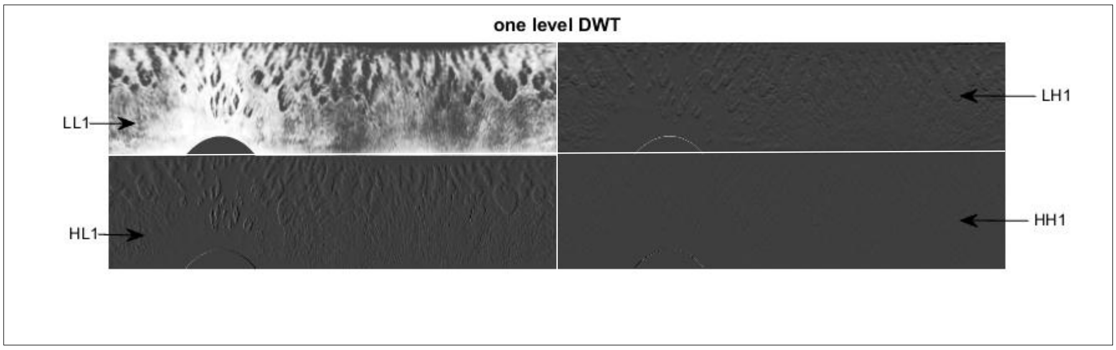


Figure 2.17: Example of DWT

Figure 2.17 illustrates a resulted image after applying encoding process. Four blocks in this figure. The first upper half block shows the approximation, while the second upper half shows horizontal detail. First lower level block shows vertical detail and second lower level block shows diagonal detail.

D. Advantages of DWT (Baviskar et al., 2016)

1. The advantage of DWT over other traditional transformations is that it performs multi resolution analysis of signals with localization both in time and frequency.
2. It gives better compression ratio without losing more information of the image.
3. It provides both spatial and frequency domain characteristic of the signal.

2.9.3. Local Binary Pattern (LBP)

LBP approach is a simple technique that is very efficient in extracting features from patterns (Li et al., 2015). Moreover, it has a simple theory and combines the properties of structural and statistical texture analysis methods. LBP approach has become a popular technique in feature extraction field from the patterns, because of its computational simplicity and it has a discriminative power, therefore; it performs analysis on the patterns in real-time settings (Ahonen et al., 2009).

A. The process of LBP

The basic LBP operator, presented by (Ojala et al., 2002). The following below is summary of the main steps of the original version of the local binary pattern:

1. The LBP works in a 3 × 3 pixel block of an image.
2. The pixels in this block are thresholded by its center pixel value, multiplied by powers of two and then summed to obtain a label for the center pixel.
3. If the result is a negative number then the pixel encoded with 0, otherwise, the pixel encoded with 1.
4. For each pixel, a binary number is revealed by concatenating the 8 binary results to form a number in a clockwise direction, which starts with its top-left neighbor.
5. The decimal value that generated from the binary number is used for labeling the pixel. The derived binary numbers are known as LBP codes.

The definition of the LBP is described as Formula 2.7.

$$LBP_{P,R} = \sum_{P=0}^{P-1} s(g_p - g_c)\, 2^p, s(x) = \begin{cases} 1, x \geq 0 \\ 0, x < 0 \end{cases} \quad (2.7)$$

Where is the g_c value of the center pixel and g_p is the gray value of its neighborhood. P is the number of neighbors involved, which determines the number of LBP patterns, i.e. 2^p. R is the radius of the neighborhood, which decides the size of the neighborhood. Illustration of the process of LBP feature extraction in Figure 2.18.

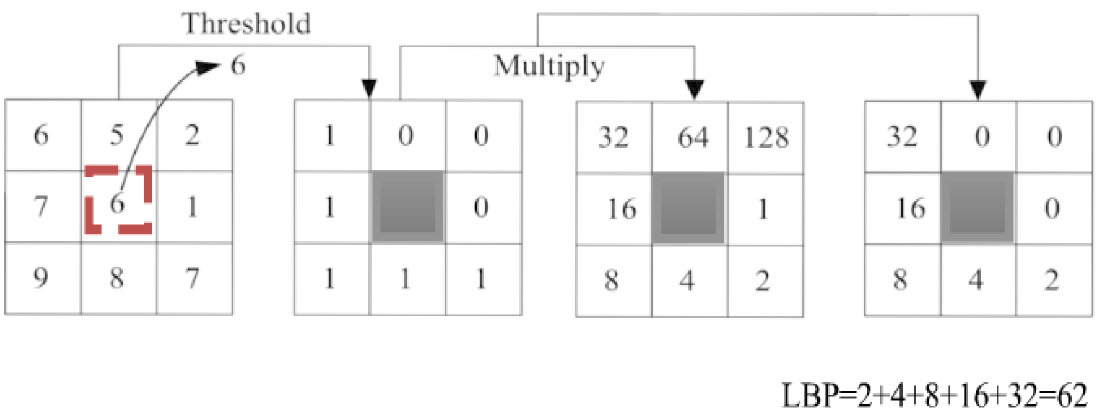


Figure 2.18: The process of LBP

Figure 2.18 explains the main mechanism of LBP approach. An input image has divided by LBP approach into several blocks. Each block is divided into '3×3' neighborhood pixels (9 cells). Next, each pixel is encoded by its intensity value. Then, threshold the value of the central pixel which is 6 in Figure 2.18, LBP ordering all surrounding pixels within the block from the upper-left corner down to the right one depending on whether it has a bigger or smaller intensity value than the central pixel (bigger value = 1; smaller = 0). Finally, we get a binary number which is (11111000), this number is converted to a decimal number to become (62) and stored in one dimensional array. Figure 2.19 shows an example of LBP on an image.

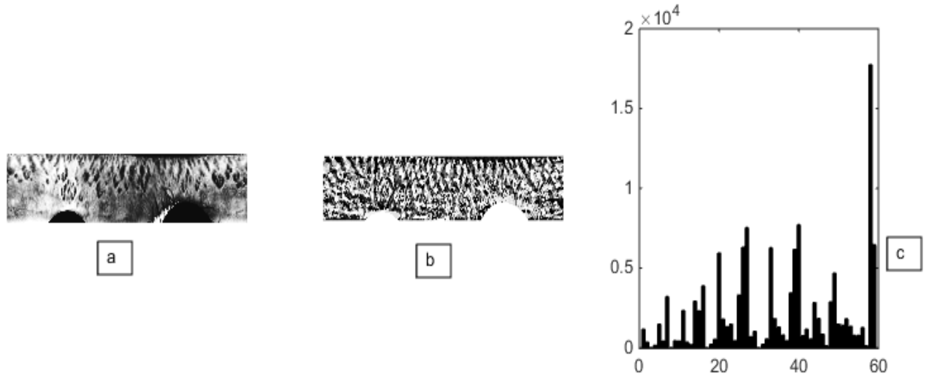


Figure 2.19: Example of LBP. a: The input image. b: The LBP image. c: The LBP histogram

B. Advantages of LBP (Pietikainen et at., 2011) (Ojala et al. , 2002)

1. LBP provides a unified description including both statistical and structural characteristics of a texture patch so that it is more powerful for texture analysis.
2. The most important attribute of the LBP approach in its applications is that its ability to control in gray-scale changes, such as illumination variations

2.10. Technique used for classification: Support Vector Machines

SVM introduced in 1992 by Boser, Guyon, and Vapnik in COLT-92 (Joachims, 1998). Support Vector Machine (SVM) is a discriminative classifier formally defined by a separating hyperplane. In other words, SVMs are a set of related supervised learning methods used for classification and regression. The SVM is a classification and regression prediction tool that uses machine learning theory to maximize predictive accuracy while automatically avoiding over-fit to the data. SVM becomes famous when using pixel maps as input. In other terms, SVM approach is used to solve the patterns classification problems. Using SVM to solve a specific practical problem, resolve many of the questions that depend on the definition of the problem.

During the model learning phase, the SVM aims to optimize the width of the gap (i.e., the maximum margin hyperplane) between classes. The resulting model can then be used to determine whether a new data vector is a member of a class or not. Figure 2.20 shows the basic of SVM takes a set of input data and for each given input, predicts which of two classes forms the input, making it a non-probabilistic binary linear classifier.

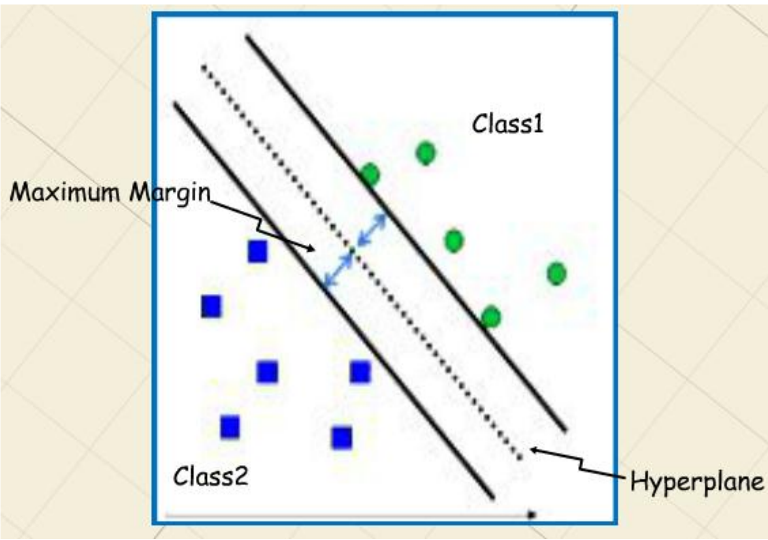


Figure 2.20: SVM with linear separable data (Anupama et al., 2017).

2.10.1. The maximum margin hyperplane

It is a component in the SVM which is the one that gives the greatest separation between two classes. Among all hyperplanes that separate the classes, the maximum margin hyperplane is the one that is as far away as possible from the two convex hulls, each of which is formed by connecting the instances of a class.

In general, a hyperplane separating the two classes in the two-attribute case, can be represented as below formula (Nalepa and Kawulok, 2018):

$$f(x) = w_t . x + b \tag{2.8}$$

Where w_t refers to weights whereas x denotes an input sample images. b is the bias.

For non-linear case, training patterns are constructed onto a high dimensional space using kernel functions. Most commonly used kernel functions are polynomial, sigmoid and Gaussian radial basis function.

2.10.2. Advantages of SVM

1. It is comparatively easy to the training.
2. It is suitable for high dimensional data and its ability to control clearly on the trade-off between classifier complexity and error.

2.11. Summary

In this chapter, the anatomy of the eye is explained briefly. And then an overview of iris recognition and the challenges that facing the researchers in this field were also presented. Furthermore, the detailed description of the techniques which will be used in this work was provided. The HE and the DCT will be carried on with SVM as a classifier. In the same context, two techniques will be applied for extracting the discriminant pattern, the DWT, and LBP. In addition, the Hough transform technique and Rubber sheet model were explained as a part of the processes in the iris preprocessing stage. More details of the utilization of DCT and HE in the work will be explained in chapter 4.

CHAPTER 3
Literature Review

3.1. Introduction

The second chapter explained that iris recognition is a succession of operations designed to extract a binary iris code from an eye image, but usually, there are some sub-problems of iris recognition: iris segmentation, iris texture analysis, and iris code matching. In addition, the DWT, DCT, LBP techniques have been focused on as if the important methods for extracting the distinctive features.

The issue of iris recognition remains a challenge for many researchers, and Texture analysis plays an important role in the issue. Numerous algorithms of textural features extraction and classification have been presented by researchers. In this chapter, the most cited human iris databases with their characteristics will be introduced. Moreover, an overview of the papers that studied the iris recognition system is provided. Studies will be categorized according to feature extraction techniques with classification techniques to find out the appropriate methods in the iris recognition system. Finally, a briefly summarized table of the previous studies of iris recognition is presented in section 3.4.

3.2. Overview of the iris databases

This section summarizes the databases available for free. CASIA, MMU, Bath, UBIRIS, IITD, and UPOL are some standard databases that are used in most studies. Below is a brief survey of databases.

3.2.1. CASIA Iris Database

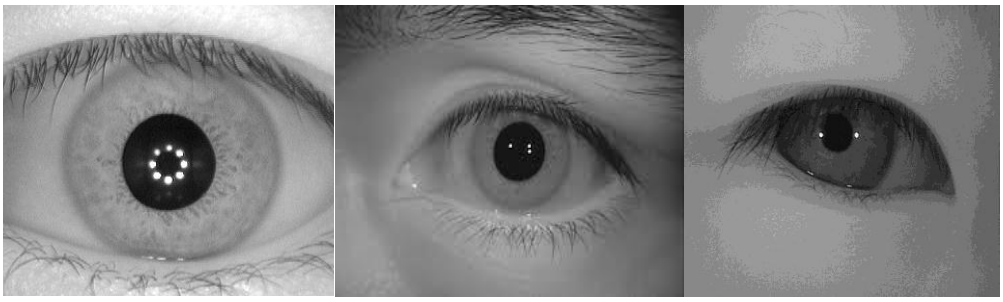
It is the most extensively used iris dataset. CASIA Iris database is the first freely available iris database for researchers. It is developed by the Chinese Academy of Sciences as a baseline for measuring the effectiveness of various iris recognition systems (Chinese Academy of Sciences, 2018). The Chinese Academy of Science produced four versions of CASIA databases. The first version is CASIA-Iris V1. It contains 756 iris images from 108 human subjects. The images in CASIA-Iris V1 have been captured using homemade iris camera, with eight circularly fitted NIR 850mn illuminators. All the images are stored in format of bmp at 320*280 resolutions. Figure 3.1 shows the sample of CASIA-Iris V1 database.

Figure 3.1: Sample from CASIA-Iris V1 database.

The second version is CASIA-Iris V2. This database involves 2400 images (Chinese Academy of Sciences, 2018), divided into two subsets captured by two different devices. The first 1200 images were captured by Irispass-h device developed by OKI, and the other 1200 images were captured by CASIA-Iris cam developed at the Chinese Academy of Science. Figure 3.2 illustrates the sample of CASIA-Iris V2.

Figure 3.2: Sample from CASIA-Iris V2 database.

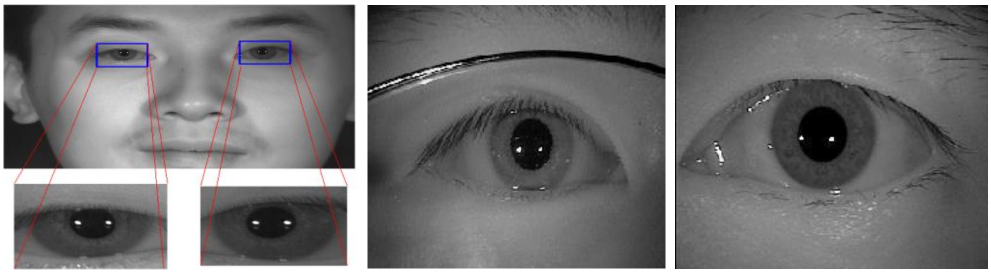
The third version is CASIA-Iris V3. It contains a total of 22,034 iris images collected from 700 humans. The database is divided into 3 subsets. The Interval data subset contains 2,639. All images are stored in jpg format of 320*280 resolutions. The Lamp subset contains 16,212 iris images with visible light on-off factor, which will cause the dilation in pupil size and a non-linear deformation in the captured images, images are stored in format of jpg and 640*480 resolution. Finally, the twin’s data subset which contains 3,183 images captured from 100 pairs of twins during the annual twin’s festival in Beijing, all images are stored in jpg format at 640*480 resolutions. Figure 3.3 shows sample images from CASIA V3 Interval, Lamp and Twins respectively.



(a) (b) (c)

Figure 3.3: Samples from CASIA-Iris V3 database. a: CASIA V3 Interval. b: CASIA V3 Lamp. c: CASIA V3 Twins

The last version is CASIA-Iris V4. It is an extension to CASIA-Iris V3 with three more subsets. The first one is called CASIA-Iris-Distance. In this dataset, the iris images have been captured over three meters distance and while the subject is moving. The database contains 2576 images with resolution of 2352*1728. The second set is called CASIA-Iris-Thousand. The third set, called CASIA-Iris-Syn contains 10,000, with resolution of 640*480. Figure 3.4 shows the sample of CASIA-Iris-Distance, CASIA-Iris-Thousand, and CASIA-Iris-Syn.



(a) (b) (c)

Figure 3.4: Samples from CASIA-Iris-V4. a: CASIA-Iris-Distance. b: CASIA-Iris-Thousand. c: CASIA-Iris-Syn.

3.2.2. Bath Iris Database

This database has been created at the University of Bath by Smart Sensor Limited (Smart-Sensor-Ltd, 2018). Bath iris database consists of 32,000 high quality iris images, captured from 800 mixed ethnic subjects (1600 classes, for left and right eye) with a pixel resolution of 1280×960. Figure 3.5 shows samples images from Bath database.

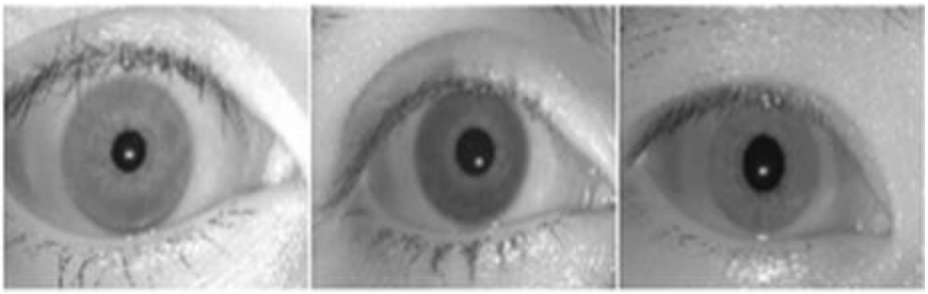


Figure 3.5: Samples images from Bath database.

3.2.3. MMU Iris Database

MMU1 and MMU2 are the iris databases have been presented by The Multimedia University (Multimedia-University, 2018). The first one comprises of 450 images, captured by a semi-automated camera dedicated for iris capturing (LG IrisAccess 2200) at 7-25 cm distance range, and the second database consists of 995 images, collected by Panasonic BM-ET100US camera at a distance range of 47-53 cm from the human subject. The images in MMU database have been collected from 100 volunteers of different ages and nationalities, with each volunteer contributing 5 images from each eye. The iris images in MMU database are homogenous, and have been taken using an NIR light source at a close distance with human subject cooperation, introducing eyelashes obstruction and eye rotation as illustrated in Figure 3.6.

Figure 3.6: Samples iris images from MMU database

3.2.4. UPOL Iris Database

The UPOL (University of Palackeho and Olomouc) (University-of-Palackeho-and-Olomouc, 2018) is the first database that used imaging framework with a visible wavelength light source. The database comprises of 384 images collected from 64 human subjects, with each subject contributing 6 images (3 from the left eye and 3 from right eye), and a SONY DXC-950P 3CCD camera connected to TOPCON TRC50IA optical device was used for iris capturing, at a resolution of 576×768 RGB 24-bit color depth as shown in Figure 3.7.

Figure 3.7: Sample of UPOL Iris Database

3.2.5. UBIRIS Iris Database

The University of Beira introduced two versions of the database called UBIRIS V1 and UBIRIS V2 (Proenca e al., 2010). The first version is composed of 1877 images collected from 241 eyes during September 2004 in two distinct sessions. It simulates less constrained imaging conditions. The output image is RGB at 2560×1704 resolution. The image size was reduced to 300×400 grey scale to reduce the database size so it can be easily uploaded and downloaded from the web. The second version has over 11357 images (and continuously growing) and more realistic noise factors (see Figure 3.8). Images were actually captured at-a-distance and on-the-move. The resultant image is 800×600, with 72 dpi vertical/horizontal resolution and 24-bit color depth, stored in tiff file format

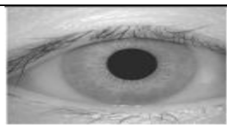
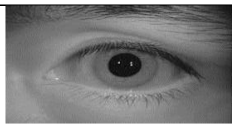
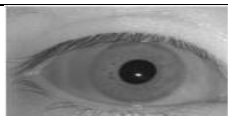
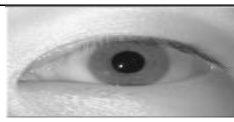
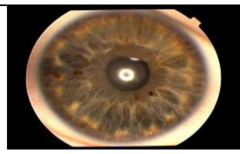
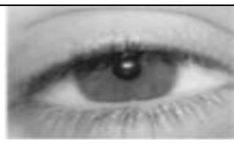
(a)

(b)

Figure 3.8: Samples from UBIRIS iris database. a: Samples of UBIRIS V1. b: Samples of UBIRIS V2

For a comprehensive comparison, the iris databases were compared according to the database size, imaging distance and the type of camera. Table 3.1 summarizes the free available iris databases and their characteristics.

Table 3.1: Comparison of free iris database

Database name	Database size	Varying distance	Camera	Sample image
CASIA V1	756	No	CASIA camera	
CASIA V2	2255	No	CASIA camera	
CASIA V3	22051	No	OKI iris-pass h	
CASIA V4	2576	Yes	IKEMB-100 dual camera	
Bath	16000	No	ISG LW 1.3 S 1394	
MMU 1	450	No	LG EOU 2200	
MMU 2	995	No	Panasonic BM ET 100 US	
UPOL	384	No	Sony DXC 950P 3CCD with TOPCON TRC501A	
UBIRIS v1	1877	No	NIKON E5700	
UBIRIS v2	11375	Yes	Canon EOS 5D	

3.3. The popular algorithms for iris recognition

The similarity of two given iris codes is assessed in the classification stage by several proposed algorithms for computing a similarity score. In order to better reflect the research trends, the previous studies of various iris techniques are listed. Moreover, at the end of each section, a table summarizing all the algorithms covered herein is included, providing a quick comparison of the main features and performance of the system.

3.3.1. Support Vector Machine (SVM)

Various techniques have been discussed in the literature for iris recognition system. For feature extraction, the researchers have been applied different techniques to extract the pattern of the iris and then used various classifiers for matching. In the same context, many researchers have used SVM such as Kulkarni et al (Kulkarni et al, 2013). In the feature extraction stage, the Gray-Level Co-Occurrence Matrix (GLCM), Gray-Level Run Length Matrix (GLRLM) and combined (GLCM & GLRLM) have been applied. then, the SVM has been used as an iris pattern classifier. 180 iris images are chosen from CASIA Database version 3. The experimental results have shown that GLCM achieved 75%, GLRLM achieved 57.14%, while the combined (GLCM & GLRLM) approach achieved 88.89%.

Also, the SVM has been used to evaluate the features and compute its accuracy by Chen et al. (Chen et al, 2014). It presented several strategies to select optimal features for iris. Initially, locating the iris area in an iris image is done by a coarse to- fine segmentation. The discriminative feature was selected based on three strategies, first, to sort orientation probability distribution function (OPDF). Second, to sort magnitude probability distribution function (MPDF). Third, to reduce the number of key points and dimension of feature element based on combined above two methods. To measure the performance of the proposed method the CASIA V3 Interval, CASIA-V3 Lamp, and MMUV1 databases have been used.

Gragnaniello et al. (Gragnaniello et al., 2016) focused on segmentation algorithm in order to improve iris recognition. This step consists of finding the iris pupillary and limbic boundaries, and localizing the upper and lower eyelids by Canny edge detection and Hough Transform. Then, the scale-invariant locale-scriptors (SID) are computed densely on iris and sclera area, and summarized through the bag-of-Features (BoF) paradigm. For classification, the linear SVM has been adopted in order to train feature vectors. The evaluation of segmentation accuracy was on different databases, NotreDame, UBIRIS.v2, and MobBIO.

Another challenge of iris feature extraction using Gray Level Co-occurrence (GLCM) technique is presented by Luhadiya and Khedkar (Luhadiya and Khedkar,2016). SVM carried out as a classifier. Furthermore, the UPOL iris database has been used in this work and the accuracy rate was 94.23%.

A feature extraction method based on multi-resolution analysis using SVM is presented by Manisha and Gengaje (Nirgude and Gengaje, 2017). Pyramid structure Wavelet

Transform (PWT) and Tree structure Wavelet Transform (TWT) have been applied to extract the feature from normalized iris image. The wavelet coefficients of different levels are combined to get detailed iris information. Experiment is performed using CASIA iris database.

A hybrid approach of iris recognition technique based on Fourier transform and Bernstein polynomial is proposed by Ramya et al. (Ramya et al, 2017) for feature extraction. For preprocessing stage, the Singular Value Decom- position (SVD) is used for removing the noise from the image. Also, Canny edge detection and Circular Hough transform are applied to segment and localize the boundaries of iris. The presented study has been applied on UBIRIS database and found better accuracy, FAR, FRR and ERR by using two classifier SVM and K-SVM algorithms.

In the same context, Nguyen et al. (Nguyen et al., 2018) designed a novel feature representation scheme to attain the upper bound on iris recognition by convolutional neural networks (CNNs). More in detail, the iris image is segmented by Daughman algorithm. Then, the segmented iris is transformed into a fixed rectangular region by the rubber-sheet model. Next, the normalized iris image is fed into the CNN feature extraction module. Finally, SVM is used as a classifier of the extracted CNN feature vector. The experimental results were on two big datasets, CASIA-Iris-Thousand and LG2200 dataset.

An approach with far fewer computations of the rubber sheet model is introduced by Shaik (Shaik, 2018). Further Log Gabor filters have been applied on normalized iris image for extracting the features. A performance comparison is presented with CASIA Iris Image version 1 and IIT Delhi IRIS databases. A classification rate analysis for the proposed normalization approach has been used by SVM and it was found that classification is decreased from 89–86% with the proposed approach.

Table 3.2: Comparison of various iris algorithms with SVM

Researcher	Feature Extraction	Database	Accuracy%
(Kulkarni et al. 2013)	GLCM	CASIA interval v3	75
	GLRLM		57.14
	GLCM+ GLRIM		88.89
(Chen et al., 2014)	OPDF+ MPDF	CASIA-V3 Lamp	92.35
		MMUV1	98.36
(Luhadiya and Khedkar, 2016)	GLCM	UPOL	94.2

(Gragnaniello et al., 2016)	BoF	NotreDame I	93.17
		NotreDame II	85.33
		IIIT-D Cogent	83.88
		IIIT-D Vista	89.78
(Nirgude and Gengaje, 2017)	PWT+TWT	CASIA V3	95.33
(Ramya et al., 2017)	Fourier transform + Bernstein polynomial	UBIRIS	85
(Nguyen et al., 2018)	CNN	CASIA-iris-thousand	90.7
		LG2200	91.1
(Shaik, 2018)	Log Gabor	CASIA v1	86
		IITD	

Table 3.2 above includes a summary of iris recognition studies that use SVM as a classifier. It is observed that the performance dropped off greatly when the GLRLM technique was applied. On the other hand, SVM achieved high results when it was used with GLCM and GLRIM.

3.3.2. Artificial Neural Network (ANN)

Many types of artificial neural networks exist such as feed forward neural networks, Radial Basis function (RBF) networks, modular neural networks, dynamic neural networks, cascading neural networks, and neuro-fuzzy networks. Moreover, the most popular is Multi-Layer Perceptron. The following is some previous studies that have used this technique.

Salve and Narote (Salve and Narote, 2016) addressed the problem of iris recognition using a simple feed forward artificial neural network and SVM. The Log Gabor wavelet has been used for feature extraction. In other words, the research has found that the recognition rate for SVM is better than ANN. The experimental tests were achieved on CASIAIrisV4 database

An attempt to develop a method in the context of iris recognition is due to Dillak and Bintiri (Dillak and Bintiri, 2016). In more detail, in the preprocessing stage, the amoeba median filter and Gaussian filter are used to enhance the area of the iris. CHT method is used for iris segmentation in order for the Homogeneous rubber sheet model to be applied on the segmented iris image. For the extraction features, the 3D-GLCM is applied. Elman Recurrent Neural Network/Levenberg-Marquardt algorithm (ERNN\LMA) has been used to produce the better accuracy of iris recognition. Furthermore, The results using CASIA v4-Syn was 91%, and it was 94% using CASIA v1-Syn.

Iris classification system using FFNNGSA and FFNNPSO was introduced by Rizk et al. (Rizk et al., 2016). For preprocessing, a Canny Edge Detection scheme, a Circular Hough Transform, and Daugman rubber sheet model have been applied. After this a combination between Haar Wavelet and principal component analysis (PCA) has been employed to extract the features from the normalized image. In order to evaluate the performance of the proposed system the CASIA database V 3.0 Iris Interval has been used.

In the same context, Mozumder and Begum (Mozumder and Begum, 2016) proposed an approach based on the fusion of modular neural network. Initially, the image has been enhancement by using Adaptive Histogram Equalization (AHE). After this, the DCT is applied on segmented iris image to extract the features. The approach was tested on (MMU2) Iris database, and achieved 97% of recognition rate

Sharkas (Sharkas, 2016) tracked the problem of iris recognition using Artificial Neural Network. CASIA iris database has been used. The implementation of the system was on right eye (R) and left eye (L). For locating the circular iris and pupil regions, Hough transform and Canny edge detection have been applied. In the research, one level DWT has been applied for extracting the features of the segmented iris image. Finally, Experimental results showed that the ANN is 75 and 98%.

Another interesting study presented by Hajari et al. (Hajari et al., 2016) for improved the performance of iris recognition rate. In more details, two neural network have been implemented, Radial Basis kernel(RBNN) and Probabilistic Neural Network(PNN). Moreover, a new algorithm for noise detection has been applied, this algorithm called noise detection and removal of a camera reflection (noise).

Anupama (Anupama, 2017) used ANN as a classifier for pattern classification to identify an individual's identity based on Iris code. For feature extraction, Wavelet Transform, Gabor filter, GLCM, and Tamura have been applied. The Canny Edge Detection, Hough transform, and rubber sheet model have been used to detect the iris edges and normalization. In addition, SVM has been used as a classifier. CASIA version 1 eye image database is used in the experiment. SVM gives the classification rate of 90.25%. On the other hand, ANN gives the accuracy rate of 83.65% for classification.

Similarly, A fuzzy entropy-based feature selection method is proposed by Deshpande and Patavardhan (Deshpande and Patavardhan, 2018). In their research, a DCT is proposed as a feature extraction method. The iris is segmented from eye images using Hough Transform method then converted into polar form by Rubber sheet daughman model. To increase the recognition performance of the system, the fuzzy entropy-based feature extraction method is used to select the best features. Then, Neural network is applied on the selected feature vectors. The system is evaluated by using CASIA long range iris images database. The recognition accuracy was 88.49%.

Table 3.3: Comparison of various iris algorithms with ANN

Researcher	Feature Extraction	Database	Accuracy%
(Salve and Narote, 2016)	Log Gabor	CASIA v4	92.5
(Dillak and Bintiri, 2016)	3D-GLCM	CASIA v1	94.22
		CASIA-Iris-Syn v4	91
(Rizk et al., 2016)	DCT+ PCA	CASIA v3	90
(Mozumder and Begum, 2016)	DCT	MMU2	98.57
(Sharkas, 2016	DWT	CASIA v3	75
			98.3
(Hajari et al., 2016)	LBP+ GLCM	CASIA	94.5
		MMU	96.5
(Anupama, 2017)	WT+GF+GLCM+ Tamura	CASIA v1	83.65
(Deshpande and Patavardhan, 2018)	Fuzzy entropy	CASIA long range	81.19

A summary of iris recognition studies that use Neural Network as a classifier is comprised in table 3.3. Using techniques like Log Gabor and DCT helps in increasing the performance of the system. In addition, some studies applied more than one method and compared them such as (Anupama et al, 2017) and (Salve and Narote, 2016), in these researches, SVM and ANN were used and they found that SVM is better than ANN.

3.3.3. K-Nearest Neighbor (KNN)

The K-Nearest Neighbor (KNN) is another algorithm that is a classified method based on learning data that has a close distance to the object. Euclidean distance, Hamming distance, Minkowski distance and Manhattan distance are some distance functions that are used for KNN.

A. Hamming Distance (HD)

The following are some approaches that used Hamming Distance. Ng et al. (Ng et al., 2010) presented an approach using Haar wavelet decomposition to extract the iris features, and Hamming distance to measure the dissimilarity between the binary iris codes. The histogram equalization has been used to enhance the normalized iris image. Results found that Haar decomposition is rather simple compared to Gabor wavelet This approach has achieved a high recognition rate up to 98.45%.

Hamouchene and Aouat (Hamouchene and Aouat, 2014) worked on the problem in iris recognition in order to extract the features by using Neighbourhood - based Binary Pattern (NBP) technique. The NBP image is decomposed into several blocks by extracting the relative connection between neighbors of pixels. After that, the mean of each block is calculated. Next, the variations of the mean are encoded. The resulted binary matrix is used as a feature that is classified by HD. CASIA database V1 has been used and achieved an accuracy of 76.25%.

In addition, the HD has been adopted by Tan and Kumar (Tan and Kumar, 2014). For features extraction, The Zernike moment (ZMs) based phase encoding has been presented. At the segmentation stage, the retinex algorithm and a random walker based algorithm have been used in order to enhance the image and perform coarse segmentation of the iris region. Thereafter, the Daugman's rubber sheet model is applied to normalize the segmented iris image. In this work, three databases have been applied, UBIRIS.v2, FRGC, and CASIA.v4-distance, the average percentage of improvement were 54.3%, 32.7% and 42.6% in EER respectively.

Li (Li, 2017) tackled the iris recognition task by describing an algorithm based on coarse and line location. To get the iris boundary the Canny edge extraction and Hough transform have been used. Gabor filter is carried out for iris feature extraction and the HD is applied to calculate the difference between the two iris images. In this work, a database has been collected which contains 160 iris image samples. The recognition rate of the system is 96.5%.

Guo and Zheng (Guo and Zheng, 2018) proposed an algorithm for identity authentication. The median filter and salt and pepper are both applied to remove noise in the image. In this work, a combined method between Hough transform and Daughman algorithm was developed for the segmentation stage. After that, the Wavelet Transform is used on the normalized image. HD is applied to find the distance between two iris images. CASIA-iris-thousand database is used and the accuracy of the system was 97.8%.

Okokpujie et al. (Okokpujie et al., 2018) presented an interesting comparative between integro-differential approach and the Hough Transform approach. This work found Hough Transform to be better than Integro-differential approach, so it has been used in this work. Next, the iris segmented image was also carried out to normalize and feature extraction using Daugman's rubber sheet and Log Gabor algorithms respectively. The work evaluated results on CASIA Iris Image Database, and HD has been applied as a classifier.

Table 3.4: Comparison of various iris algorithms with HD

Researcher	Feature Extraction	Database	Accuracy%
(Ng et al., 2010)	Haar wavelet	CASIA intervalv3	98.45
(Hamouchene and Aouat, 2014)	NBP	CASIA v1	76.25
(Tan and Kumar, 2014)	ZMs	CASIA.v4 Distance	97.1
		UBIRIS.v2	88.04
		FRGC	80.14
(Li, 2017)	GF	Not mentioned	96.5
(Guo and Zheng, 2018)	WT	CASIA-iris-thousand	97.8
(Okokpujie et al., 2018)	Log Gabor	CASIA Iris	93.6

Table 3.4 concludes some researches that carried out the HD in their works. It was found to perform well with HD when it is used with Haar wavelet and Log Gabor, whereas the system performance rate decreases when NBP is used. On the other hand, Okokpujie et al. (Okokpujie et al., 2018) found that Hough Transform to be better than the Integro-differential approach. So, it will be adopted at the segmentation step in this study.

B. Euclidean Distance (ED)

Many researchers carried out ED method in their studies and obtained good results. One of the proposals concerning the use of ED for iris recognition has been presented by Savithiri et al (Savithiri et al, 2011). Three methods for feature extraction have been discussed, Gabor Wavelet, LBP, and Histogram of Oriented Gradient techniques for improving the performance of an iris recognition system. Integro-differential operator has been used for localization of the iris region. Moreover, two types of measures such as HD and ED are used for classification. Experiments are conducted on 130 images chosen from MMU iris database.

Patil et al. (Patil et al., 2012) presented a nice comparison between three methods for feature extraction, Gabor Wavelet, Log Gabor Wavelet, and PCA. The performance of these algorithms is analyzed using CASIA database. In this proposed system, the Hough transform and rubber sheet model have been adopted for iris localization and normalization. After that the normalized iris image is enhanced by histogram equalization to extract the iris regions features the three methods (GW, LGW, and PCA) have been applied. Finally, the ED and HD have been used for classification. Moreover, Gabor filter based was better than the Log Gabor wavelet and PCA.

Another contribution to the development of the iris recognition system has been presented by He et al. (He et al., 2013). This research focuses on the optimization of Gabor parameters based on a real-coded genetic algorithm to get a better reliability of iris recognition system. For classification, the ED was adopted. Two databases have been used in this research, JLUBR-IRIS and CASIA V3. The performance rate was 97.3% on JLUBR-IRIS database and 92.8 on CASIA database.

Another proposed method to improve the iris recognition system has been proposed by Mrinalini et al. (Mrinalini et al., 2015). Triangular DCT based Feature Extraction (T-DCT), Binary Particle Swarm Optimization (BPSO) based feature selection, and Radon Transform (RT) based Pre-processing have been presented to extract the features. In this work, different pre-processing techniques have been adopted because three standard databases have been used. The experimental results have been applied on three databases, Phoenix, MMU, and IITD. In other words, the ED classifier has been used to compute the distance between the test image and the trained images from the database. The performance of the proposed method was 78.04% on MMU database, 88.89% on Phoenix database, and 94.04% on IITD database.

Dhage et al. (Dhage et al., 2015) submitted more contributions to enhancement the iris recognition. Initially, the Radon Transform and Top hat filtering have been used in the preprocessing stage to detect and enhance the iris image. Then, a combination of DWT and DCT have been applied for extracting the features. Next, the Binary Particle Swarm Optimization (BPSO) algorithm has been used to obtain the most important iris features. Finally, the ED has been used as a classifier. In the same context, the Phoenix and ITT databases have been selected to test the proposed method and the experimental results showed that average rate of 90.5% for ITT database, and 88% for Phoenix database.

Hamd and Ahmed (Hamd and Ahmed, 2017) used Manhattan, Euclidean, and Cosine classifiers to compare the distance measurement method. The CASIA-v1 and CASIA-v4-interval have been used to test the performance of the system. This study found that the accuracy rate of Fourier descriptors and principal component analysis with Euclidean distance was 94%, 92% respectively.

In addition, Rana et al (Rana et al, 2017) utilized the K-Nearest Neighbor and presented a technique that used (PCA) based on (DWT) for selecting a feature of iris templates to increase the efficiency of iris recognition. The Hough Transformation is used to locate the circular iris region. For normalization, the Daugman's rubber-sheet model is applied. DWT is applied on the normalized iris image. Then, PCA is applied on the LL sub-band feature to find the most discriminating information present in LL. The CASIA-Iris V4 database is used for experimental results. Also, this research displayed a comparison of the accuracy of several feature extraction techniques, DCT, DWT, PCA, and the proposed method. The results were 75%, 82%, 90.2%, and 92.6% respectively.

Similarly, Khotimah and Juniati (Khotimah and Juniati, 2018) adopted KNN and the fractal dimension of box counting method to iris recognition. Initially, extracting the important feature on an image, such as lines, circles by using Canny edge detection algorithm. Then, the circular Hough transform and Daugman's rubber sheet model have been applied to detect the radius and center coordinates of the pupil, and normalization of iris regions. Next, using the box-counting method to determine the iris image dimension. The proposed method has been applied on CASIA interval-V4 database. Moreover, the proposed system achieved a recognition rate of 92.63 % with 3-NN.

Table 3.5: Comparison of various iris algorithms with ED

Researcher	Feature Extraction	Database	Accuracy%
(Savithiri et al., 2011)	GE+LBP+HOG	MMU	99
(Patil et al., 2012)	GW	CASIA	99
	LGW		92
	PCA		90
(He et al., 2013)	GF+ genetic algorithm	JLUBR-IRIS	97.3
		CASIA V3	92.8
(Dhage et al., 2015)	DWT+DCT+ BPSO	IITD	97.81
		Phoenix	94.53
(Mrinalini et al., 2015)	T-DCT+ BPSO+RT	MMU	78.04
		Phoenix	88.89
		IITD	94.04
(Rana et al., 2017)	PCA+ DWT	CASIA iris v4	92.6
(Hamd and Ahmed, 2017)	FDs +PCA	CASIA intervalv4	94 92
(Khotimah and Juniati, 2018)	box-counting	CASIA interval v4	92.63

Table 3.5 shows a summary of some previous studies that focused on ED to solve the problem of iris recognition. It can be noticed that the performance of T-DCT, BPSO and

RT approaches are diminished on MMU database, whereas they increased on IITD database. On the other hand, LBP was applied on MMU database and achieved good results.

3.3.4. Random Forest (RF)

The Random Forest is a technique used for measuring the similarity between two iris codes as well. Some researchers tackled iris recognition by using this algorithm such as Manjunath and Raja (Manjunath and Raja, 2013). Where comparison of the efficacy and efficiency of RF, SVM, and KNN was conducted. This work used CASIA iris database. The experimental results show that iris recognition when using KNN method is relatively increased as compared to RF and SVM.

An attempt to compare three algorithms for extracting the features from the iris image with RF is made by Akbar et al. (Akbar et al., 2014). The three algorithms are Discrete Sine Transform (DST), Hilbert transform and Fast Walsh Hadamard Transform(FWHT). This research reached a reasonable result with (DST). Furthermore, the experimental results of the system were applied on MMU database.

The recognition problem in a semi naïve Bayesian classification framework to maintain simplicity and robustness has been formulated by Chai et al. (Chai et al., 2017). The circular Hough transform and rubber sheet model have been used for detecting the iris and pupil boundaries and normalization. Then, the normalized iris pattern convolved with Log-Gabor wavelets. The experimental results were applied on CASIA V1 iris database.

Gnana et al. (Gnana et al., 2018) proposed a novel architecture for Iris Recognition. A comparative analysis using LBPH features and Zernike features and two classifiers, RF and SVM has been done. The inner circle of the iris is extracted using a fusion of contour-based and Hough transform, while the outer circle of the iris is extracted using Daugman’s approach. The proposed approach was tested with the dataset (Warsaw-BioBase).

Table 3.6: Comparison of various iris algorithms with RF

Researcher	Feature Extraction	database	Accuracy%
(Manjunath et al., 2013)	DWT+ PCA	CASIA V1	98
(Akbar et al., 2014)	DST	MMU	93.4
	FWHT		87
	Hilbert		86.4
(Chai et al., 2017)	Log Gabor	CASIA v1	95.07
(Gnana et al., 2018)	LBPH	Warsaw-BioBase	95

Table 3.6 presents brief information about the literature studies that applied RF in their works. It also observes that the combination of DWT and PCA achieve the highest performance of iris recognition with RF (Manjunath and Raja, 2013). Moreover, DST, LBP, and Log Gabor are suitable methods with RF whereas; the recognition rate drops when Hilbert transform technique is used.

3.4. Comparison of the previous study

A summary of iris recognition, which is surveyed above is included in Table 3.7. Note from the table the difference in the use of databases and its size. Furthermore, various techniques for extracting distinctive features and matching.

Table 3.7: Comparison of feature extraction algorithms and classification algorithms

Researcher	Feature Extraction	Matching	Database	Accuracy%
(Kulkarni et al., 2013)	GLCM	SVM	CASIA interval v3	75
	GLRLM			57.14
	GLCM+ GLRLM			88.89
(Luhadiya and Khedkar, 2016)	GLCM	SVM	UPOL	94.2
(Salve and Narote, 2016)	Log Gabor	SVM	CASIA v4	95.9
(Anupama, 2017)	WT+GF+ GLCM+ Tamura	SVM	CASIA v1	92.25
(Nirgude and Gengaje, 2017)	PWT+TWT	SVM	CASIA v3	95.33
(Shaik, 2018)	Log Gabor	SVM	CASIA v1	86
			IITD	
(Salve and Narote, 2016)	Log Gabor	ANN	CASIA v4	92.5
(Dillak and Bintiri, 2016)	3D-GLCM	ANN	CASIA v1	94.22
			CASIA-Iris-Syn v4	91
(Rizk, 2016)	HW+ PCA	ANN	CASIA v3	90%
(Mozumder and Begum, 2016)	DCT	ANN	MMU2	98.57
(Sharkas, 2016)	DWT	ANN	CASIA v3	98.3
(Hajari, 2016)	LBP+ GLCM	ANN	CASIA	94.5
			MMU	96.5

(Anupama, 2017)	WT+GF+GLCM+ Tamura	ANN	CASIA v1	83.65
(Hamouchene and Aouat, 2014)	NBP	HD	CASIA v1	76.25
(Guo and Zheng, 2018)	WT	HD	CASIA-iris-thousand	97.8%
(Okokpujie et al., 2018)	Log Gabor	HD	CASIA Iris	93.6
(Savithiri et al., 2011)	GE+LBP+HOG	ED	MMU	99%
(Rana et al. 2017)	PCA+ DWT	ED	CASIA iris v4	92.6
(Mrinalini et al., 2015)	T-DCT+ BPSO+RT	ED	MMU	78.04
			Phoenix	88.89
			IITD	94.04
(Patil et al., 2012)	GW	ED	CASIA	99
	LGW			92
	PCA			90
(Dhage et al., 2015)	DWT+DCT+ BPSO	ED	IITD	97.81
			Phoenix	94.53
(He et al., 2013)	GF+ genetic algorithm	ED	JLUBR-IRIS	97.3
			CASIA V3	92.8
(Manjunath and Raja, 2013)	DWT+ PCA	RF	CASIA V1	98
(Akbar et al., 2014)	DST	RF	MMU	93.4
	FWHT			87.9
	Hilbert			86.4
(Chai et al., 2017)	Log Gabor	RF	CASIA V1	95.07
(Gnana et al., 2018)	LBPH	RF	Warsaw-BioBase	95%

It can be noticed that most works use the Chinese Academy of Sciences Institute of Automation (CASIA) iris image as the dataset. MMU, Bath, UBIRIS, IITD, and UPOL are also some standard databases used in the above studies. As a matter of fact, picking the database and the classifier method greatly affects the accuracy rate of the system. Notwithstanding the researchers in (Shaik, 2017) and in (Patil et al , 2012) carried out the implementation using the same database on their works, moreover, both researchers used Log Gabor for extracting the features, but the results in the mentioned studies were different. It seems because the first work used SVM and the other one used ED.

In one word, some techniques achieve good results in spite of the different database and classification method. DWT, PCA, DCT, GLCM achieved reasonable accuracy rates in most by other surveyed methods.

3.5. Related work

In point of fact, a difficulty for a thorough discussion is that only part of the datasets are used, and that part is randomly chosen or not clearly identified, therefore the results of these discussions when comparing studies cannot be confirmed. In this chapter, an overview of the iris databases was provided. This chapter has focused on the most common types of iris recognition in the literature. The captured images must be high quality images so the CASIA iris database are selected, which is an extensively used iris dataset. This literature review provides a summary of information derived from existing related work.

From previous studies, it can be noticed that most works use the Circular Hough Transform for localization of iris region. In the same context, Integro-differential operator technique can be also used, but Hough Transform to be better than Integro-differential approach because the circular Hough transform implementation's degree of accuracy is higher than that of the Integro-differential operator implementation's accuracy.

Moreover, the produced segmented iris image by HE has a uniform distribution that yields better contrast than the original image. The advantage of this method is the calculation is not computationally intensive. So in theory, if the HE function is known, then the original histogram can be recovered.

In terms of feature extraction, a number of approaches in iris recognition have been classified in several different categories in the literature. DCT, DWT, and LBP techniques are powerful tools for image processing. Furthermore, they are very efficient in extracting features from patterns.

SVM is suitable for high dimensional data and its ability to control clearly on the trade-off between classifier complexity and error. For this reason, it has been picked as a classifier in this study.

3.6. Summary

In this chapter, an overview of iris recognition system was provided. Accordingly, the HE and DCT techniques will be used for enhancing and extracting features respectively from iris image in this work. The combination of these two techniques may be promising, in terms of performance and accuracy. Then, the SVM is applied as a classifier. After that, DWT, LBP techniques are carried out with SVM separately.

The next chapter presents an approach for iris recognition based on a combination of the HE and DCT techniques for enhancing and extracting features with SVM as a classifier. The combination of these techniques may be promising in terms of performance and accuracy. After that, DWT and LBP techniques will be carried out with SVM separately.

CHAPTER 4
Research Methodology

4.1. Introduction

A complete iris recognition system can be split into four stages; image acquisition, preprocessing, feature extraction, and iris matching. Chapter 2 presented an overview of some techniques that will be used in the work.

In this chapter, the main methodology of this work is illustrated in Figure 4.1. Then a detailed description of each stage is provided. Firstly, brief information about the database in this study is presented. Next, the preprocessing stage of iris recognition is explained in section 4.3. This stage includes iris segmentation, iris normalization, and image enhancement. After that, the HE and DCT techniques are explained for enhancing and extracting the feature from the normalized iris image. The combination of these two techniques in order to enhance the performance of iris recognition system. In addition, DWT and LBP have been also used separately for extracting the features. Finally, details about the classification algorithm (SVM) are provided in section 4.5. The chapter ends with a summary in section 4.6.

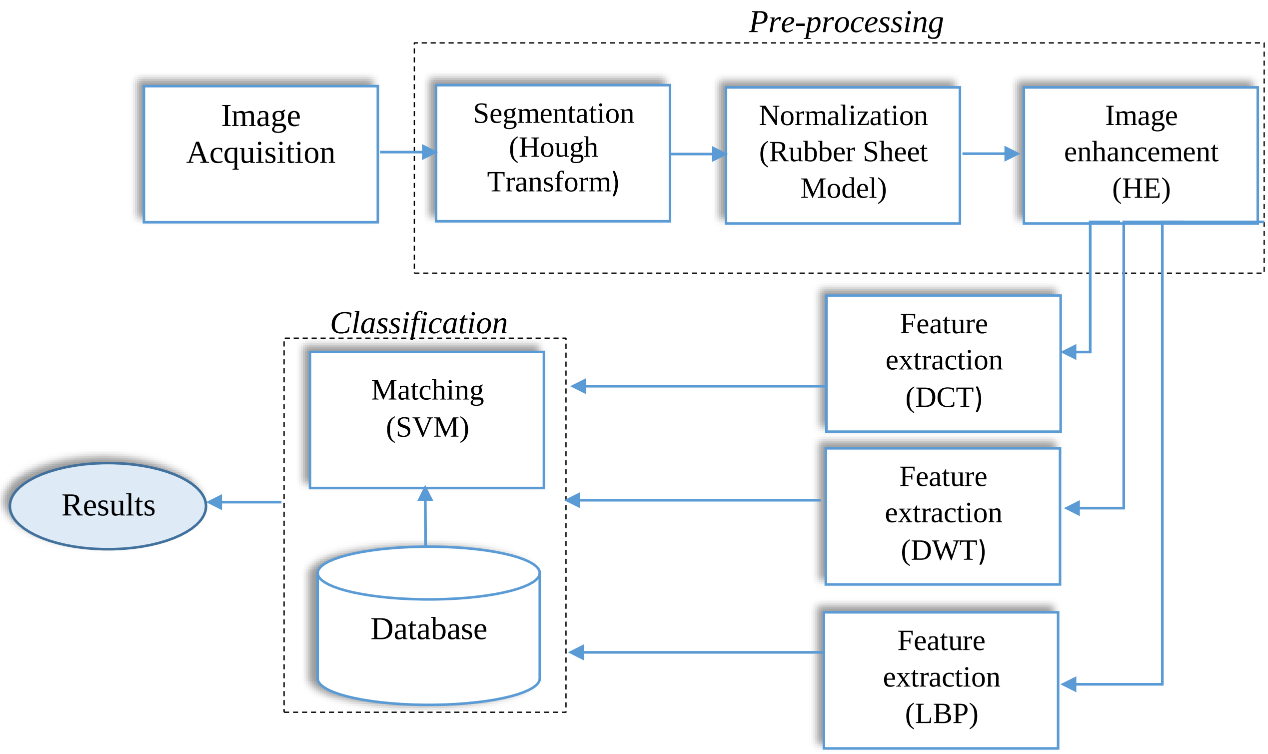


Figure 4.1: Block Diagram of Iris Recognition System

4.2. Image Acquisition

The captured images must be high quality images and are selected from CASIA iris database (Chinese Academy of Sciences, 2018), which is an extensively used iris dataset, it is developed by the Chinese Academy of Sciences as a baseline for measuring the effectiveness of various iris recognition systems. In this work, CASIA-V4-interval subset is selected. It is an extension of CASIA-IrisV3 and contains six subsets. The three subsets from CASIA-IrisV3 are CASIA-Iris-Interval, CASIA-Iris-Lamp, and CASIA-Iris-Twins respectively. The three new subsets are CASIA-Iris-Distance, CASIA-Iris- Thousand, and CASIA-Iris-Syn. CASIA-Iris-Interval contains a total of 2,639 iris images. All iris images are 8 bit gray-level JPEG files with a resolution of 320 × 280 pixels, collected under near infrared illumination or synthesized. Figure 4.2 shows samples from CASIA-V4-interval. The file name of each image in CASIA-IrisV4 is unique and denotes some useful properties associated with the image.

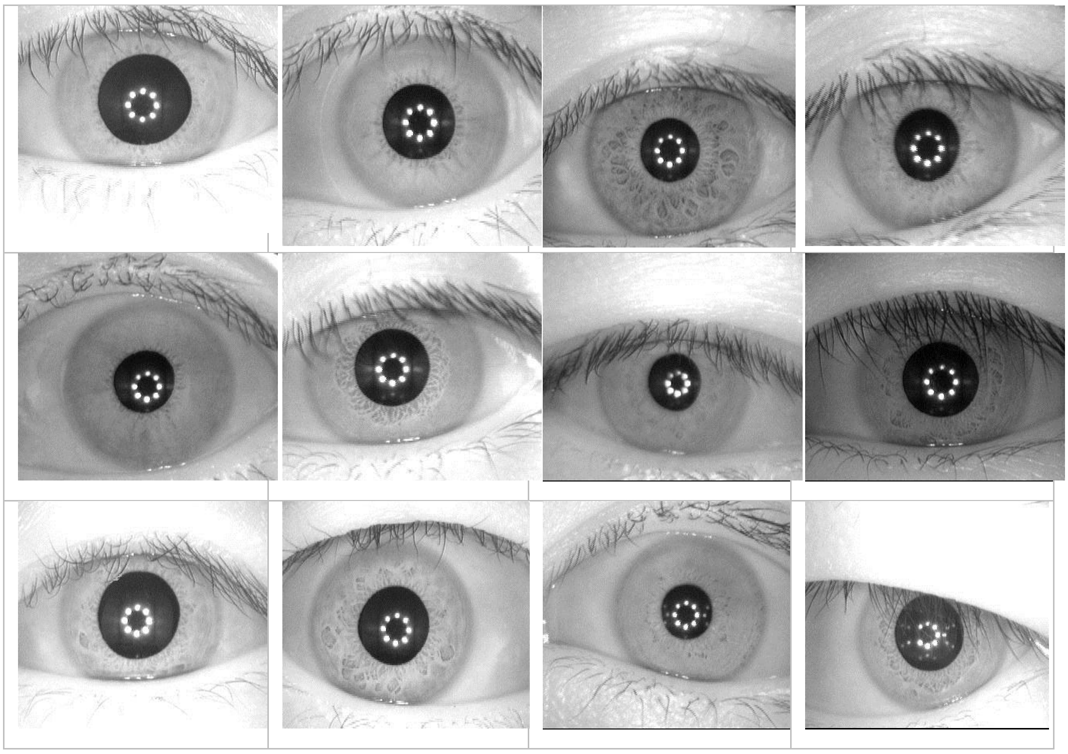


Figure 4.2: A sample of CASIA-V4-interval dataset.

4.3. Image Pre-processing

It is the first step of a typical iris recognition system which involves iris segmentation and normalization. Digital images are greatly affected by various noises (Dhage et al., 2015). Preprocessing of an image is done to enhance only the region of interests. The images in the database may have low contrast because of non-uniform illumination caused by the position of light sources. To achieve uniform illumination with high contrast, image characteristics must be enhanced.

4.3.1. Localization of the Iris Region

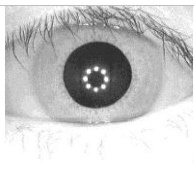
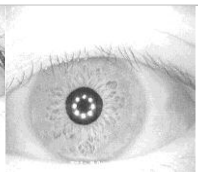
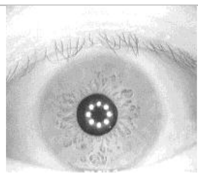
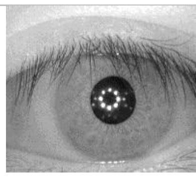
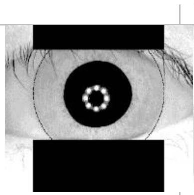
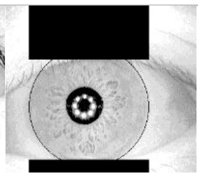
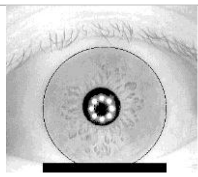
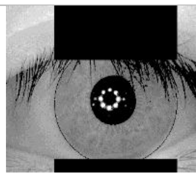
Segmentation is used for the localization of the correct iris region. The Localization process determines the iris boundaries and pupil boundaries and then converts this part to a suitable template in the normalization stage. Iris can be approximated by two circles. One for iris outer, it is between iris and sclera boundary. The other circle is for inner boundaries, it is between iris and pupil boundary. Also, localization of boundaries between iris and eyelids. The Circular Hough Transform algorithm which explained in section 2.6 of chapter 2 is used to determine the radius and center coordinates of the pupil and iris regions. The range of radius values to look for is set manually, based on the database used. For the CASIA database, values of the iris radius range from 90 to 150 pixels, while the pupil radius ranges from 28 to 75 pixels. In this work, Canny operator in MATLAB was used because it is one of the most optimal edge detection methods (Canny, 1987). This operator works on the canny edge detection algorithm. The detected edges consisted of boundaries of iris, pupil and to some extent eyelashes. Table 4.1 includes the segmentation value of the iris image which is represented in the center coordinates and radius of the detected pupil boundary, and the center coordinates and radius of the detected iris boundary of Hough Transform technique. Moreover, Samples of the results of segmentation shown in Table 4.2.

Table 4.1: The segmentation for pupil and iris using Hough Transform technique

Image Name	Circle Pupil			Circle Iris		
	X-Pos	**Y-Pos**	**R**	**X-Pos**	**Y-Pos**	**R**
S1001L01.jpg	118	156	57	115	158	110
S1001L02.jpg	132	160	50	133	160	113
S1036L02.jpg	170	133	32	170	140	100

S1036L04.jpg	172	160	33	173	165	103
S1146L05.jpg	160	182	40	165	185	103
S1090L01.jpg	149	160	40	150	165	103
S1159L06.jpg	128	145	55	118	148	115

Table 4.2: A sample of segmented iris images

Input Image				
Segmented Iris image				

4.3.2. Iris Normalization

Iris segmentation is followed by a normalization to generate fixed dimensional feature vectors. The normalization process creates iris regions, which have the same fixed dimensions, so that two images of the same iris in different conditions will have distinctive features at the same spatial location. The rubber sheet model is designed for this purpose as explained in section 2.7 of chapter 2. Applying this model on segmented iris of CASIA-V4-interval is illustrated in Figure 4.3, which is converted from circular shape to rectangular shape, thus the iris has become ready to feature extraction stage.

The image resizing technique is applied on normalized iris patterns to prepare for the feature extraction stage. The size of the normalized iris pattern of CASIA database is equal to (180×720 pixels).

(a)

(b)

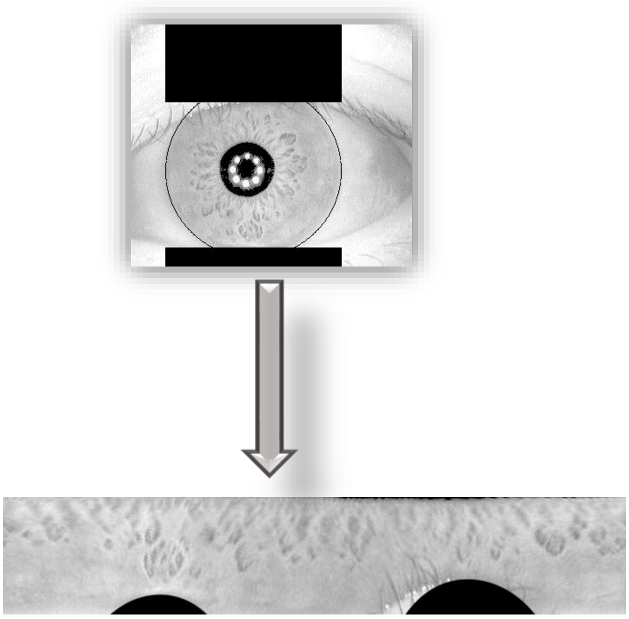


Figure 4.3: The iris normalization. a.Segmented iris. b.Normalized iris

4.3.3. Image Enhancement (Histogram Equalization)

The normalized iris image has low contrast and may have non-uniform illumination caused by the position of the light source. These may impair the result of the texture analysis. The proposed system, enhance the normalized iris image and reduce the effect of non-uniform illumination by means of HE. Figure 4.4 shows the unwrapped texture and texture image after enhancement respectively.

(a)

(b)

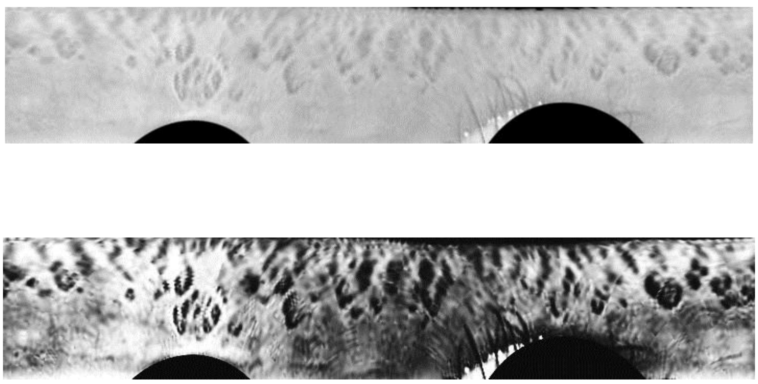
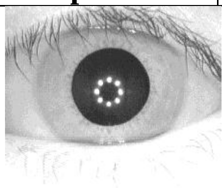
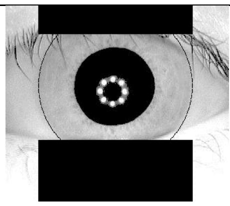
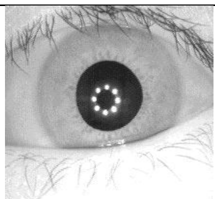
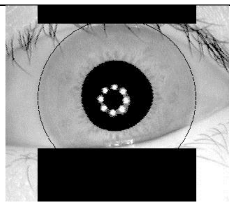
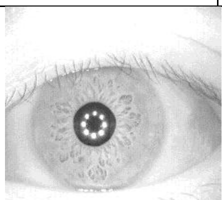
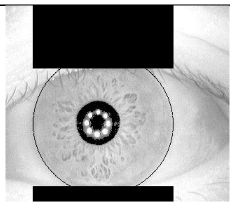
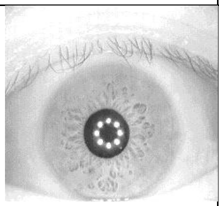
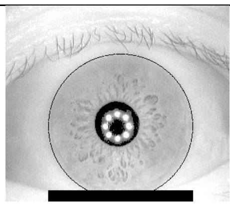
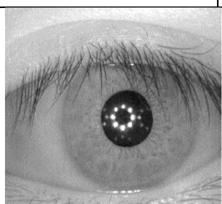
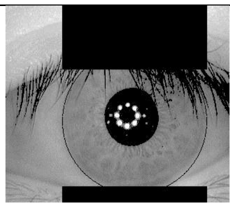
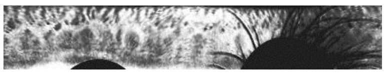


Figure 4.4: The Enhancement process. a. The image before enhancement. b. The image after enhancement.

In brief, Iris segmentation process is important stage in iris recognition system, because if the iris segmentation process succeeded this will lead to extract features correctly, and therefore, high performance in iris recognition system will be achieved. In this work, the Hough Transform algorithm has achieved high performance. Table 4.3 below shows samples images from CASIA database and the results which are obtained from the iris segmentation stage.

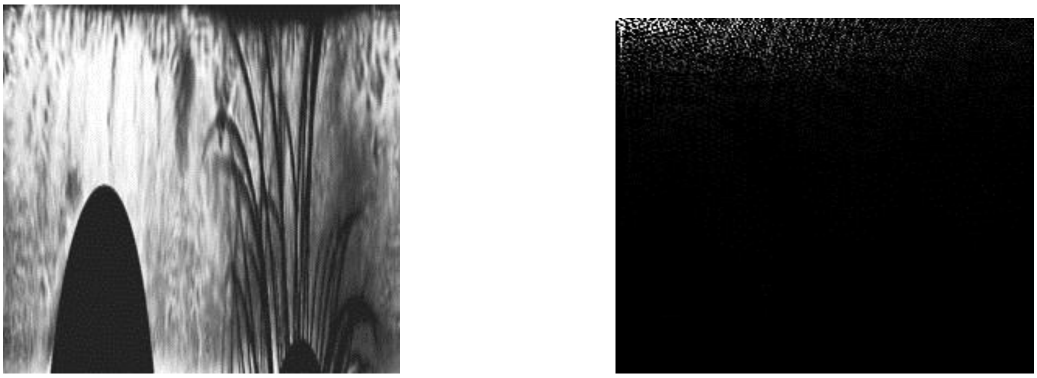
Table 4.3: Examples of segmented iris images

Image name	Input iris	Iris localization	Normalized image
S1001L01.jpg			
S1001L02.jpg			
S1036L02.jpg			
S1036L04.jpg			
S1146L05.jpg			

4.4. Feature extraction (DCT)

The preprocessed image is fed to the feature extraction stage. Extracting the most discriminating information that presents in the iris pattern affects positively on recognition of individuals. The iris consists of many irregular shapes, such as freckles, coronas, stripes, furrows, and crypts (Li, 2017). Different algorithms have been used at this stage by researchers. In this study, the DCT is adapted to extract the features of the iris and its detail was provided in section 2.9.1 of chapter 2. This technique is widely used in the field of digital signal processing application.

The DCT is a good candidate for feature extraction and is thus used here as a means of representing the intricate and detailed variations in the human iris texture. In this research, DCT approach has been applied on the normalized iris image to extract the features. Figure 4.5 illustrates the DCT process on normalized image. As explained earlier, DCT basically suppresses all the information of the image and concentrates on the coefficients present at the most top left corner. The DCT of the normalized iris pattern has been yielded from formula (2.5 and 2.6) that has been presented clearly in chapter two. After applying DCT on each block of the dataset, the DCT coefficients are extracted in a zigzag as illustrated in Figure 4.6. The retained coefficients stored in a feature vector. The most appropriate number of DCT coefficients was 90, where many experiments were performed to ensure a good selection. Next, the vector is passed onto the classification process.



(a) **(b)**

Figure 4.5: The DCT process. (a) Normalized iris (b) Example of DCT approach

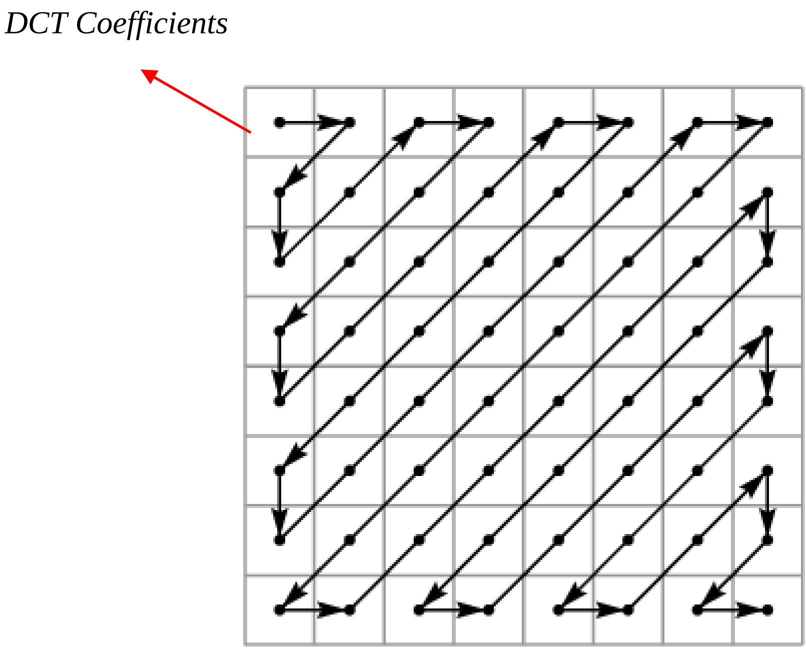


Figure 4.6: Coefficients in the zigzag order

The DCT algorithm that is have been used for this study on iris recognition is as shown below:

Algorithm 4.1: DCT- Features Extraction

Input: enhanced image **Output: DCT Features**
Step1: Read the input image Step2: Compute DCT for the input image using the equation (2.5). Step3: Convert the DCT image into 1D array by zigzag order Step4: Select the first 90 DCT coefficients as features Step5: Return (DCT features vector)

4.5. Discrete Wavelet Transform (DWT)

As it mentioned in section 2.9.2 of chapter 2, the DWT is a tool that divides the information of an image into different frequency components (approximation and details sub-signals). In this thesis, Haar has been used as mother wavelet. Moreover, a third level DWT is implemented on the normalized iris image by the Haar wavelet and generates a feature vector with size of 180 coefficients. Figure 4.7 shows a decomposition with three levels.

(a)

(b)

Figure 4.7: (a) Normalized iris (b) Example of DWT approach

4.6. Local Binary Pattern (LBP)

LBP approach is applied on iris normalized of CASIA-V4-interval database. The results shown in Figure 4.8 shows the ability of LBP approach to capture entire the iris by looking to each pixel's neighbors, these pixels will be computed, where the LBP will extract all the features of this iris and create a one dimensional array of patterns that can be classified later by using any classification algorithm.

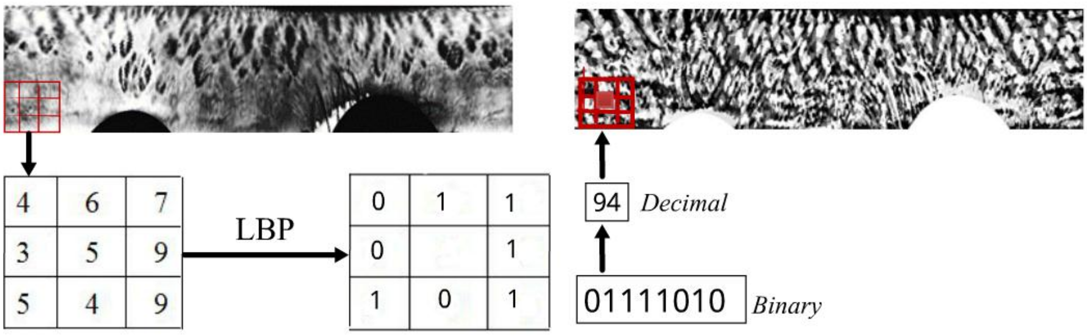


Figure 4.8: Extraction the LBP pattern from normalized iris image

4.7. Classification (Support Vector Machines)

In this study, the SVM was chosen as a metric for recognition, since this classifier is trained and tested by features extracted from iris pattern, SVM classifier is trained several times by the set of iris images then tested by other sets of iris images. In another term, a simple multi-class SVM has been used (He et al., 2012) due to its popularity and efficiency in image classification. This approach was useful to solve the multi-class problem and implement iris recognition system. In this work, each person is represented as a class; therefore, the CASIA-V4-interval dataset consists of 100 classes. The multi-class SVM for 100 classes is implemented as a one-against-all strategy, which is equivalent to combining 100 binary SVM classifiers, with every classifier discriminating a single class against all other classes. The test sample is assigned to the class with the largest margin. In another meaning, each class against all other classes, in this case, class 1 represents the positive samples and all other classes together represent the negative samples. Moreover, in the second case, class 2 represents the positive samples and the all other classes together represent the negative samples including class 1 and the classifier carries on to the last class. Finally, the classifier selects the suitable class related to each tested sample.

Algorithm 4.2: SVM Training

Input: Feature base

Output: Multi SVM Model

Step1: Load the base of the feature

Step2: Assign a unique class label for the feature vectors group of the iris sub-images that have same iris image.

Step3: For all class labels

- 3.1: Gather the feature vectors of the same class label as a group
- 3.2: Assign a positive label (+1) for the first group, and negative label(-1) for the other groups
- 3.3: Train the SVM within the groups and their labels
- 3.4: Build SVM model for the first group
- 3.5: Repeat 3.1,3.2,3.3 and 3.4 steps for the remaining groups

End For

Step4: Assign back the unique label in step2 for each output SVM model

Step5: Save all the SVM models and their labels as one general model(Multi SVM Model)

Step6: Return (Multi SVM model)

Algorithm 4.3: SVM testing

Input: Feature vector **Output:** predicted labels

Step1: Load the features vector (testing set)
Step2: Load the Multi SVM model
Step3: Assign a unique class label for the feature vectors group of the iris sub-images that have same iris image.
Step4: For all class labels
    4.1: Gather the feature vectors of the same class label as a group
    4.2: Test each group based on the Multi SVM model(Algorithm4.2) //predict the desired labels
    4.3: Save the outputs of the testing as 1D vector of the predicted class labels.
    End For
Step5: Return (predicted class labels)

4.8. Summary

In this chapter, the methodology of the research is provided, where, HE is used in order to enhance the segmented iris image quality. This process facilitates the application of the following steps. The DCT is applied for extracting the features from the normalized iris image. Furthermore, DWT and LBP also applied with SVM. More than one technique will be implemented to extract the features of the iris image to test its performance with the SVM. In the next chapter, the experimental results of these techniques will be provided.

CHAPTER 5

Results and Discussions

5.1. Introduction

In the previous chapters, the basic concept of the iris recognition system has been introduced. In addition, the normalized iris image has been enhanced by (HE). DCT has been used for extracting the features from normalized iris image. Moreover, the way of using SVM was explained to match the two iris code.

In this chapter, the empirical testing of this system is explained by running and comparing a series of experiments. DWT and LBP have been also used separately for extracting the features. Section 5.4 illustrates the results obtained in experiment 1 using the DCT technique. While section 5.5 shows the results of the system in experiment 2, which used DWT technique. Finally, the LBP technique was applied on the same data used in the previous two experiments and the results are presented in section 5.6.

The experiments were carried out using eye images obtained from CASIA interval-v4 data set.

5.2. Hardware and Software Environments

All of the experiments are implemented by using MATLAB version R2014a on a laptop computer with Intel(R) Core(TM) i5-2450M CPU @ 2.50GHz, 4096MB of RAM and Windows 7 operating system.

Various techniques are applied on CASIA interval-v4 data set, DCT, DWT, and LBP are used for feature extraction and Support Vector Machine is used for classification. Each algorithm is applied separately, and then the obtained results are compared with each other to determine which algorithm is the best between the methods used.

5.3. Experimentation

The CASIA interval-v4 data set is used as described in section 3.2.1 of chapter 3, because the iris images are captured very clear. It is well-suited for studying the detailed texture features of iris images. The experiments were carried out using a CASIA interval-v4 database containing 700 iris images for 100 persons. Three techniques (DCT, DWT, and LBP) were used and compared in terms of the content of information of features extracted from the iris image with the same SVM structure in the classification stage. To allow for a fair comparison, the same number of images is used for evaluation. The experiments were carried out in three steps with different distribution for the data. Firstly, the data set is divided into two sets (400 images for training and 300 images for testing). In the second step, the data are distributed into (500 images for training and 200 images for testing). In the last step, the data was divided into (600 images for training and 100 images for testing). SVM classifier is trained using 400 images and testing is carried out using 300 images in the first approach. In the second approach, SVM classifier is trained using 500 images and testing is carried out using 200 images. In the same context, the SVM classifier is trained using 600 images and testing is performed using 100 images in the last approach.

5.4. Experiment 1

In this experiment, features are extracted by DCT approach. After this, the SVM is applied to classify these features. More than one experiment was applied to choose the best appropriate number of DCT coefficients. Experiments were carried out using different values of coefficients, and it can be observed that the performance of DCT based on Zigzag at 90 coefficients is better than with 60 and 120 coefficients as illustrated in table 5.1. The images are distributed in different ways as illustrated table 5.1. The best performance was when the testing set contains 100 images and the training set contains 600 images and it achieved 100% recognition rate. Figure 5.1 illustrates the best accuracy of DCT with 90 coefficients.

Table 5.1: Results of DCT

Number of coefficients	**Images for each individual**		
	400 images for training & 300 for testing	**500 images for training & 200 for testing**	**600 images for training & 100 for testing**
60	89.50%	92.67%	96%
90	96.67%	98.50%	100%
120	92.67%	96%	98.50%

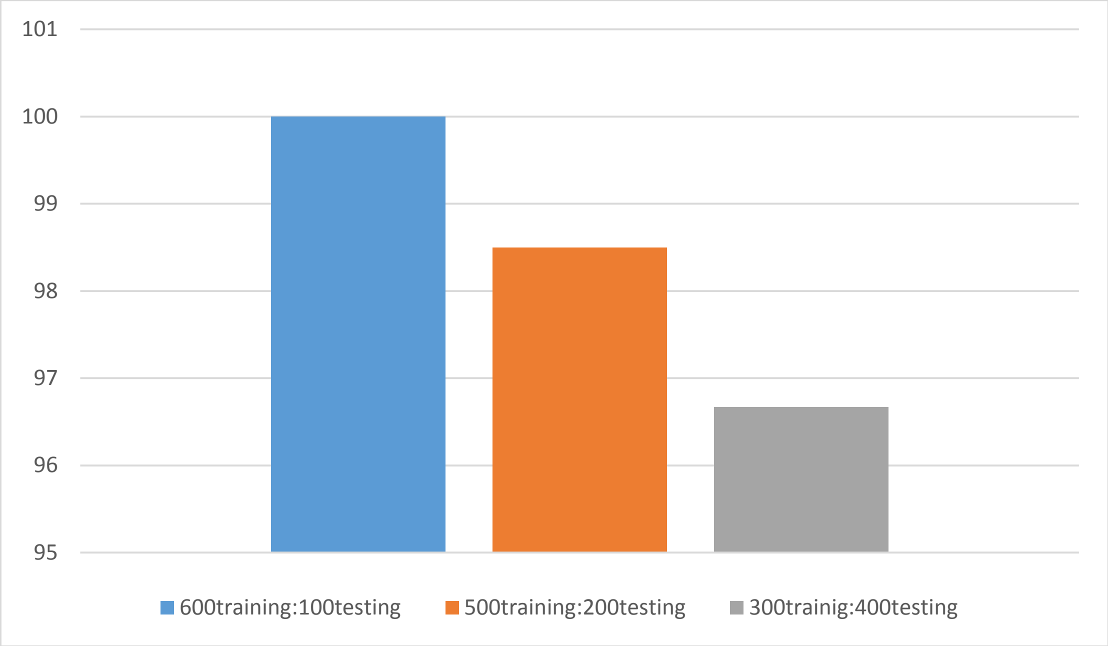


Figure 5.1: The accuracy of DCT on datasets

5.5. Experiment 2

The DWT has been applied in this experiment. In DWT approach, LL coefficients of level three were used and fed to the SVM. Initially, Features are extracted using three approaches, using a normalized image to arrive at an optimum number of features with a high recognition rate. In the first approach, DWT has been applied up to two levels using Haar wavelet. After two levels of DWT decomposition using 720 approximate, horizontal, vertical, and detail coefficients are obtained.

In the second approach, the normalized image is applied on DWT to three levels using Haar wavelet as well. After decomposition using DWT 180 approximate, horizontal, vertical, detail coefficients are obtained at three levels.

In the final approach, the normalized image is implemented on DWT to four levels. From the results, it can be observed that DWT of three levels achieved the best accuracy. Furthermore, the best performance was when the testing set contains 100 images and the training set contains 600 images as shown in table 5.2. The achieved accuracy was 100% (see Figure 5.2).

Table 5.2: Results of DWT

Level of DWT	Images for each individual		
	400 images for training & 300 for testing	**500 images for training & 200 for testing**	**600 images for training & 100 for testing**
Two Levels	91%	93%	96%
Three Levels	94.33%	98%	100%
Four Levels	76.67%	80.50%	89%

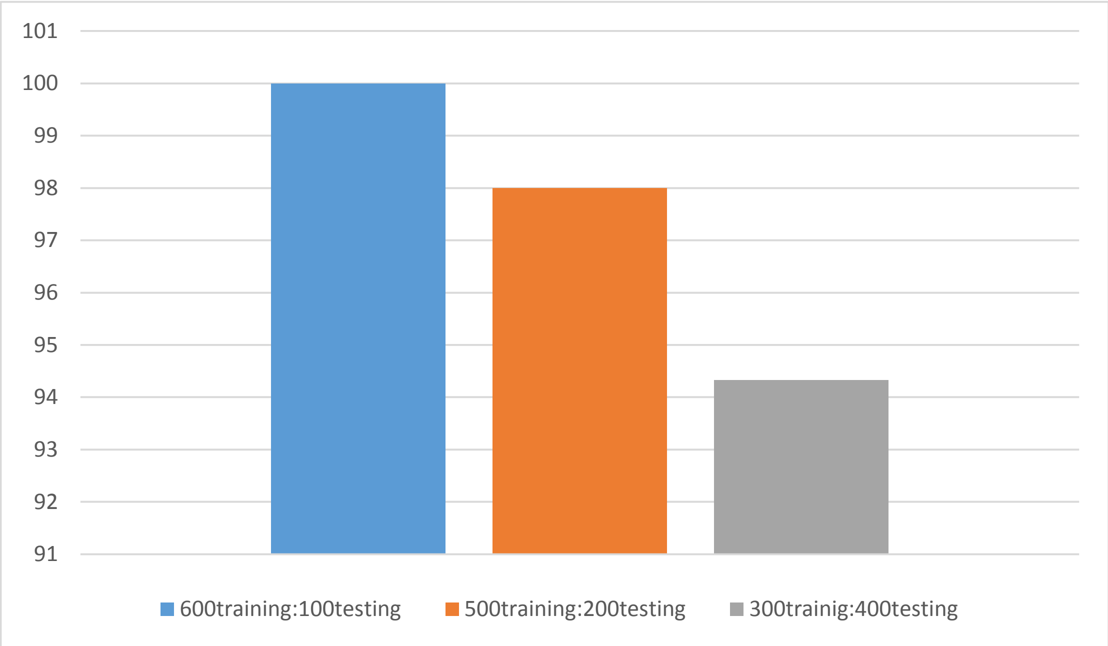


Figure 5.2: The accuracy of three levels DWT on datasets

5.6. Experiment 3

The LBP technique has been also implemented in this work. LBP is another technique which is used for extracting features from a normalized iris image as well. The size of feature vector is 1×59 where the LBP histogram is extracted which is only 59 bins vector. These features are classified using SVM. Furthermore, the best performance was when the testing set contains 100 images and the training set contains 600 images as shown in table 5.3 and Figure 5.3. The achieved accuracy was 96%.

Table 5.3: Results of LBP

Images for each individual		
400 images for training & 300 for testing	**500 images for training & 200 for testing**	**600 images for training & 100 for testing**
89%	91.50%	96%

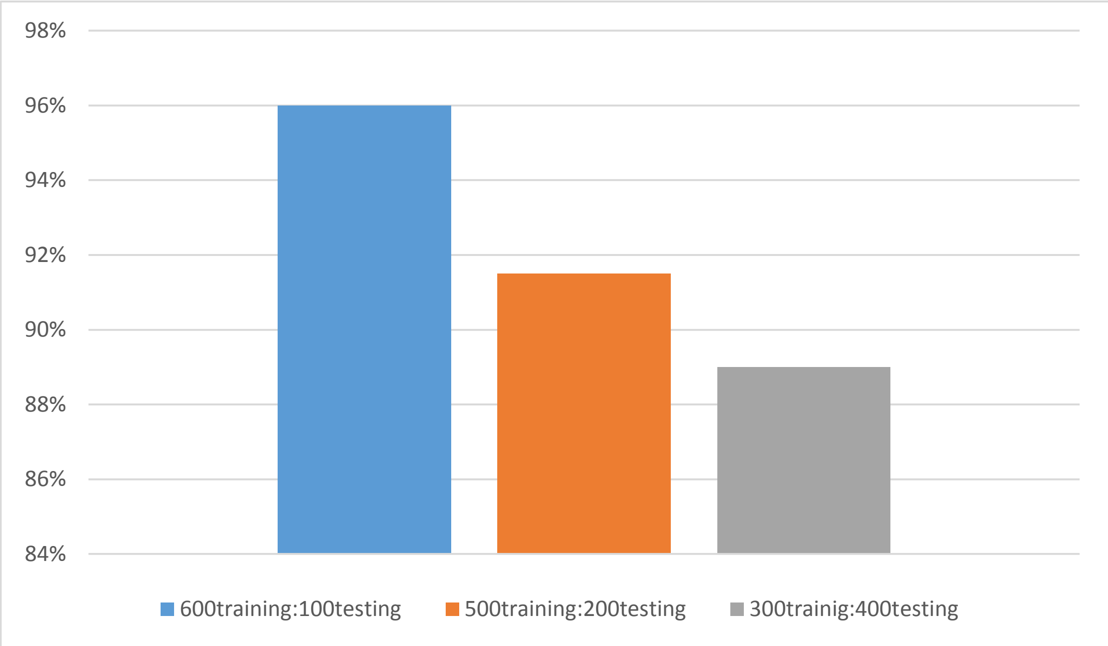


Figure 5.3: The accuracy of LBP on datasets

For summarizing the performance classification algorithm using DCT, DWT, and LBP techniques, the confusion matrix has been used. In the following, there is an example of the first approach of our data set; some classes are selected randomly to represent them into the confusion matrix. The Figure 5.4 shows the confusion matrix of DCT for random classes, while the accuracy of the model for these classes is 100%. The performance recognition of DWT is 93.3% as in Figure 5.5. Finally, Figure 5.6 illustrates the confusion matrix of LBP and the achieved accuracy for these classes is 83.3%.

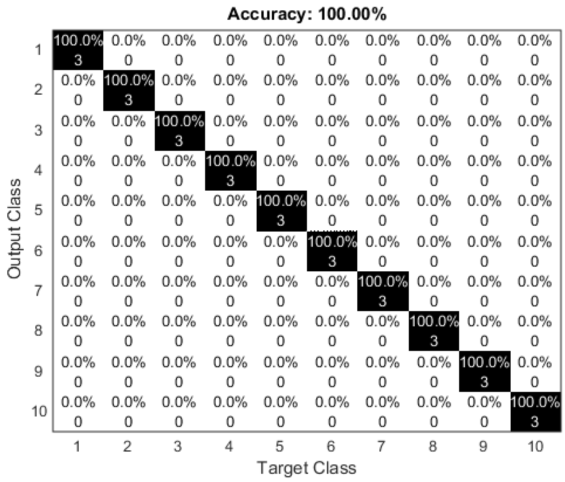


Figure 5.4. Confusion matrix of DCT with SVM

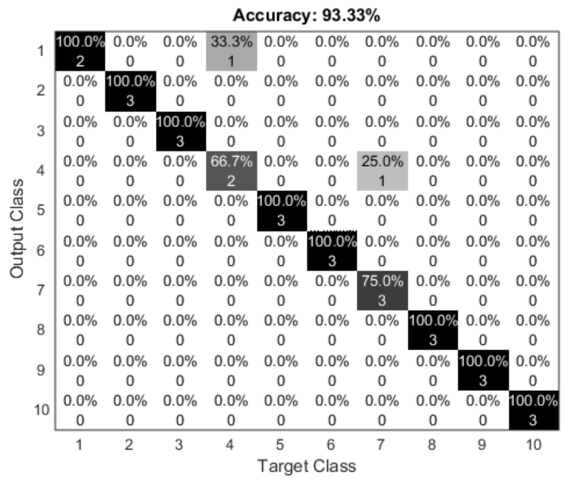


Figure 5.5. Confusion matrix of DWT with SVM

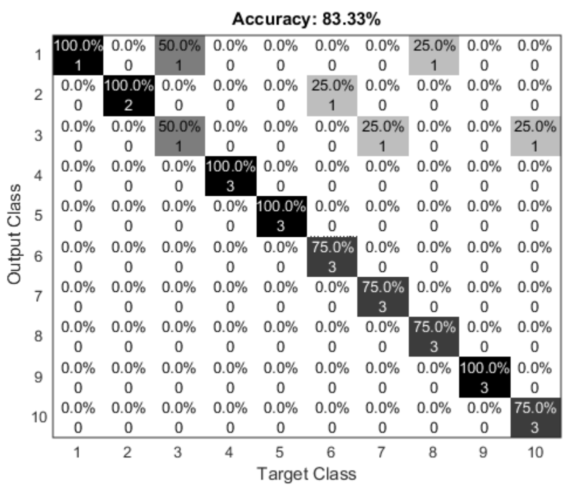


Figure 5.6: Confusion matrix of LBP with SVM

5.7. Discussion and analysis results of DCT, DWT, and LBP techniques

Though our experiments applied on the same number of data sets, the results show that DCT technique is much efficient than DWT and LBP techniques in quality and efficiency. In order to evaluate the recognition accuracy rate for testing images the formula 5.1 has been used:

$$\text{Recognition accuracy rate for testing images} = \frac{\textit{Correctly classified testing images}}{\textit{Total number of testing images}} \quad (5.1)$$

For DCT technique, it achieved the best recognition rate (Correct Accept Rate) 100% and the lowest recognition rate 96.67%. Also, DWT achieved the best recognition rate 100%, whereas the lowest recognition rate 94.33%. The best performance accuracy of LBP technique was 96% and the lowest recognition rate was 89%. Table 5.4 shows the comparison results of these techniques with SVM as a classifier. Moreover, these results are used to draw a graph for the analysis data. In the same context, in order to evaluate the approaches the false reject rate is computed in each experiment with the given formula 5.2:

$$\text{False Reject Rate (FRR)} = \frac{N_m}{N_t} \quad (5.2)$$

Where N_m is the number of misclassified images and N_t is the number of the test set images. The results are summarized in table 5.4. Figure 5.7 illustrates the difference of recognition rate for all approaches that used in this study.

Table 5.4: Classification results using Support Vector Machine (SVM)

Algorithm	**Images for each individual**					
	400 images for training & 300 for testing		**500 images for training & 200 for testing**		**600 images for training & 100 for testing**	
	FRR	Accuracy	FRR	Accuracy	FRR	Accuracy
DCT	0.03	96.67%	0.02	98.50%	0	100%
DWT	0.06	94.33%	0.03	98%	0	100%
LBP	0.10	89%	0.09	91.50%	0.04	96%

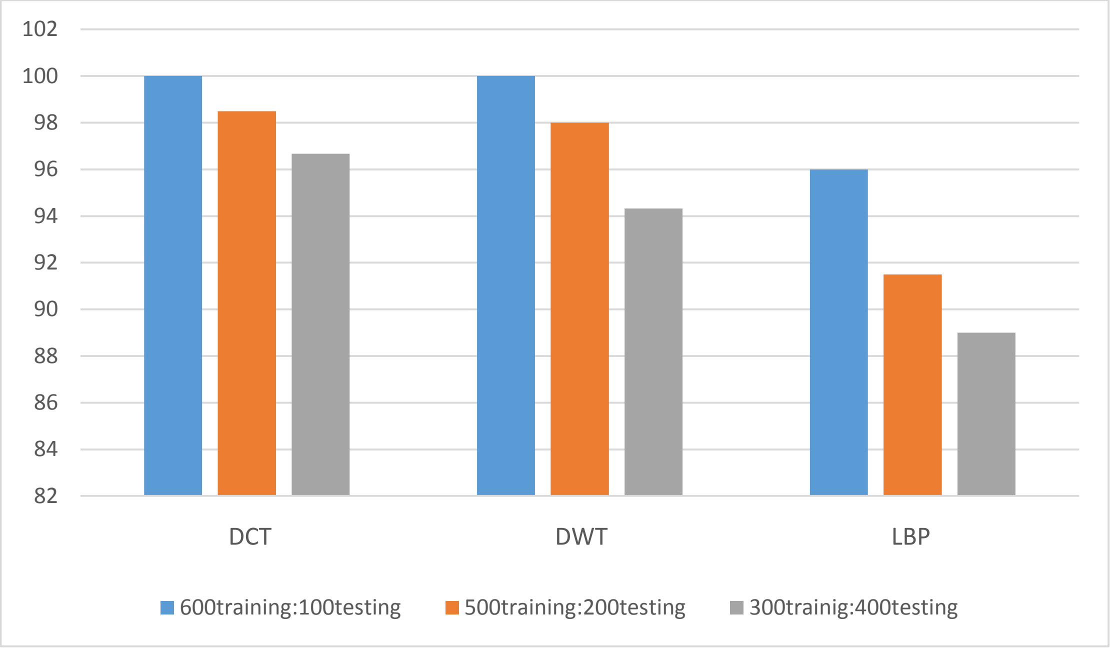


Figure 5.7: Comparison of recognition rate by using different techniques

The comparison results show that using more samples for training increase the recognition accuracy. In addition, from the results it is noted that DCT approach has a higher recognition rate than DWT and LBP. DCT has strong energy compaction property for data compression; some special properties of DCT make it a powerful transform in image processing applications. Moreover, the DCT has a robust ability for data decorrelation, it uses an average filter for smoothing the image as well as non-uniform illumination removal (Dabbaghchian et al., 2010) (Nigam et al., 2015). All these advantages of DCT may be the reason to achieve good recognition rate. On the other hand, a decrease in the performance was noted in LBP technique. Because in fact, the neighborhood of the central pixel is thresholded by its value using the LBP method. Therefore, LBP gets the relationship between each neighbor and the central pixel (Hamouchene and Aouat, 2014). Also, The structural information captured by it is limited. Only pixel difference is used, and magnitude information is ignored.

5.8. Comparison with previous approaches

The comparison between the previous approaches and the proposed approach are provided in table 5.5. It contains some studies uses the same database that has been utilized in our study, CASIA interval database.

As the results shown, it can be observed that previous studies applied different techniques in feature extraction stage and classification stage. However, the proposed system has a higher recognition accuracy.

The difference between the performance of the proposed methods and the previous methods depends on the techniques that are used in feature extraction, and classification stages.

Table 5.5: Comparison between the performance of previous studies and proposed study

Researcher name	Feature Extraction technique	Classification technique	Accuracy%
(Kulkarni et al., 2013)	(GLCM, GLRLM)	SVM	88.89
(Salve and Narote, 2016)	Log Gabor	ANN	95
(Rana et al. 2017)	DWT+PCA	ED	92.6
(Nirgude and Gengaje, 2017)	PWT+TWP	SVM	95.33
(Khotimah and Juniati, 2018)	box-counting	KNN	92.63
Proposed system	DCT	SVM	100
			98.50
			96.67

5.9. Summary

In this chapter, the proposed experiments were examined in order to recognize iris from the iris image collected from CASIA interval-v4. The experiments were implemented using three techniques, DCT, DWT, and LBP separately. And then using SVM to match the two iris templates.

Through the experiments, some important points can be observed such as:

- The use of HE with DCT has further improved this technique.
- The performance of DCT and HE with SVM better than DWT and LBP with SVM
- Increasing the number of images in the training set leads to obtain high performance.
- False Reject Rate and the confusion matrix are used in order to evaluate the recognition accuracy rate for testing images.

CHAPTER 6
Conclusion and future work

This chapter aims to review the proposed solution of this study in relation to the proposed iris recognition system. The study has discussed developments carried out in the implementation of iris recognition systems and proposed solutions in the field of recognition systems.

In general, Iris is one of the most currently used traits for identifying a human due to its unique nature. This research has presented an approach of iris recognition system, which was tested using the CASIA database of greyscale eye images in order to verify the claimed performance of iris recognition technology. This research is mainly focused on extracting texture feature of an image using various techniques. HE and DCT are used for enhancing and extracting the feature from normalized iris image. Therefore the combination of these two techniques is most promising in terms of performance and accuracy. SVM is applied as a classifier. And then the result of this stage is compared against DWT, and LBP with SVM separately.

6.1. Summary of work

- Firstly, the Circular Hough Transform algorithm has been used which would localize the iris region from an eye image and isolate eyelid, eyelash and reflection areas.
- After that, the segmented iris region was normalized to eliminate dimensional inconsistencies between iris regions. The Daugman's rubber sheet model has been implemented for normalizing segmented iris image, where the iris is modeled as a flexible rubber sheet, which is unwrapped into a rectangular block with constant polar dimensions.
- The normalized iris image is processed to improve the quality of the image. For this reason, the HE technique is carried on the normalized iris image.
- Next, features of the iris were encoded by using three techniques, DCT, DWT, and LBP separately. The outputs of this stage in order to produce three biometric templates for each normalized iris image.
- Finally, SVM classifier has been utilized to classify the iris features.

- Furthermore, these techniques are applied on CASIA interval-v4 data set, which has a main role in the evaluation of the proposed system performance.
- The dataset is divided into training set and testing set. The classification results of the iris recognition system depend on the feature extraction algorithm. The results in Chapter 5 also show that the feature extraction can be a difficult stage in the iris recognition system because its success affects on iris matching.
- In order to evaluate the recognition accuracy rate, the recognition accuracy rate for testing images and False Reject Rate (FRR) were calculated. In the same context, the confusion matrix has been used. The results showed that all proposed techniques achieved different performances.
- The empirical testing of this proposed system conducted using MATLAB version R2014a showed that the combination of the two techniques HE and DCT with SVM as a classifier achieved good results compared to DWT and LBP.

6.2. Future work

Researches in the area of iris recognition systems are growing fast. Due to the continued spreading of using iris recognition system in several applications. The current work focuses on the feature extraction stage. In addition, various techniques have been applied to achieve optimal performance in this work. However, there are still a number of issues which need to be addressed. In below some points that related future works:

- Apply the proposed system on different databases such as UPOL, UBIRIS, and MMU and compare the obtained results with the results in this research.
- Combine more than one technique to extract the feature of iris such as LBP with Gabor filter and compare the results with the results obtained in this research.
- In order to produce impressive results, deep learning may be used in iris classification.
- In real-time recognition, the speed of the system would have to be considered. Speed was not one of the objectives for developing this work. Speed benefits could be made by implementing computationally intensive parts in Java or C++.

REFERENCES

Ahonen, T., Matas, J., He, C., & Pietikäinen, M. 2009, June. Rotation invariant image description with local binary pattern histogram fourier features. In *Scandinavian conference on image analysis* (pp. 61-70). Springer, Berlin, Heidelberg.

Akbar, S., Ahmad, A. and Hayat, M., 2014. Iris detection by discrete sine transform based feature vector using random forest. *J Appl Environ Biol Sci*, *4*, pp.19-23.

Anupama, B.L., 2017. A Novel Classifier for Gender Classification from Iris Code Used for Recognition. Central Library, 6(3), pp.325-331.

Baviskar, A., Baviskar, J., Mulla, A., Jain, N. and Dave, P. 2016, March. Coded sub band replacement DWT based space image compression. In 2016 IEEE Aerospace Conference (pp. 1-8). IEEE.

Boles, W.W. and Boashash, B., 1998. A human identification technique using images of the iris and wavelet transform. IEEE transactions on signal processing, 46(4), pp.1185-1188.

Britanak, V., Yip, P.C. and Rao, K.R. 2010. *Discrete cosine and sine transforms: general properties, fast algorithms and integer approximations*. Elsevier.

Canny, J., 1987. A computational approach to edge detection. In *Readings in computer vision* (pp. 184-203). Morgan Kaufmann.

Chen, Y., Liu, Y., Zhu, X., He, F., Wang, H. and Deng, N., 2014. Efficient iris recognition based on optimal subfeature selection and weighted subregion fusion. *The Scientific World Journal*, *2014*.

Chai, T.Y., Goi, B.M., Tay, Y.H. and Nyee, W.J., 2017, December. A Trainable Method For Iris Recognition Using Random Feature Points. In *2017 Conference on Technologies and Applications of Artificial Intelligence (TAAI)* (pp. 142-147). IEEE.

Chinese Academy of Sciences. CASIA Iris Image Database, 2018. Biometrics.idealtest.org. Retrieved 23 April 2018, from http://biometrics.idealtest.org/dbDetailForUser.do?id=4

Daugman, J., 2009. How iris recognition works. In *The essential guide to image processing* (pp. 715-739). Academic Press.

Deshpande, A. and Patavardhan, P.P., 2018. Feature Extraction and Fuzzy-Based Feature Selection Method for Long Range Captured Iris Images. In *Networking Communication and Data Knowledge Engineering* (pp. 137-144). Springer, Singapore.

Dhage, S.S., Hegde, S.S., Manikantan, K. and Ramachandran, S., 2015. DWT-based feature extraction and radon transform based contrast enhancement for improved iris recognition. *Procedia Computer Science*, *45*, pp.256-265.

Dillak. R, and Bintiri. M, 2016, A Novel Approach for Iris Recognition, Advances in Electronics Communication and Computer Technology (ICAECCT) 2016 IEEE International Conference on, pp. 231-236.

Duan, D., Xie, M., Mo, Q., Han, Z. and Wan, Y., 2010, October. An improved Hough transform for line detection. In *2010 International Conference on Computer Application and System Modeling (ICCASM 2010)* (Vol. 2, pp. V2-354). IEEE.

Hajari, K., Gawande, U. and Golhar, Y., 2016. Neural network approach to iris recognition in noisy environment. *Procedia Computer Science*, *78*, pp.675-682.

Hamd, M.H. and Ahmed, S.K., 2017. A Biometric System for Iris Recognition Based on Fourier Descriptors and Principle Component Analysis. *Iraqi Journal for Electrical And Electronic Engineering*, *13*(2), pp.180-187.

Hamouchene, I. and Aouat, S., 2014. A new texture analysis approach for iris recognition. *AASRI Procedia*, *9*, pp.2-7.

He, X., Wang, Z., Jin, C., Zheng, Y. and Xue, X., 2012. A simplified multi-class support vector machine with reduced dual optimization. *Pattern Recognition Letters*, *33*(1), pp.71-82.

He, F., Liu, Y., Zhu, X., Deng, W., Zhang, X. and Huo, G., 2013, November. The affection of gabor parameters to iris recognition and their optimization. In *Chinese Conference on Biometric Recognition* (pp. 330-337). Springer, Cham.

Gnana, P.R., Ravi, V.M. and Sriraam, K.M., 2018, May. Iris Recognition Using Visible Images Based on the Fusion of Daugman's Approach and Hough Transform.

In *Proceedings of the 2018 2nd International Conference on Biometric Engineering and Applications* (pp. 24-29). ACM.

Gragnaniello, D., Poggi, G., Sansone, C. and Verdoliva, L., 2016. Using iris and sclera for detection and classification of contact lenses. *Pattern Recognition Letters, 82*, pp.251-257.

Gupta, D. and Choubey, S., 2015. Discrete wavelet transform for image processing. International Journal of Emerging Technology and Advanced Engineering, 4(3), pp.598-602.

Gupta, M. and Garg, A.K., 2012. Analysis of image compression algorithm using DCT. *International Journal of Engineering Research and Applications (IJERA)*, *2*(1), pp.515-521.

Guo, Q. and Zheng, J., 2018, January. An Iris Recognition Algorithm for Identity Authentication. In *2018 International Conference on Intelligent Transportation, Big Data & Smart City (ICITBS)*,pp. 621-624. IEEE.

Jain, A.K., Flynn, P. and Ross, A.A. eds., 2007. *Handbook of biometrics*. Springer Science & Business Media.

Joachims, T., 1998, April. Text categorization with support vector machines: Learning with many relevant features. In European conference on machine learning (pp. 137-142). Springer, Berlin, Heidelberg.

Khotimah, C. and Juniati, D., 2018, January. Iris Recognition Using Feature Extraction of Box Counting Fractal Dimension. In *Journal of Physics: Conference Series* (Vol. 947, No. 1, p. 012004). IOP Publishing.

Kulkarni, S.B., Shweta, S., Hegadi, R.S. and Kulkarni, U.P., 2013. Iris Recognition using Fusion of Gray Level Co-occurrence matrix and Gray Level Run Length Matrix. In *International Conference on Signal and Information Processing (ICSIP-2013) Bangalore* (pp. 241-246).

Kumar, D.S., Raja, K.B., Nuthan, N., Sindhuja, B., Supriya, P., Chhotaray, R.K. and Pattnaik, S., 2011, October. Iris recognition based on DWT and PCA. In *2011 International Conference on Computational Intelligence and Communication Networks* (pp. 489-493). IEEE.

Lawgali, A., Bouridane, A., Angelova, M. and Ghassemlooy, Z., 2011. Handwritten Arabic character recognition: Which feature extraction method?. *International Journal of Advanced Science and Technology*, *34*, pp.1-8.

Li, C., Zhou, W. and Yuan, S., 2015. Iris recognition based on a novel variation of local binary pattern. The Visual Computer, 31(10), pp.1419-1429.

Li, Z., 2017, March. An Iris recognition algorithm based on coarse and fine location. In 2017 IEEE 2nd International Conference on Big Data Analysis (ICBDA)((pp. 744-747). IEEE.

Lim, S., Lee, K., Byeon, O. and Kim, T., 2001. Efficient iris recognition through improvement of feature vector and classifier. ETRI journal, 23(2), pp.61-70.

Luhadiya, R. and Khedkar, A., 2016, December. Iris detection for person identification using multiclass svm. In *2016 IEEE International Conference on Advances in Electronics, Communication and Computer Technology (ICAECCT)* (pp. 387-392). IEEE.

Manjunath, M. and Raja, K.B., 2013. A Novel Approach for Iris Recognition using DWT&PCA. *International Journal of Advanced Networking and Applications*, *5*(1), p.1830.

Masek, L., 2003. Recognition of human iris patterns for biometric identification (Doctoral dissertation, Master's thesis, University of Western Australia).

Mrinalini, I.R., Pratusha, B.P., Manikantan, K. and Ramachandran, S., 2015, February. Enhanced Iris Recognition using discrete cosine transform and radon transform. In *2015 2nd International Conference on Electronics and Communication Systems (ICECS)* (pp. 1-6). IEEE.

Mozumder, A.I. and Begum, S.A., 2016, December. An efficient approach towards iris recognition with modular neural network match score fusion. In *2016 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)* (pp. 1-6). IEEE.

Multimedia-University. MMU Database 2018. Retrieved 23 April 2018, from http://pesona.mmu.edu.my/~ccteo/.

Nalepa, J. and Kawulok, M., 2018. Selecting training sets for support vector machines: a review. *Artificial Intelligence Review*, pp.1-44.

Ng, T.W., Tay, T.L. and Khor, S.W., 2010, July. Iris recognition using rapid Haar wavelet decomposition. In *2010 2nd International Conference on Signal Processing Systems* (Vol. 1, pp. V1-820). IEEE.

Nigam, A., Kumar, B., Triyar, J. and Gupta, P., 2015, September. Iris Recognition Using Discrete Cosine Transform and Relational Measures. In *International Conference on Computer Analysis of Images and Patterns* (pp. 506-517). Springer, Cham.

Nirgude, M. and Gengaje, S., 2017. Iris Recognition System based on Multi-resolution Analysis and Support Vector Machine. International Journal of Computer Applications, 975, p.8887.

Nguyen, K., Fookes, C., Ross, A. and Sridharan, S., 2018. Iris recognition with off-the-shelf CNN features: A deep learning perspective. *IEEE Access*, *6*, pp.18848-18855.

Ojala, T., Pietikäinen, M. and Mäenpää, T., 2002. Multiresolution gray-scale and rotation invariant texture classification with local binary patterns. IEEE Transactions on Pattern Analysis & Machine Intelligence, 24(7), pp.971-987.

Okokpujie, K., Noma-Osaghae, E., John, S. and Ajulibe, A., 2018. An improved iris segmentation technique using circular Hough transform. In *IT Convergence and Security 2017* (pp. 203-211). Springer, Singapore.

Patil, P.S., Kolhe, S.R., Patil, R.V. and Patil, P.M., 2012. The comparison of iris recognition using principal component analysis, Log Gabor and Gabor wavelets. *International Journal of Computer Applications, 43*(1), pp.29-33.

Pato, J. And Millett, L., 2010 *Biometric Recognition: Challenges and Opportunities*, 1st ed. Washington, D.C: the National Academics Press, 2010, p. 182.

Pedersen, S.J.K., 2007. Circular hough transform. Aalborg University, Vision, Graphics, and Interactive Systems, 123(6).

Pietikainen, M., Hadid, A., Zhao, G. and Ahonen, T., 2011. Local binary patterns for still images. In *Computer vision using local binary patterns* (pp. 13-47). Springer, London.

Proenca, H., Filipe, S., Santos, R., Oliveira, J. and Alexandre, L.A., 2010. The biris. v2: A database of visible wavelength iris images captured on-the-move and at-a-distance. IEEE Transactions on Pattern Analysis and Machine Intelligence, 32(8), pp.1529-1535.

Rabie, T. and Kamel, I., 2016. On the embedding limits of the discrete cosine transform. *Multimedia Tools and Applications*, *75*(10), pp.5939-5957.

Rai, H. and Yadav, A., 2014. Iris recognition using combined support vector machine and Hamming distance approach. *Expert systems with applications*, *41*(2), pp.588-593.

Ramya, M., Krishnaveni, V. and Sridharan, K.S., 2017. Certain investigation on iris image recognition using hybrid approach of Fourier transform and Bernstein polynomials. *Pattern Recognition Letters*, *94*, pp.154-162.

Rana, H. Azam, M and Rashida,M., 2017 Iris Recognition System Using PCA Based on DWT. SM J Biometrics Biostat, 2(3), 1015.

Rani, N. and Bishnoi, S., 2014. Comparative analysis of image compression using DCT and DWT transforms. *International Journal of computer Science and Mobile Computing*, *3*(7).

Rizk, M.R., Farag, H.H. and Said, L.A., 2016, March. Neural network classification for iris recognition using both particle swarm optimization and gravitational search algorithm. In *2016 World Symposium on Computer Applications & Research (WSCAR)* (pp. 12-17). IEEE.

Salve, S.S. and Narote, S.P., 2016, March. Iris recognition using SVM and ANN. In *2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)* (pp. 474-478). IEEE.

Saminathan, K., Chakravarthy, T. and Devi, M.C., 2015. Iris recognition based on kernels of support vector machine. *ICTACT J. Soft Comput.*, *5*(2), pp.889-895.

Savithiri, G. and Murugan, A., 2011. Performance analysis on half iris feature extraction using GW, LBP and HOG. *International journal of computer applications*, *22*(2), pp.27-32.

Senior, K.R. ed., 2010. The eye: the physiology of human perception. The Rosen Publishing Group, Inc.

Shaik, M., 2018. Improved Normalization Approach for Iris Image Classification Using SVM. In *Advances in Electronics, Communication and Computing* (pp. 139-145). Springer, Singapore.

Sharkas, M., 2016, July. A neural network based approach for iris recognition based on both eyes. In *2016 SAI Computing Conference (SAI)* (pp. 253-258). IEEE.

Smart-Sensor-Ltd. BATH Iris Database 2018. Retrieved 23 April 2018, from http://www.smartsensors.co.uk/products/iris-database/.

Srivastava, G. and Rawat, T.K., 2013, August. Histogram equalization: A comparative analysis & a segmented approach to process digital images. In 2013 Sixth International Conference on Contemporary Computing (IC3) (pp. 81-85). IEEE.

Stanković, R.S. and Falkowski, B.J., 2003. The Haar wavelet transform: its status and achievements. *Computers & Electrical Engineering*, *29*(1), pp.25-44.

Tan, C.W. and Kumar, A., 2014. Accurate iris recognition at a distance using stabilized iris encoding and Zernike moments phase features. *IEEE Transactions on Image Processing*, *23*(9), pp.3962-3974.

Tisse, C.L., Martin, L., Torres, L. and Robert, M., 2002, May. Person identification technique using human iris recognition. In Proc. Vision Interface (Vol. 294, No. 299, pp. 294-299).

University-of-Palackeho-and-Olomouc . UPOL Iris Database, 2018. Retrieved 23 April 2018, from http://phoenix.inf.upol.cz/iris/.

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

Xiaoyin, Z., 2010. *Efficient architecture for discrete wavelet transform using daubechies* (Doctoral dissertation).

تحليل أداء تقنيات استخلاص الميزة لنظام التعرف على قزحية العين

قدمت من قبل:

أمينة عطية عبـدو

تحت إشراف:

د. أحمد الأوجـلـي

الخلاصــة

تستخدم الحكومات والشركات والمنظمات نظم المقاييس الحيوية على نطاق واسع لتحديد الأشخاص استناداً إلى شخصياتهم البيولوجية. والغرض الرئيسي من استخدام هذه النظم هو تحسين أمن النظم، ولكن يمكن استخدامها أيضا للحصول على مزيد من المعلومات عن الأفراد. يتم استخدام بعض السمات الحيوية للمصادقة على هوية الشخص مثل الوجه والبصمة والكتابة اليدوية والتوقيع والصوت والحمض النووي والأذن. ومن بين أكثر الطرق سرعة وتطورًا في تحديد الهوية بواسطة القياسات الحيوية هو التعرف على بصمة العين ؛ حيث أن القزحية البشرية تتمتع بملمس فريد يتضمن حقيقة التفاصيل. وقد اكتسب التعرف على بصمة العين تحدياً للعديد من الباحثين. تَحدث العديد من التحديات بسبب الأخطاء في طريقة التقاط الصور، الإضاءة الضعيفة، أبعاد الصورة، القزحية خارج الزاوية، إلخ. وقد اعتمد الباحثون أساليب مختلفة لتحسين وزيادة أداء التعرف على بصمة العين.

تتضمن معظم أنظمة التعرف على بصمة العين عمليات قبل مرحلة استخراج الميزات؛ أولا، مرحلة ما قبل المعالجة التي يتم إجراؤها لتحسين منطقة الاهتمامات فقط وتتضمن التجزئة والتطبيع. يتم استخدام التجزئة لتحديد موقع منطقة القزحية الصحيحة وتم تطبيق تقنية (CHT) Circular

Hough Transformلهذه المرحلة. في مرحلة التطبيع، تحول منطقة القزحية إلى شـكل مناسـب بأبعاد محددة. تم استخدام نموذج Daugman’s Rubber Sheet لإعادة ضبط كل نقطة داخل منطقة القزحية إلى زوج من الإحداثيات القطبية. وأخيرا، لتحسين صورة القزحية الطبيعية، تم تطبيق تقنية Histogram Equalization لتسهيل تطبيق خطوة استخراج الميزة.

في هذا البحث، يهمنا تحقيق دقة عالية لنظام التعرف على بصــمة العين البشــرية. لقد قدمنا نهج الجمع بين تقنيات (HE) Histogram Equalization و Discrete Cosine Transform (DCT) لتحسـين واسـتخراج الميزات مع (SVM) Support Vector Machine كمصـنف. ثم قيّم هذا مقابل (LBP) Local Binary Pattern و(DWT) Discrete Wavelet Transform مع SVM.تم تنفيذ هذا النهج باســـتخدام MATLAB version R2014a. للتحقق من نهجنا، اســتخدمنا قاعدة بيانات عامة مجانية للقزحية (CASIA interval-v4). وتوضــح التجارب التي أجريت على CASIA interval-v4 أن أداء نهجنا أفضل DWT وLBP مع SVM.

تحليل أداء تقنيات استخلاص الميزة لنظام التعرف على قزحية العين

قدمت من قبل:

أمينة عطية عبـدو

تحت إشراف:

د. أحمد الأوجـلـي

قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في علوم الحاسوب

جامعة بنغازي

كلية تقنية المعلومات

2020