KARZAN RASHAD HAMAD

FACE RECOGNITION USING LOCAL BINARY PATTERN AND DISCRETE WAVELET TRANSFORM

NEU
2019

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES
OF
NEAR EAST UNIVERSITY

By

KARZAN RASHAD HAMAD

In Partial Fulfillment of the Requirements for

the Degree of Master of Science

in

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Approval of Director of Graduate School of Applied Sciences

Prof. Dr. Nadire CAVUS

We certify this thesis is a satisfactory for the award of degree of Master of Science in Computer Engineering

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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Signature:
Date:

ACKNOWLEDGEMENTS

First and foremost, I want to thank God for this fantastic chance which gave me to start a master study in computer engineering

I would like to thank my supervisor Prof. Dr. Rahib H.ABIYEV, for his encouragement, support and guidance, and special thanks to Dr. Raber Rashid, who was helping me like a brother throughout the research.

I would like to thank Prof. Dr. Nadire Cavuş, she has been very helpful through the duration of my thesis.

I dedicate this thesis to my beloved grandparents, parents, my dearest father and my lovely mother, my lovely wife, my lovely girls, my lovely son, brothers and sisters, for their unconditional support and love. I love you all.

Among the people, I would like to specially deliver my sincere gratitude to my friends; Muhammad Saeed, Dr.Osman Saleh, Ahmed Saleh, Dr. Omed Salim, Shakhawan Talaat, Haval Rostam, Sangar Saleh, Ranjdar Kamaran, Dana Ahmed, Hiwa Mawlana, Muhammed Kamal, Aram Ismael, Shakhawan Farhad, Balin Babaker, Aram Nabi and Suzan Sulaiman.

At last, it is an honor for me to offer my gratitude to the Gasha Institute, Erbil for giving me this magnificent opportunity to undergo for my master's degree program.

To my parents (Rashad and Nakhshin), my lovely wife (Awaz) and my children…

ABSTRACT

Face recognition is the practice of recognizing a person based on an image of their face and is now turned into a prominent avenue of research. This technique allows the use of a person's facial images to validate them to a secure system, criminal identification, passport verification, monitoring, and so on. Face recognition is now incorporated into a number of study fields such as machine visibility, pattern recognition, bioinformatics, etc., and is known as a potential research area. The main problem with face detection is how to accurately find the best attribute for face detection. A considerable number of innovative features extraction algorithms exist; they chiefly include three aspects: face geometry, face and statistical characteristics. As the name carries it, face recognition method uses images of people’s faces as its primary source of investigation to identify individuals through digital images and video frames. Hence, proposed algorithms can be either one of geometric feature-based or appearance-based.

In this thesis, Local Binary Pattern (LBP) and Discrete Wavelet Transform (DWT) are used and implemented to obtain the feature of images by using ORL and Yale databases. Face will be characterized as recognized or unrecognized face after matching with the already saved dataset. We apply DWT and LBP on the input face images which provide us high performance and clearer image compared to other algorithms. Simulations results in this work showed that the proposed approaches based on DWT and LBP was achieved very high accuracy performance.

Keywords: Biometric Systems; face recognition; feature extraction algorithms; discrete wavelet transform; local binary pattern

ÖZET

Yüz tanıma, bir insanın yüzlerinin görüntüsüne dayanarak tanınma pratiğidir ve şimdi önemli bir araştırma alanına dönüştürülmüştür. Bu teknik, bir kişinin yüz görüntülerinin, onları güvenli bir sisteme, suç tanımlamasına, pasaport doğrulamasına, izlenmesine vb. Doğrulamak için kullanılmasına izin verir. Yüz tanıma şimdi makine görünürlüğü, örüntü tanıma, biyoinformatik vb. Gibi bir dizi çalışma alanına dahil edilmiştir ve potansiyel bir araştırma alanı olarak bilinir. Yüz algılama ile ilgili temel sorun, yüz algılama için en iyi özniteliğin nasıl doğru bir şekilde bulunacağıdır. Önemli sayıda yenilikçi özellik ekstraksiyon algoritması mevcuttur; Genel olarak üç yönü içerirler: yüz geometrisi, yüz ve istatistiksel özellikler. Adını taşıdığı için, yüz tanıma yöntemi dijital görüntü ve video kareleri aracılığıyla bireyleri tanımlamak için birincil soruşturma kaynağı olarak insanların yüzlerinin görüntülerini kullanır. Bu nedenle, önerilen algoritmalar ya geometrik özellik tabanlı ya da görünüm tabanlı biri olabilir.

Bu tezde, ORL ve Yale veri tabanları kullanılarak görüntülerin özelliğinin elde edilmesi için Ayrık Dalgacık Dönüşümü (DWT) ve Yerel İkili Kalıp (LBP) kullanılmıştır. Yüz, önceden kaydedilmiş veri kümesiyle eşleştikten sonra tanınan veya tanınmayan yüz olarak karakterize edilecektir. DWT ve LBP'yi, diğer algoritmalara kıyasla yüksek performans ve daha net görüntü sağlayan giriş yüzü görüntülerine uyguluyoruz. Bu çalışmada elde edilen simülasyonlar, DWT ve LBP'ye dayalı önerilen yaklaşımların çok yüksek doğruluk performansı elde edildiğini göstermiştir.

Anahtar Kelimeler: Biyometrik Sistemler; yüz tanıma; özellik ekstraksiyon algoritmaları; ayrık dalgacık dönüşümü; yerel ikili desen

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LIST OF ABBREVIATIONS

2D:	Two Dimensional
2D-DWT:	Two-Dimensional Discrete Wavelet Transform
3D:	Three Dimensional
ORL:	Olivette Research Laboratory
LBP:	Local Binary Pattern
DWT:	Discrete Wavelet Transform
LDA	Linear Discriminant Analysis
PCA	Principal Component Analysis
KNN	k-Nearest Neighbor
HL:	High pass Low pass sub-band
HH:	High pass High pass sub-band
LL:	Low pass Low pass sub-band
LH:	Low pass High pass sub-band
GUI:	Graphical User Interface
SURF:	Speeded-Up Robust Features
SIFT:	Scale-Invariance Feature Transform

CHAPTER 1
INTRODUCTION

1.1 Overview

Nowadays, computer security is considered significantly in the world. The technical term of Biometrics is crucially recommended in computer security. The human natural properties such as iris, hand geometry, voice, face and fingerprints, are called biometrics. These components allow the authentication for authorized users and let them pass the security system of computer. The function of these systems of security is applicable at distinct areas such as passport, banking, smart cards, credit cards, access control, PIN and network security which identifies the user according to a password and a username. Using any one of biometric aspects provides an advantage for changing the username and passwords (Sonkamble, et al., 2010).

1.2 Biometric Systems

The Biometrics system confirms ones live depend on the physiological properties which are unique inside human body. Biometrics are known to be the safest and the most trustworthy authentication techniques because it cannot be forgotten, theft or varied due to being unique and belonging to human, when it's established first. Any Biometric system composed of a set of basic components which are: a device or a system for the delivering of the persons either digital image or video scanning, saving the images in our device to be ready for processing and then a system and a comparison with using a GUI for authenticating the user. Fingerprint is the most significant physiological property that human body owns (FATHE, 2014).

Through using physical characteristics, Biometric System will be able to know and either recognizes the user or not. The two main categories are grouped for this feature:

1. Physiological traits: are a person's whole static data which obtained from iris pattern, fingerprints, face image or a shape of the hand pattern.

2. Behavioral traits: are a human’s specific actions style, it can be audio track, his writings and the style he presses and pounds the keyboard.

The physiological traits are not like behavioral traits which are changing frequently and need update frequently as well, in fact most of physiological parts are not changing in a big ratio with passing time but slightly. The identification and the recognition are the main task of the biological system thus identifying different individuals and subjects (FATHE, 2014).

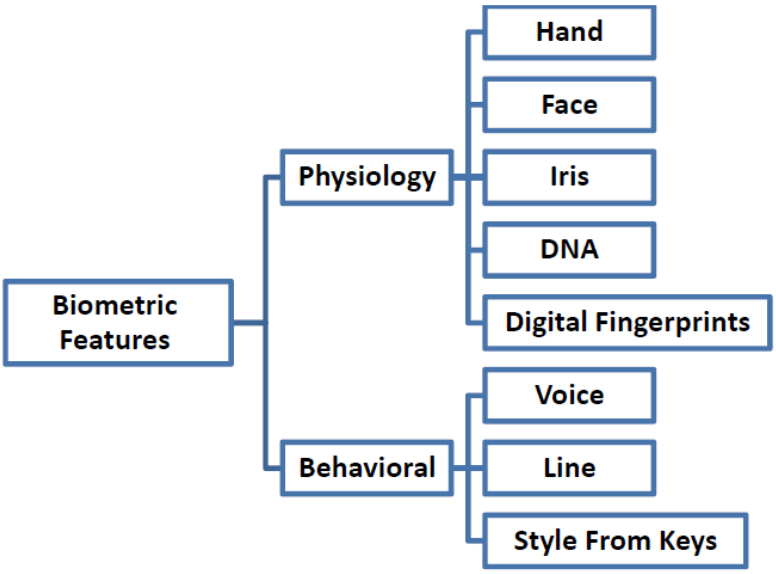

Figure 1.1: Biometric Features (FATHEL, 2014)

Recognition or identification systems hold a couple of different meanings:

1. Identity verification: is identifying the subject or the person and assuring either the person is the real person whom he shows to be Figure 1.2.a.

2. Recognition of identities: Its responsible for showing either the person is matching with any existing subject or instance inside the system or archive. It is not a must to show the matching and declaring the identity as shown in Figure 1.2.b.

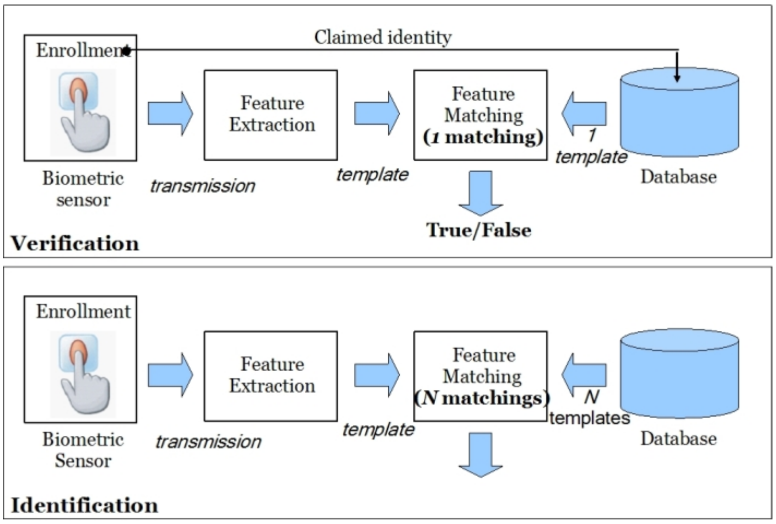

Figure 1.2: Biometric Systems (a) verification, (b) identification (FATHEL, 2014)

Biometrics are systems of identification which extrapolate different types of information from the human body, relying on a specific feature to create a good system is not logical, but either using different traits to build a system with less mistakes and more dependable (FATHEL, 2014).

1.3 Biometric Classifications

A comparison can be done through all the biometric systems listed below in Figure 1.3 to find the efficiency and applicability of that application and to observe more on it. So, to build an application for a biometric which is easy to used, applicable, foremost safe and efficient it needs an in-depth analysis of the features of that biometric system to create the required application for it (Jain el al., 2006).

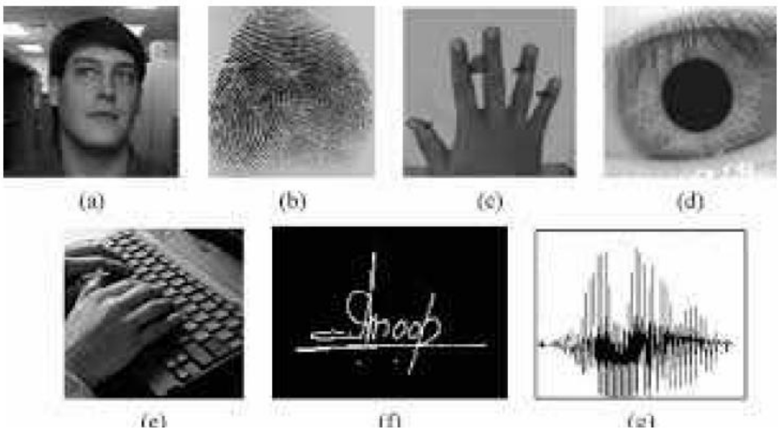

Figure 1.3: Biometrics examples (Jain el al., 2006)

In fact, the meaning of Biometric is “life measurement”. As it’s known, there are many biometric systems and applications available around. These biometrics work on the unique physiological features of human, thus identifying a person by its biometric features. Still, there is no decision of the biometric application to be optimal. In below, we have summarized different biometric applications according with a brief introduction about them (Arulalan, el al., 2014).

1.3.1. Hand Geometry

Human being uses their hands to do their daily works, but at the same time these hands are such unique in thickness, width, length and most importantly curvatures, that can be used to identify and recognize the owner (Huopio, 1988).

Figure 1.4: Hand geometry biometric devices (Huopio, 1988)

1.3.2. Iris Recognition

Iris recognition has the highest accuracy among other biometric systems including fingerprint as well. The ratio of its accuracy is even increasing with knowing that it’s very difficult or near to impossible to alter, manipulate the iris inside eyes, either through contact lenses, glasses or surgery. It’s also important to mention that the identification process in iris recognition is simple and as possible as the other identification systems. As its seen now a day, iris recognition application has been used in many airports, banks, governmental authentications and also in automated teller machine. Iris recognition is highly efficient but the person has to be very near to the recognition system (Kolb et al., 2005).

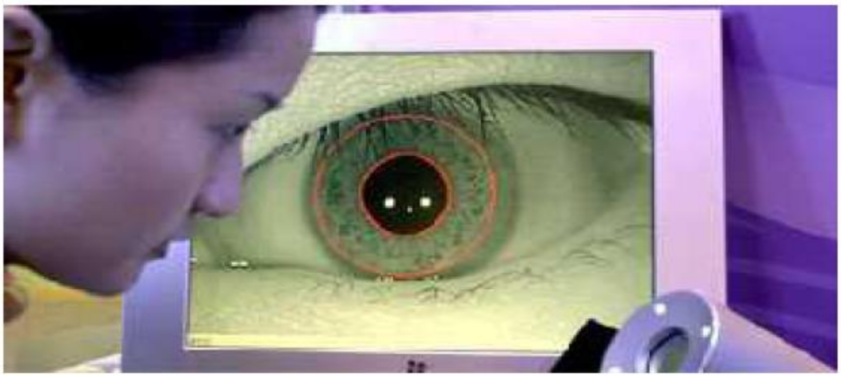

Figure 1.5: Iris manipulations (Kolb et al., 2005)

Iris of the right eye is different from the left eye in the same human, which somehow makes the system to be more secure. Also, iris of a human being doesn't change after the two years of birth, so through life the one person's iris is not changing, thus iris identification systems don't need the renewing of the database. It also worth mentioning that, the efficiency and accuracy of the scanning system of iris recognition is much faster than the other identification systems such as finger, retina or palm print (FATHEL, 2014).

1.3.3 DNA Recognition

Except the twin children all person DNA which stands for Deoxyribonucleic Acid is a unique one-dimensional strand code that is differ from all people around even father, mother or other brothers. No two people has the same DNA in the world. This system now a day is mostly used for forensic applications in recognizing the person who owns the DNA (Rohs et al., 2009).

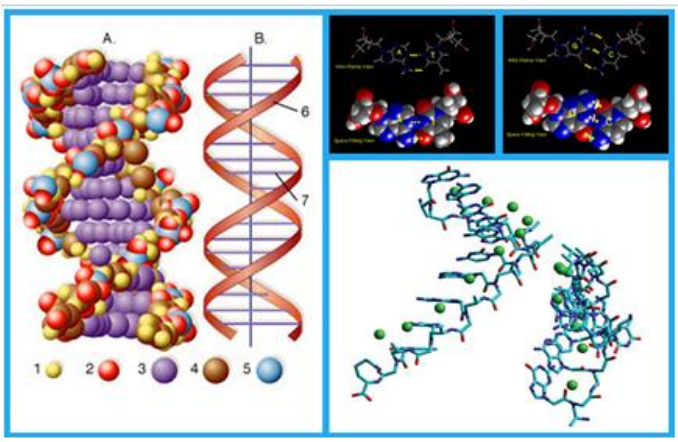

Figure 1.6: DNA recognition (Rohs et al., 2009)

1.3.4. Fingerprint Recognition

One of the most common and widely used personal identification systems is fingerprint recognition. As other identification systems it’s been used for the recognition and authentication of the user. The features here are the formation and lines on the surface of human fingertips. Scanner will scan the fingertips and according the user will be authenticated or either not allowed compared to the stored samples inside the application database (Jiang and Yau, 2000).

Figure 1.7: Fingerprint Minutiae (Jiang and Yau, 2000)

1.3.5. Voice Recognition

Voice has both biometric properties of behavioral and physiological. Physiological properties do not change through time which means it’s a unique property special related to that person but behavioral property of voice changes frequently through time, age, illness and emotional state as well. Although voice is considered as a biometric system and can be used for the identification but the level of voice is not stable which makes the voice identification not be so accurate (Arulalan, el al., 2014).

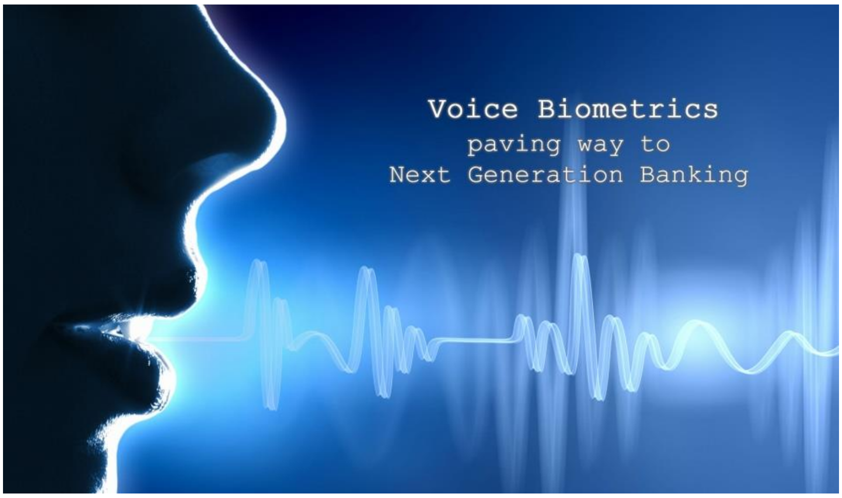

Figure 1.8: Vocal apparatus (Arulalan, el al., 2014)

1.3.6. Signature Recognition

The identification allows or denies according to the letter of the name of the person who signed, the drawing pattern or the curve the person makes during the signature and certain line or angles of the signature as well. The altering of any of the mentioned properties makes identification system deny the allowance or the sameness of the two signatures (Merkle, 1990, January)

Figure 1.9: Electronic tablet (Merkle, 1990, January)

1.3.7 Face Recognition

Human being identifies others through face recognition. The first thing a human being looks at when tries to recognize either an object, animal or a human being is their faces. We certainly cannot recognize others with fingerprints, palm print, iris or retina. Researches show that after looking at faces of the person, human being look at parts of the body that are unusual or have different sizes or shapes than normal people around like aquiline nose, big ears, and etc. … and less than these parts, will look at internal features like mouth, nose iris, hair, and head shape (Kroeker, 2009).

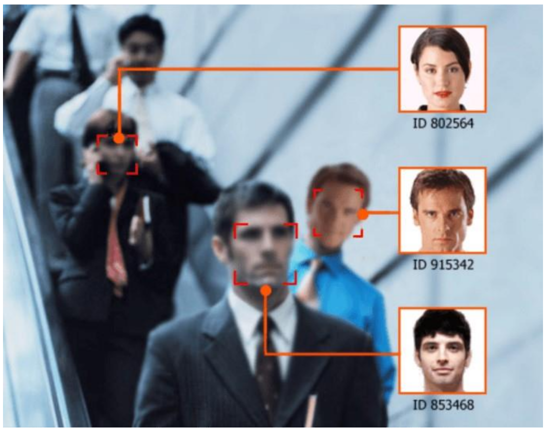

Figure 1.10: Face recognition (Kroeker, 2009)

The computer program that tries to identify and recognize a person through a face image or a video stream that contains the face of a person is known as face recognition or facial identification system. The technique of recognizing a person through an image or a frame from a video stream is by comparing the taken image with the all the facial images database of the system, if the input image has the same or near to the same of the features or the spatial geometry, of the face of one of the objects inside the facial database, the system will accept it as a recognized image. This cheap technology is well used all around in identifying criminal, terrorists, burglar and etc. Due to the effect of aging, curves, disease and other things on changing the face of a human, and because the face recognition system is used for identification, recognition and verification, so the complexity of the implementation of an optimum face recognition system is still a challenging issue (Ameen, 2016).

The face recognition system composed of five main stages starting from either extracting the face image from a video stream or having an input still image, then the location of the face is determined, afterwards an analysis is done to the facial image and features are extracted to be compared to the database, at last the comparison and matching process is done. Then the result is either match or no match is found. Face recognition application may work on a single face image, range to a multiple face such as airports. Facial recognition may work on two mechanisms, either the shape, location of face features like nose, eyes, eyebrows, lips and the spatial relationship between them or the face image's total analysis which shows a face as a weighted combination of number of canonical faces (Ameen, 2016).

Four main steps build up a face recognition system that are: face detection, preprocessing, face feature extraction and feature matching. The steps are shown in the following diagram of Figure 1.1. which describes the steps of face recognition (Ameen, 2016)?

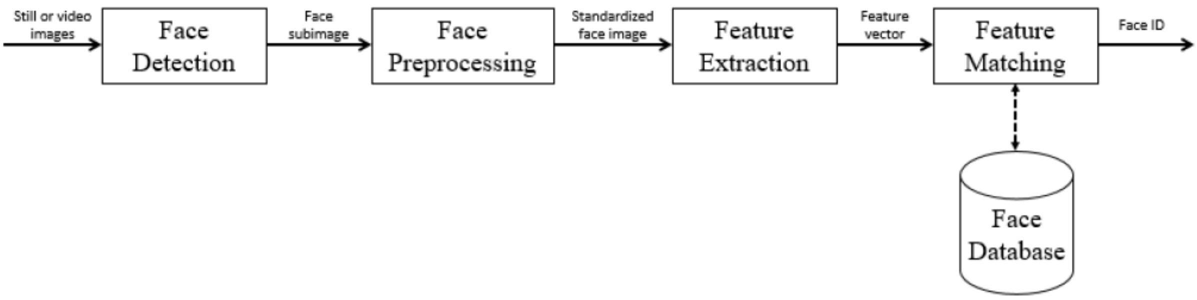

Figure 1.11: The four general steps in facial recognition (Ameen, M. M. 2016)

1.3.6.1. Face Detection

Localization of the face images is the main point in the face detection. In having a video stream input, it tracks the face images in different frames which in case reduces the time used for computation and the identity of the face images will be preserved between different frames.

1.3.6.2. Face Preprocessing

In order to get a better feature extraction this step is applied which affects in stabilizing the face detection step output. Depending on the application, different processes occurred in preprocessing step, such as; illumination correlation, illumination normalization, and alignment (scaling, rotation, translation).

1.3.6.3. Feature Extraction

Different algorithms are used in feature extraction step such as LDA, DWT, PCA, SIFT, SURF, LBP … Finding and extracting stable, solid key point and discriminating feature on the image is the aim of this step.

1.3.6.4. Feature Matching

The comparison and finding matching points between trial and test images are done in this step. This step matches the feature vectors taken from the input image with the feature vectors of the images which are stored in the database we have. Different algorithms have been used which are vary from the most common and easiest of knn (k-Nearest Neighbor) to the difficult algorithm such as Neural Networks.

Advantages of Face Recognition

a. The biometric works with legacy photograph databases, video tape and other image sources.
b. It is a good biometric identifier for small-scale verification application.
c. Face recognition systems are the least intrusive because they neither require contact nor the awareness of the subject (Deokar and Talele, 2014).

Disadvantages of Face Recognition

a. The blockage of face by glasses, hair, hats, etc. and easy to change under illuminations, and through different face expressions and gestures.
b. Aging of face through time.

c. In the systems of automated face authentications it needs a good illumination sources for the face to be seen fine (Deokar, and Talele, 2014).

Table 1.1

Comparison of biometric technologies, the data is based on the perception of the authors. High, Medium, and Low are denoted by H, M, and L, respectively. (Yun, 2002).

Factors / Biometric Identifier	Universality	Distinctiveness	Presentence	Collectable	Performance	Acceptability	Circumvention
Hand Geometry	M	M	M	H	M	M	M
Iris	H	H	H	M	H	L	L
Face	H	H	M	H	L	H	H
Voice	M	L	L	M	L	H	H
Fingerprint	M	H	H	M	H	M	M
Signature	L	L	L	H	L	H	H
DNA	H	H	H	L	H	L	L

1.4 Problem Definition

Basically, the whole problem is expressed as below: given an image of an individual face image, identify subject using an enrolled database of face images.

Face recognition is one of the difficult problems because of the overall similar shape of faces combined with many differences between images of the same face. Recognition of face images taken from a wild environment is a very complex and difficult process: illumination condition may change with a big difference; face shapes and expressions are also differing from time to time; face may appear at diverse directions. Furthermore, depending on the type of application, handling and extracting face aging should be required.

Although existing applications and algorithms perform well under controlled environments, the difficulties with the performance and recognition rate still remained unsolved. The proposed approach, tries to increase performance rate of recognition over the conventional algorithms.

Since the algorithms and methods that are used and available in the face recognition applications might rely on the task and job of the system, there are two general classes of face recognition that can be identified:

1. Finding an individual within a large database of face images.
2. Identifying specific people in real time like tracking systems.

In this thesis, we mainly focus on the first task. Our goal is to provide a better performance in recognizing the correct faces from all subjects in the database.

1.5 Thesis Outline

The rest of the thesis is organized as follows:

Chapter Two, Feature extraction algorithms that are being used in proposed approach were given in detail. The working mechanism and properties of these feature descriptors are discussed.

Chapter Three, Presents the detailed methodology followed in carrying out the work and the explanation of the proposed approaches. The feature extraction algorithms used and transformation algorithms were also discussed.

Chapter Four, gives the simulations results and comments on every result obtained. This chapter also covers the general discussion of results.

Chapter Five, include the general conclusions and potential directions for future research work.

CHAPTER 2
FEATURE EXTRACTION ALGORITHMS

2.1 Overview

For the purpose of classification and analysis a process takes place which is known as feature extraction that finds the important features and properties that represents the information. In image retrieval, the color of the image is one of the most common features used. To describe it, a color model is used which shows a good representation of the colors. Common and most used color models that are used nowadays are RGB and HSV which stands for (red, green, blue) and (hue, saturation, value) respectively. In visual recognition, one of the most important features is texture. It can be described with many different terms like grainy, flat, smooth, uneven, even, uniform and random. For extracting features in the edges, shapes are used. In order to be experimented in the image database, an image contour should be detected from face edge determination (Vijayarani and Priyatharsini, 2015). Main goal in feature extraction is to extract important key points and both geometrical and photometrical interpersonal discriminating features within the face (Kaur and Kaur, 2016).

For the purpose of reducing dimensionality and representing the real image with important key points or determining important image parts with large efficiency in the face, feature extraction is beneficial, after all the important key points are all represented as a compact feature vector. For the large image cases this will be very useful. Generally, it cannot be said which feature extraction algorithm is the best among all the others. It's always according to some criteria that the best and the most useable algorithm is chosen for your solution, which are dependent on:

(1) The exact task its needed and used for (2) either the method used is supervised or unsupervised (3) The algorithm which is needed to perform our task is a less computational method or a strong computational method etc.

Dimensionality reduction is the key base for feature extraction, this is done through picking most different or dominant features which represents the face image most properly less differ from the original image which is called as having less distortion. Different algorithms have been proposed to pick the most important features from the relevant patterns. In fact, representing the face image is done in two techniques: first technique is applied to the whole face image by determining the appearance texture features (holistic). The second technique is applied on the linear relationship between the parts of the face such as mouth, eyes and nose and known as component-based technique. This second approach is done by using some specific facial points, then extract the features around each point by using a bank of filters which characterizes these points well (Agrawal, 2016).

In fact, first approach which affects the whole face image is more interesting and has more importance than component-based approach. Here in this study both LBP & DWT are used and studied briefly for the extraction of face image feature points.

2.2. Local Binary Pattern (LBP)

It's the measure of invariant texture for gray-scale images, in fact it's obtained from overall meaning of texture in a local area(neighborhood). In various applications such as outdoor scene analysis, visual inspection, remote sensing, image retrieval, biomedical image examination, location modeling and motion analysis, LBP texture operator is popularly been used because of its computational simplicity and discriminative power. LBP also gives marvelous results in analyzing and showing faces in both video sequences and still images (Hadid, 2008).

First Ojala et al introduced LBP in 1996, and described this approach as well-arranged set of binary comparison for pixel intensities happened between the surrounding of the pixel and the center of the pixel. This approach mostly used to extract useful and unique features from images before processing in preprocessing stage and it's the most up-to-date method for face recognition. LBP makes it likely for scientists to define the digital image shape and its texture. LBP gives each pixel of an image a code which comes from the conversion of the binary code to decimal code (Ali et al., 2012).

First of all, the image is divided into many small blocks to let the features be extracted. After this step, the LBP histogram is calculated for each small blocks of the features which have been obtained. Then, all the histograms that are obtained are combined to become one concatenated vector. In fact, the similarity (distance) for the histogram of images is the comparison between the images. Many researches and studies are showing the significance working of LBP in face recognition for different face expressions, aging of persons, image rotation and different lightening conditions. Also, the discrimination performance and its speed is very good and worth's to mention (Ali et al., 2012).

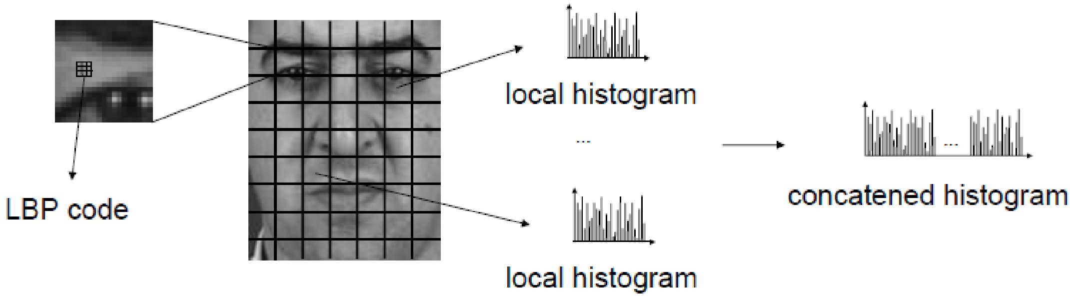

Figure 2.1: LBP description of the face (Marcel et al., 2007)

LBP represents information in three levels (Figure 2.1): (1) local histograms are labeled in LBP (pixel level), (2)local histograms(region level) and then (3) a nice and global description of the image is built from the concatenated histogram (image level). Initially, LBP was created for face verification and face recognition, so it's been used in many applications worldwide. In the past few years, and still, LBP is undergoing many different improvements and extensions to be more robust (Marcel et al., 2007).

2.2.1. Uniform Local Binary Pattern

Uniform LBP is a special case version of LBP. The property of having maximum two bitwise transition in the LBP descriptor makes uniform LBP special which are zero to one or vice versa. It's impossible for the LBP descriptor to have the occurrence of only one transition, because the given binary string is known to be circular.

Simply this indicates of having either nothing or having two transitions. If we are giving examples for zero bitwise and two bitwise transitions in uniform LBP, we see 11111111 and 10001111 respectively. The possible combination for a P sample on the edge of a circle which is the total number of sampling points, is 2^p for LBP but it decreased to P (P−1) if its bitwise transitions have been calculated which happens in uniform LBP. One more important positive point in using uniform LBP is the detection of only important features and properties in the preprocessed sample image such as line ends, edges, spots and corners. More specifically we can see the number of bins in uniform LBP is 59 bins while its 256 bins in normal LBP (Marcel et al.,2007).

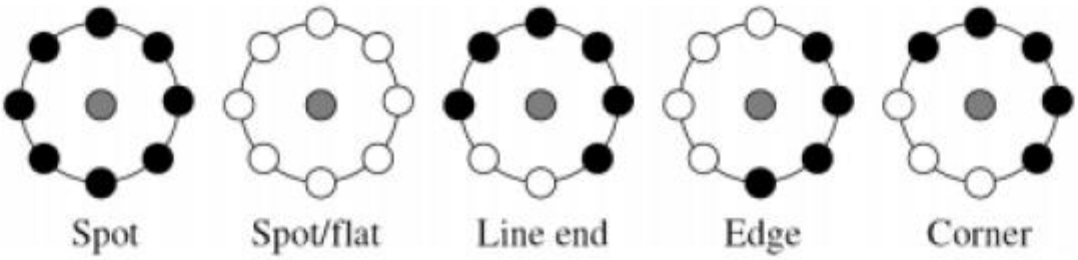

Figure 2.2: Different texture primitive detected by the LBP operator (Marcel et al.,2007)

2.2.2. LBP operator

As it's known and clear LBP works with 8 neighborhood pixels around the aimed pixel with one pixel of radius around it, the formula for it is $LBP^{u2}_{8,1}$. Later on many other researchers have been working on it using different operators to recover the dimension of the feature vector. Through these researches and extensions, it became available to choose different sizes for sampling points or neighborhood pixels. It mentioned the best results came from most databases are obtained through using $LBP^{u2}_{8,2}$ (radius of 2 pixels for eight neighborhood pixels) and $LBP^{u2}_{16,2}$ (radius of 2 pixels for sixteen neighborhood pixels). In fact, the uniform patterns are formed using $LBP^{u2}_{8,1}$ which has 8 neighborhoods and one pixel of radius. In fact, the former one is represented by P and the latter is represented by R (Lindahl, 2007).

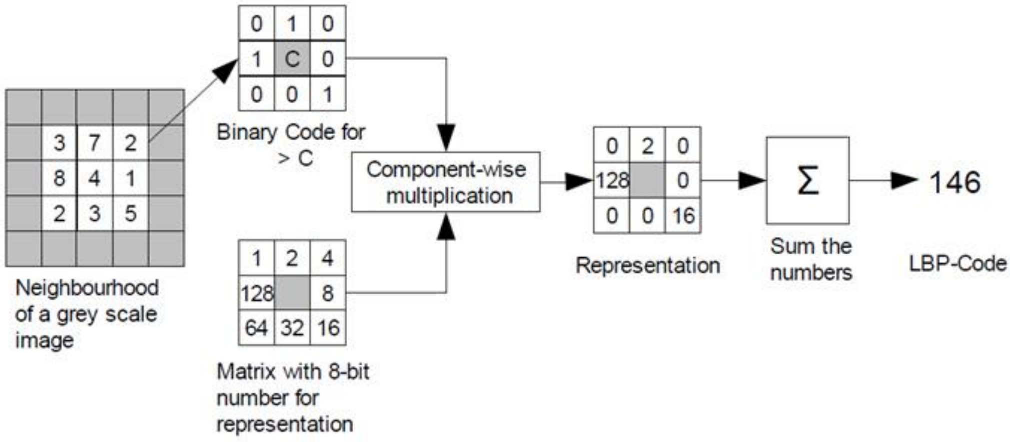

Figure 2.3: Example of how the LBP operator works (Lindahl, 2007)

2.2.3. Region Sizes

In fact, the feature vectors length is decided according to the blocks that the image is composed of. So, each image is divided in to some blocks, the more the number of blocks the more is the feature vector length. As an example, if the number of blocks is m large, so the feature vector's length is m times larger.

2.2.4. Mathematical Module

Through drawing a circle around the specified pixel with radius of R, LBP operator uses different sized of neighborhood. In the following image, different number of samples that we denote by p are taken on the edges of the circle, these samples then compared to the center pixel (Ali et al., 2012).

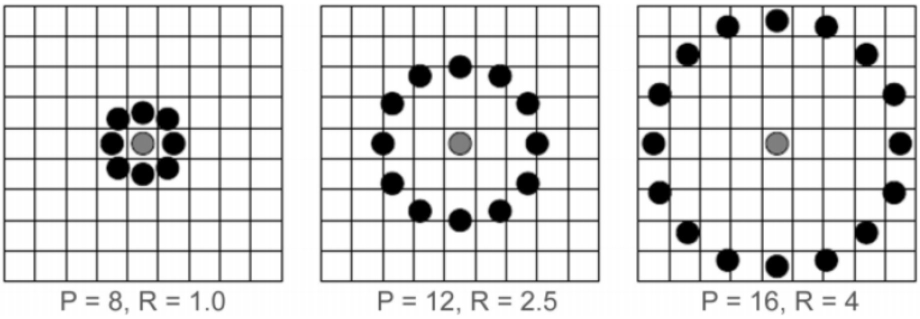

Figure 2.4: circularly neighbor-sets for three different values of P and R (Ali et al., 2012)

There can be a calculation for the neighborhood pixel coordinates on the P of center pixel by assuming $(x_p\ ,\ y_p)$ according to the center coordinate which we assume by $(x_c\ ,\ y_c)$ having a radius of R with the equations of (1) and (2). Here P is the whole number of the all the selection points, according small p denotes each of the sample point individuals (Lindahl, 2007).

$$x_p = x_c + Rcos\left(\frac{2\pi p}{p}\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. \quad (1)$$

$$y_p = y_c + Rcos\left(\frac{2\pi p}{p}\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. \quad (2)$$

The production of LBP is done for pixel $(x_c\ ,\ y_c)$ through using the equation (3) in which a binomial weight 2^P is allocated to each sign.

$\sum_{p=0}^{p-1} s\left(g_p\ ,\ g_c\right)$. These binomial weights are summed as:

$$LBP_{P,R\,(X_C,Y_C)} = \sum_{p=0}^{p-1} s\left(g_p\ ,\ g_c\right)2^p \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots\dots\dots.\dots \quad (3)$$

At last the comparison of the two face images are done by equation (4) using Euclidean distance is used as a classifier for matching. It is also called Pythagorean distance. The minimum Euclidean distance gives the similarity between the unknown face image that is being tested and the ones in the database. In Cartesian coordinates, if p= (p1, p2, p3,….pn) and q=(q1, q2, q3, …..qn) are two points in Euclidean space, then the distance from p to q .

$$d(p,q) = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2 + \dots + (q_n - p_n)^2} \ .\dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots\dots\dots..\dots. \quad (4)$$

2.3. Discrete Wavelet Transform (DWT)

Due to having powerful ability for the analysis of multi-resolution, Discrete Wavelet Transform (DWT) is mostly used tool for the texture classification and image compression. It also acts a good role in extracting the essential features from any face image for the purpose of image recognition. Because of these many articles have mentioned its ability, mathematical equation and advantages through using it. DWT can be used for the decomposition of the images due to the following reasons (Mohamed et al., 2012):

- In DWT the computational complexity is reduced as the image decomposed with it, this is because the resolution of the image is reduced in to sub-band images all with lower resolution than the real image before DWT been used. This makes the computational complexity reduce as well.
- Computational overhead also reduced after the image has been decomposed in to the sub-bands in which it creates images with different frequency ranges. These sub-bands on the other hand can be good enough and having all the requirements to be used for the next step.
- DWT also provides the characteristics of spatial frequency for the image, in which it permits having different domains (frequency and space) for the local information.

In such cases we are applying WT over the images in two directions (horizontal or row direction and vertical direction or column) through applying four different filters:

$$\varphi(n_1, n_2) = \varphi(n_1)\varphi(n_2)$$
$$\psi^H(n_1, n_2) = \psi(n_1)\varphi(n_2)$$
$$\psi^V(n_1, n_2) = \varphi(n_1)\psi(n_2)$$
$$\psi^D(n_1, n_2) = \psi(n_1)\psi(n_2)$$

Here n_2 identifies vertical direction while n_1 identifies the horizontal direction, φ identifies a function of scaling which is filter named low pass in our case, ψ is high pass filter which is a wavelet function, so the multiplication of $\varphi(n_1)$ $\psi(n_2)$ is low pass filter applying in horizontal direction and high pass filter applying in vertical direction, accordingly all the four filters can be understood like this. In the other part a super script of H can be seen which means a high pass filter have been used to the straight direction, this method an recognize of the superscripts of D and V is obtained (Mohamed et al., 2012).

The outcome of the decomposition of a face image with DWT is four sub-bands HL (through the parallel direction applying filter called high pass while on through the perpendicular direction applying low pass) LL (on the parallel direction applying low pass and on the vertical direction applying low pass filter as well), LH and HH. It's clear the LL band has a very similar approximation to the input image but with a lower resolution while bands of HL and LH shows the changes of the input images with the Horizontal and Vertical directions. On the other hand, HH band has a high frequency property of the picture (Mohamed et al., 2012).

To apply second decomposition on the output image from DWT we have to use of the four outputs of the DWT result that is approximately similar to the original image and must be rich in low frequency contents, for this purpose only one of the sub-bands can be used which is LL. In case of having second level decomposition we use LL1 to as an input to second level of DWT and we get LL2. Although to have the third level of decomposition we use LL2 as an input image to DWT, as a result we will get LL3 and so on. As a result, we say DWT decomposes an image in to four sub-bands in which one of them approximates the original image, while the other detailed images are horizontal, diagonal and vertical (Mohamed et al., 2012).

The two-dimensional DWT is done on the result of the first level of DWT on the original image, by re-applying the DWT on one of the results of DWT, thus the decomposition of the second scale is giving us seven sub-bands: LL2, LH2, HL2, HH2, LH1, HL1, and HH1.

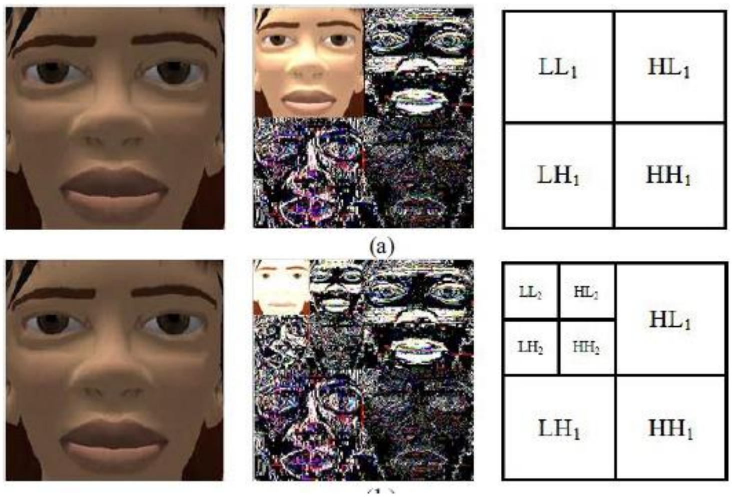

Figure 2.5: (a) The decomposed face images by one-level (b) The decomposed face images by two-level (Mohamed et al., 2012)

The two-dimensional discrete wavelet transforms (2D-DWT) is not a real two dimensional, in fact it's a one-dimensional analysis at a time of a two-dimensional signal. It simply involves only one dimension in a separate time; this means that, in a separate time it works on rows then it works on columns of the input image. In the first step it applies low pass filter and high pass filter on the input image, which creates two new images. One of the two new images is composed of a detailed row coefficient while the other image is composed of a coarse row coefficient. Afterwards, it works on the column and applies low pass filter and high pass filter as well, which creates four different images with different feature properties that are called sub-bands. L represents the rows and columns that low pass filter have been applied on while H means the rows and columns that high pass filter been applies to. So, LH sub band represents an image that is obtained from the affecting of low pass filter on the rows and high pass filter on the columns of the input image. The following figure enlightens and shows a simple graph of the procedure (Ameen, 2016).

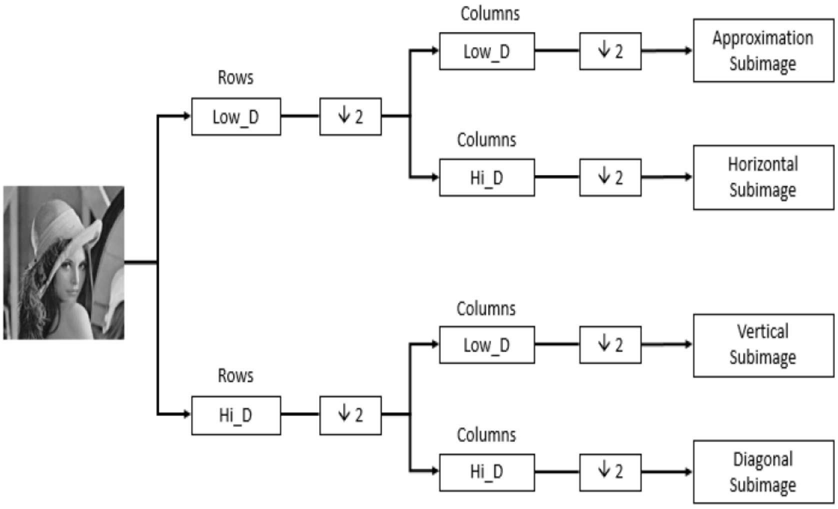

Figure 2.6: 2D-DWT, the high and low pass filters operate separately On the row and columns to create four different sub images (Ameen, 2016)

The sub-band images possess different information of the original image, each of them has some properties of the image as shown in the below figure 2.7. The (LL) sub-band image approximates the original image with the removal of all the high frequency textures through both rows and columns. (HL) sub image emphasizes the high frequency textures through the row and eliminates high frequency texture through the column which means, in other words HL sub-band shows the horizontal edges. (LH) sub-band deletes the high frequency textures on the row and gives value to high frequency textures along the column which makes the image to have vertical edges the most. (HH) sub-band shows the diagonal edges.

Figure 2.7: 2D-DWT transform on face image (Ameen, 2016)

2.3.2. Haar Wavelet Transform

Discrete wavelet transforms (DWT) was the first method for feature extraction. Alfred Haar who was a Hungarian scientist of mathematics invented it in1909. There are different advantages of using different methods either its DWT or Fourier transforms, but the main advantage of using the former over the latter is temporal resolution. We can see that DWT can capture both spatial information and frequency. Due to this property, it has many applications so far in different branches such as computer science, engineering. Mathematics and science. The Haar transformation is the simplest wavelet transform (WT), that's why we have used here and it does our task successfully. In using Wavelet transforms we see merits which are multi-scale decomposition, multiresolution and so on. To decompose a 2D image with standard decompositions, at first, the 1D wavelet transform is applied to each row. This gives us a detail coefficient and an average pixel values to each row.

Then, these transformed and changed rows are seen and behaved as they were a part of the real image. After that, an ID wavelet transform are applied to each column. As a result, detail coefficients are obtained instead of all the pixel values except for a single overall average coefficient (Wadkar et al., 2011).

Table 2.1

Haar wavelet transform is the process of differencing and averaging as follows:

Resolution	Average	Detail Coefficients
4	[9 7 3 5]	
2	[8 4]	[1 -1]
1	[6]	[2]

2.3.2.1. Two-dimensional Haar wavelet transforms

There are two types of wavelet decompositions over an image which are standard and nonstandard. By applying one-dimensional WT in each of them we get the generalization of two dimensions. In the case of standard decomposition; on each pixel values in each row we apply one-dimensional wavelet transform. This gives us a detail coefficient and an average pixel values to each row. Then, these transformed and changed rows are seen and behaved as they were a part of the real image. After finishing the row, this time the operation is applied on the columns. As a result, detail coefficients are obtained instead of all the pixel values except for a one total average amount. The below figure 2.8. illustrates the steps for computing standard decomposition operation (Wadkar et al., 2011).

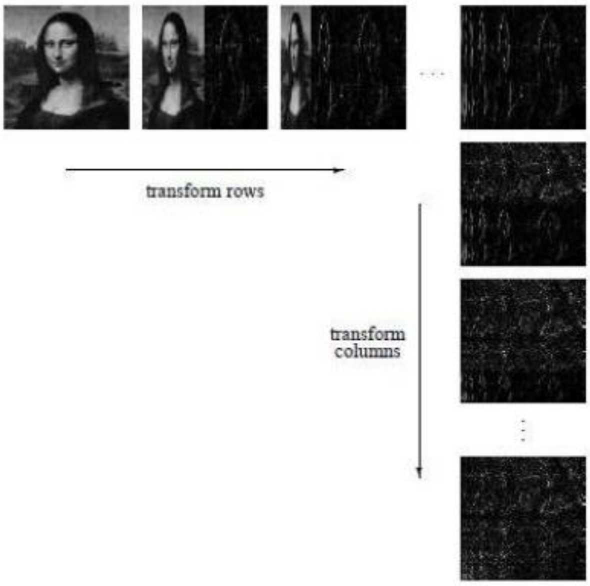

Figure 2.8: Standard decomposition of an image (Wadkar et al., 2011)

The second type of WT decomposition is known as nonstandard decomposition. This type is near to the standard decomposition procedure but this time operation on rows and columns alternated. First, we achieve one stage of flat pair wise averaging and differencing on the pixel values in averaging and differencing to each column of the result.

In order the transform to be completed, on both directions and on the quadrant holding averages, the repetition process will happen recursively. Below in Figure 2.9 all the steps are shown involving the procedure of the nonstandard decomposition.

Figure 2.9: Nonstandard decomposition of an image (Wadkar et al., 2011)

CHAPTER 3

METHODOLOGY

3.1. Overview

In this chapter we will give in details the framework of the proposed method which is proposing face biometric recognition system. The details include, proposed face feature extraction algorithm using Discrete Wavelet Transform (DWT) and Local Binary Pattern (LBP) feature extractors.

3.2. Proposed Biometric Face Recognition Method

Biometric face recognition system in our project is explained in figure 3.1, which is consisting of several steps:

- First Step: In this step the algorithm will read the facial image
- Second Step: After face image is read, we need to extract features from the face to be ready for the next step which is classification step. The features are extracted using two different methods (DWT and LBP).
- Third Step: When the face features are ready then we will run it to the classification step to decide where the face features are recognized or not by comparing with the previously saved set of features and saved in a database.

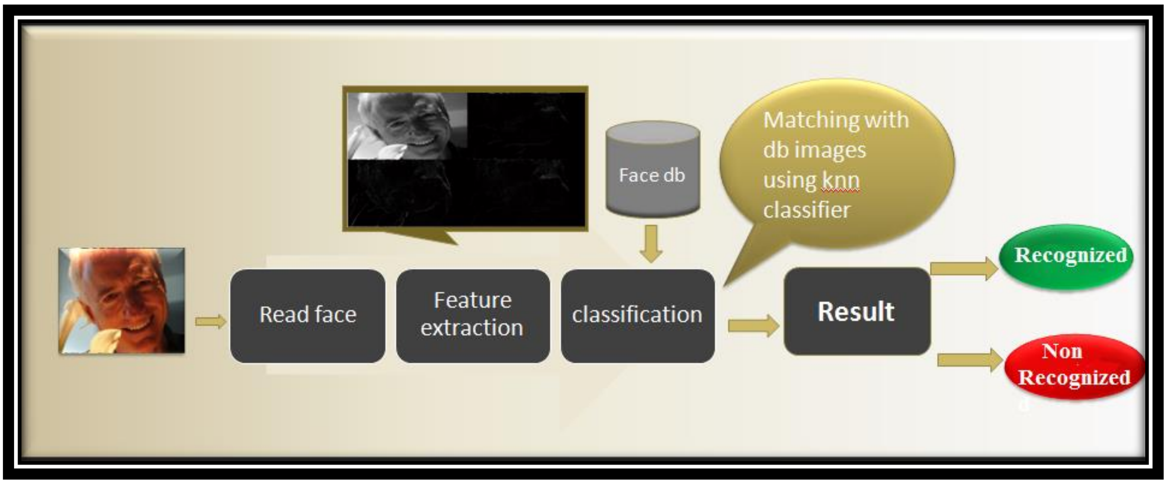

Figure 3.1: Face recognition system (Rashid et al.,2013)

The modern world of technology and development has adapted face recognition as one of the fast progressing tools for enhancing security. Face recognition operates with already stored pictures and video database to recognize faces. However, establishing a face recognition model can be bit challenging. Face recognition can face issues of face variations like pose, facial expressions, and problems with illumination within changing environment locations. Hence, the technology is beneficent with some challenges that are not very hard to tackle (Rashid et al.,2013).

This study adapted two publicly accessible databases of face recognition for evaluating the effectiveness of proposed model. The first ORL database adapted by the study had 40 different objects that had 10 distinguishing images that were taken in up-right frontal position with112 × 92-pixel resolutions. The second database was Yale that consisted of 15 individuals and there were 11 images for each individual with variations expression, illumination, and distinguishing poses including glasses with -pixel resolution of 96×80 (Rashid et al.,2013). Some samples of images from this database are shown in figure 3.2

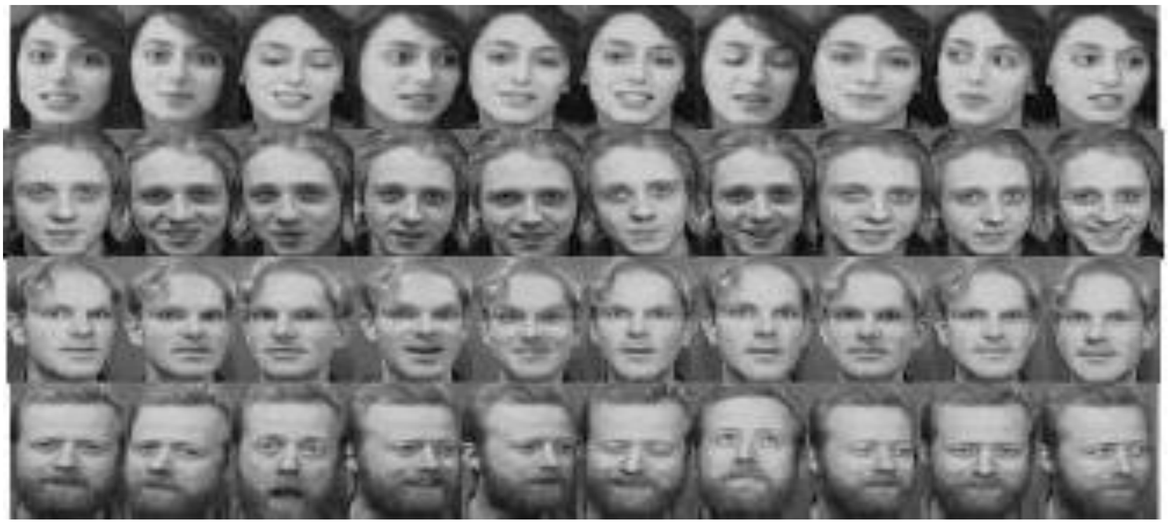

Figure 3.2: Samples of ORL Database (Rashid et al.,2013)

Figure 3.3: Samples of Yale Database (Rashid et al.,2013)

3.3. Feature Used

For extracting features in the second step of the proposed scheme, we used two techniques DWT and LBP.

3.3.1 Discrete Wavelet Transform

For Discrete Wavelet Transform (DWT), We applied three levels of as a feature extraction process. From the extracted sub-bands, we use Approximation, Horizontal, Vertical, and Diagonal sub-bands as a feature individually used after that in recognition step. The strategy of separating images to test set and training set based on leave one out strategy (i.e. one image used as a test image and all remained images inside database used as training images). All images are gray-scale images. After we applied three levels of DWT, we obtain results of features as the following:

When first level of DWT is performed over the images then the result is four sub-bands each with size 56X46 and the feature size obtained is 2576 for each sub-band (i.e. cA, cH, cV and cD). The same process can be performed over the sub-bands obtained from the second level. In this case size of each sub-bands obtained will be 28X23 with reduced feature size to only 644 features. While after applying the third level of dwt the sub-bands obtained has only 14X12 coefficients (i.e. only 168 features)

The block diagram for discrete wavelet transform system is shown in figure 3.4.

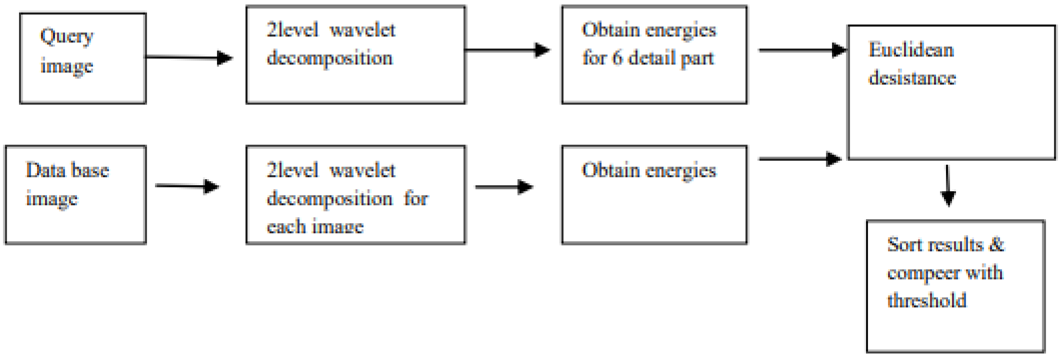

Figure 3.4: block diagram for discrete wavelet transform (Alwan, 2014)

3.3.1.1 Discrete Wavelet Transform Algorithm Steps.

First stage or Input: - Insert file of face image in our database.

Result of work or Output: - Compare face with exciting face database found or not found.

1st Step: - Check and loading face image file.

2nd Step: - Change or convert all images to gray level.

3rd Step: - By using 2D DWT with levels to decompose the image.

4th step: - For 6 sub-images it should calculate normalized energy.

5th step: - Compute 2D-DWT and kept it with their energy for each image in stored database.

6th step: - In order to perform recognition, we used Euclidean distances as a feature vector.

7th step: - Compare with threshold.

FLOWCHART

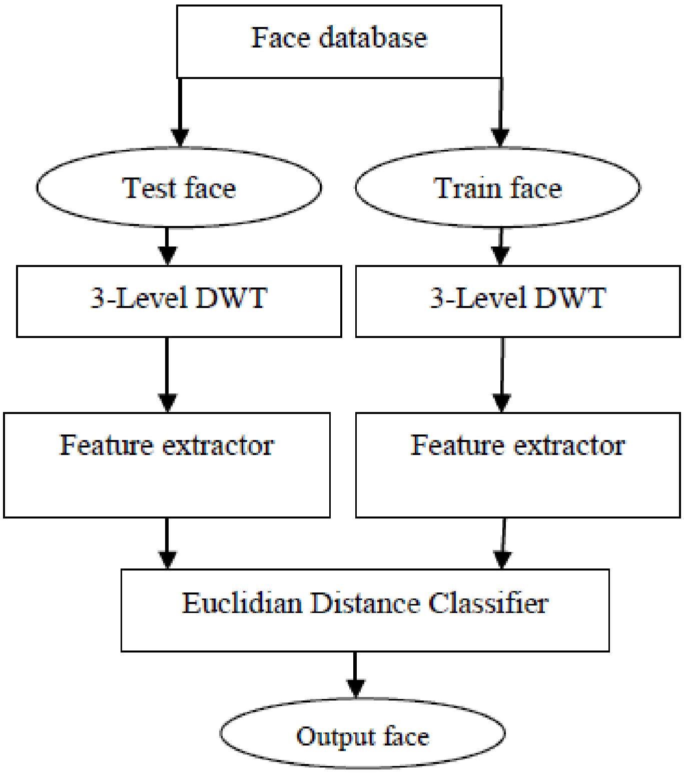

Figure 3.5: Flowchart of the Proposed Algorithm (Abdulrahman et al., 2014)

3.3.1.2 Mathematical Module of DWT

The following shows translated and scaled basis elements for 2D wavelet transform

$$LL = \phi(x,y) = \phi(x)\,\phi(y)$$
$$LH = \psi^{H}(x,y) = \psi(x)\phi(y)$$
$$HL = \psi^{V}(x,y) = \phi(x)\,\psi(y)$$
$$HH = \psi^{D}(x,y) = \psi(x)\,\psi(y)$$

where the great writings H, V, and D mention to the decomposition route of the wavelet. For a part of image manipulation two dimensional wavelets is employed (Ravichandran et al., 2016). Below equations give us the multiresolution representation of wavelet functions and scaling for 2-D:

$$\phi_{j,m,n}(x,y) = 2^{j/2}\phi(2^j x - m, 2^j y - n)$$

$$\psi^i_{j,m,n}(x,y) = 2^{j/2}\psi^i(2^j x - m, 2^j y - n)$$

where I = { H,V,D}

1. Wavelet representation equation of scaling function shown below

$$W_\phi(j_o, m, n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y)\, \phi_{j_o,m,n}(x,y)$$

Wavelet function which is corresponding for the horizontal, vertical and diagonal representation of the pictures are as follows:

2. Representation equation of horizontal sub band

$$W_\psi^H(j,m,n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y)\, \psi^H_{j,m,n}(x,y)$$

3. Representation equation of vertical sub band

$$W_\psi^V(j,m,n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y)\, \psi^V_{j,m,n}(x,y)$$

4. Representation equation of diagonal sub band

$$W_\psi^D(j,m,n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y)\, \psi^D_{j,m,n}(x,y)$$

By using the equations that above-mentioned scaling and wavelet functions, it symbolled $W\phi$ and $W\psi$, it can simply obtain through the inverse discrete wavelet transform for the image signal as

$$f(x,y) = \frac{1}{\sqrt{MN}} \sum_{m} \sum_{n} W_{\phi}\,(j_0, m, n)\, \phi_{j_{o,m,n}}(x,y) + \frac{1}{\sqrt{MN}} \sum_{i=H,V,D} \sum_{j=j_0}^{\infty} \sum_{m} \sum_{n} W_{\psi}^{i}\,(j, m, n)\, \psi_{j,m,n}^{i}(x,y)$$

3.3.2. Local Binary Pattern

In this study, the researcher divided the face image in several blocks for representing local face characteristics. Thus, similar face characteristics are extracted from these sub blocks. Al these features that make up a recognition were later combined together to develop one single face recognition system. It is argued that dividing main feature into sub features for face recognition is essential (Hadid, 2008). Different sub blocking is used such as:

- 1by1 with only 59 features
- 2by2 with 236 features.
- 3by3 with 531 features.
- 4by4 with 944 features.
- 5by5 with 1475 features.

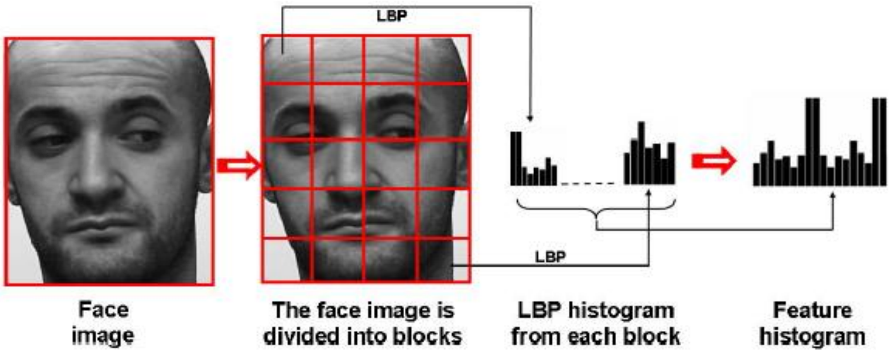

Figure 3.6: Example of an LBP based facial representation (Hadid, 2008)

3.3.2.1 Local Binary Pattern Algorithm Steps

The proposed face recognition model of the study comprises of four fundamental parts.

1) Preprocessing stage will apply the Tan and Triggs' illumination algorithm to help in normalization. The Tan and Triggs aimed to overcome the illumination issues due to face variations. The processing stage also minimized the further processing of face alignment to save time and for bringing up accurate results.

2) LBP operator application stage computes LBP for each pixel that enables the model to develop a smooth description of picture.

3) Local feature extraction process stage produces local characteristics by figuring the LBP's histogram over local image zones.

4) Classification stages compare for individual face image in the test with face image in the training set through local features obtained in the algorithm. The algorithm used in this study has unique characteristics of feature extraction and classification that is not commonly found in other algorithms.

The fundamental issues face recognition the identification of unknown face image at extraction and the classification stage. The local binary features of the face have been extracted from the face image to complete identification process as they are compared with the existing images of database. The face recognition is affected by the illumination and environment as they are viewed therefore; face image varies with the variations in the expressions. Hence the local binary patterns methodology is adapted by the current study to evaluate the local special structure for the particular face. The local binary patterns train the set of binary evaluations of pixels' strengths among center pixels with its eight surrounding pixels for face recognition normalization (Singh et al., 2015).

LBP is defined as an order set of binary comparisons of pixels' intensities between the center pixels and its eight surrounding pixels in the image.

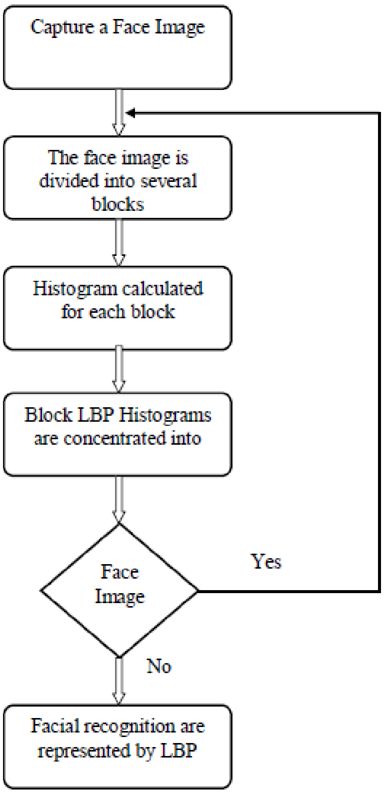

Figure 3.7: Flow chart for Local Binary Pattern (Singh et al., 2015)

3.3.2.2 Mathematical Module of LBP

The study adapted local binary patterns approach which is a simple yet efficient. The LBP marks the pixels of a picture through 3x3 area of separate pixel by the value of the focal pixel and considers the consequence as a binary number. Equation 1 is used as the mathematical expression of LBP given as:

$$LBP_{P,R} = \sum_{p=0}^{P-1} s(g_p - g_c)2^p \qquad \text{(1)}$$

Where,

1. gc is the gray value of the center pixel (xc; yc),
2. gp is the gray values of P equally spaced pixels on a circle of radius R,
3. and s is a function as follows:

$$s(x) = \begin{cases} 1, \; if \; x \; \geq \; 0; \\ 0, \; otherwise. \end{cases} \qquad \text{(2)}$$

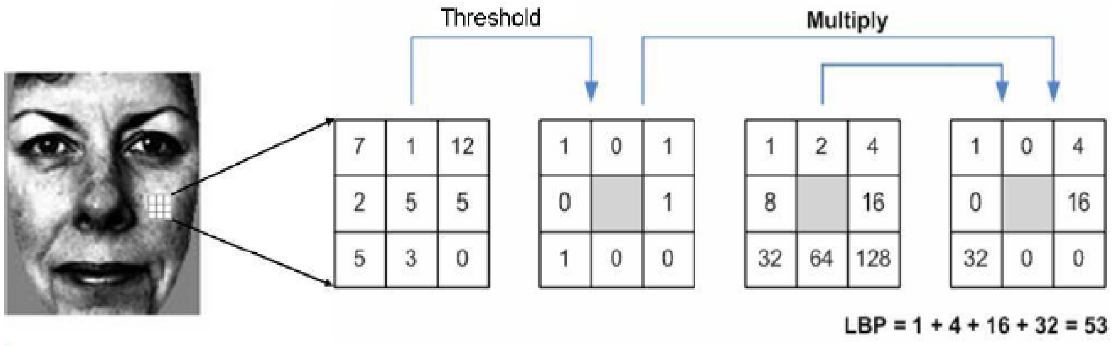

Figure 3.8: Example of an LBP calculation (Hadid, 2008)

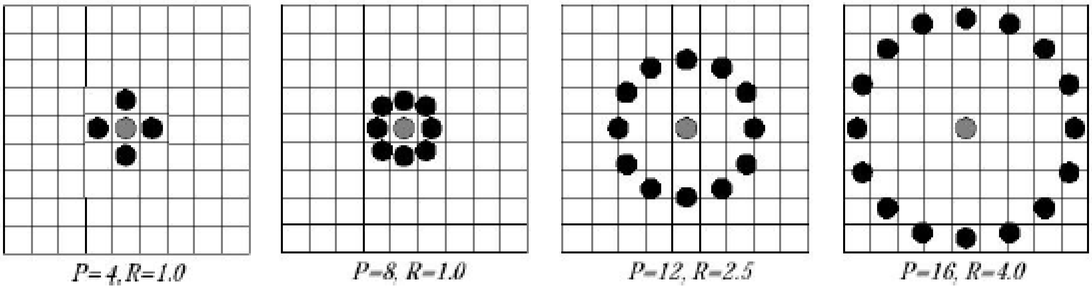

Figure 3.9: Neighborhood set for different (P, R) (Hadid, 2011)

The main function of LBP is testing the relationship between the pixel and its subsequent area thus, encoding this relationship in the form of a binary number that is 0 and 1. However 256-bin histogram of the tags presented above an area is used as a texture descriptor. The unique LPB operator considers diversified sizes of neighborhood. For instance, the operator $LBP_{4;1}$ uses only 4 neighbors while $LBP_{16;2}$ considers the 16 neighbors on a circle of radius 2 (Liao, Law and Chung, 2009).

The $LBP_{P;R}$ operator refers to the area generally identical to the size of P that has similarly spaced pixels spread over a radius of R. it is circular and symmetrical. $LBP_{P;R}$ processes two output standards as the 2^P binary patterns that can be shaped by the number of pixels in that area. There are bins located in the area that certainly have distinguishing number of information. Thus, the model can also use only the succeeding 2^P of LBP in order to describe the textured images. (Ojala et al.,2002) identified these subsequent as the bitwise transitions ranging from 0 to 1and so on.

3.4. Classification Strategies

For the recognition purpose we used nearest neighbor with Euclidean distance as a measure for calculating the similarity between images. To test any proposed face feature extraction methods, you need to follow one of the strategies of separating images to test and training sets. There are several strategies that is used in classification such as leave one out strategy, %50 of samples selected as test and other %50 used as training, or one sample image used as training and the rest of images used as testing (Rashid et al.,2013).

In our project we used the simplest one which is Leave one out strategy. In Leave one out strategy only one image from the database is used as test while all remaining images are used as a training set. We repeat the procedure of selecting image as test image n times which n is the total number of images in the database. More especially in our case we repeated the procedure 400 times because our ORL database includes 400 images. While for Yale database we repeated the experiments 165 times since the database include 165 images (Rashid et al.,2013).

3.5. Software Used (MATLAB)

The study incorporated MATLAB® software to develop the face recognition program. It is one of the widely acknowledged software the combined computation, imagining, and programming in effective and more accessible skills in programming a way to develop programs and/or applications as it focuses on:

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building.

Matrix Laboratory (MATLAB) is one of those user-friendly programming languages that is multi-paradigm. It is interactive and helps in developing solutions to the technical computing issues for programs with matrix and vectors. It is one of the fastest and reliable programming languages as compared to C and FORTRAN. It is consistently and commonly used programming language in the area of computer, engineering, and science for developing programs and software. It is equally helpful in research and development (R&D). MATLAB consists of toolboxes that allow users to add-on application-specific solutions that provide wide-ranging an informatics groups of MATLAB functions (M-files). MATLAB has an extended environment provided to the users to solve particular programming problems including, (1) Signal processing, (2) Control systems, (3) Neural networks, (4) Fuzzy logic, (5), (6)Wavelets, (7) Simulation(Guo et al.,2010).

CHAPTER 4
SIMULATION RESULTS

4.1. Overview

In this chapter, the simulation outcomes of the base line recognition performance of the ORL and Yale face database images will introduce accordingly. All the simulations had been performed by the usage of the MATLAB R2010a software package. A short discussion and statement are drawn in every class of the simulation carried-out. Finally, typical discussions of outcomes have been presented at the end.

4.2. Simulation Setup

The suggested methods are tested on two special face databases: ORL and Yale face databases. For most of the experiments in every dataset, 1 randomly chosen face picture from every class (subject) available in the data set are viewed as the probe (test) set while the rest face images are viewed as the gallery (train) set. Subjects in both databases right here have more than one face picture and every subject has unique photo conditions like (illumination, pose, expression…etc.). Face images that are in gallery set do not exist in the probe set. Each of the pictures in probe set is matched in opposition to the images in the gallery set, and the outcomes and rankings are fused and the decision will be made. Both of the mentioned databases have one of a kind properties to check and asses our proposed algorithms. ORL face images are taken at exclusive time duration and have different head poses. Yale face photos have been recorded in partly managed light conditions over a constant historical past and they have distinct head pose variants and, in some images, subjects wear glasses. This contains us a probability to calculate the recognition performance of our planned technique with the others the use of a uniform and standardized database.

Conventional algorithms and our proposed method have been examined with unique variety of subjects. We run software n times, every time with unique randomly chosen subjects. After every experiment, scores will be fused and compared. In all of the experiments, database face pictures have been separated in to two classes; gallery (train) and probe (test) set. In most of the experiments, gallery set contains n1 pictures per subject and the remain one from all subjects is in probe set. Proposed methods had been applied with a range of extraction algorithm like LBP and transform algorithm DWT. With DWT, special types of filters were applied like (db1, db2, db3, db4, db5, haar…). In the following sections, two face databases are explained in detail and performance outcomes of the use of these databases in our proposed strategy are given, with comparisons with some popular traditional face recognition algorithms.

Figure 4.1: Different face poses from ORL face images (Rashid et al.,2013)

4.3. Databases Used

4.3.1. Face Database of ORL

Olivetti Research Laboratory (ORL) face database is examined in order to determine our proposed method in the existence of head poses and editions in time since pictures had been taken between April 1992 and April 1994. There are 40 unique subjects (persons), 10 images per subject, a whole of 400 face images. For most of the subjects, the face pictures had been recorded at light variance, time variance, face details (glasses / no glasses), face style (shut eyes / open, laughing / not laughing) and head poses (rotation and tilting up to 20°). Most of the face pix have been recorded in opposition to a dark regular background. Figure 4.2 shows the whole set of 40subjects' face images.

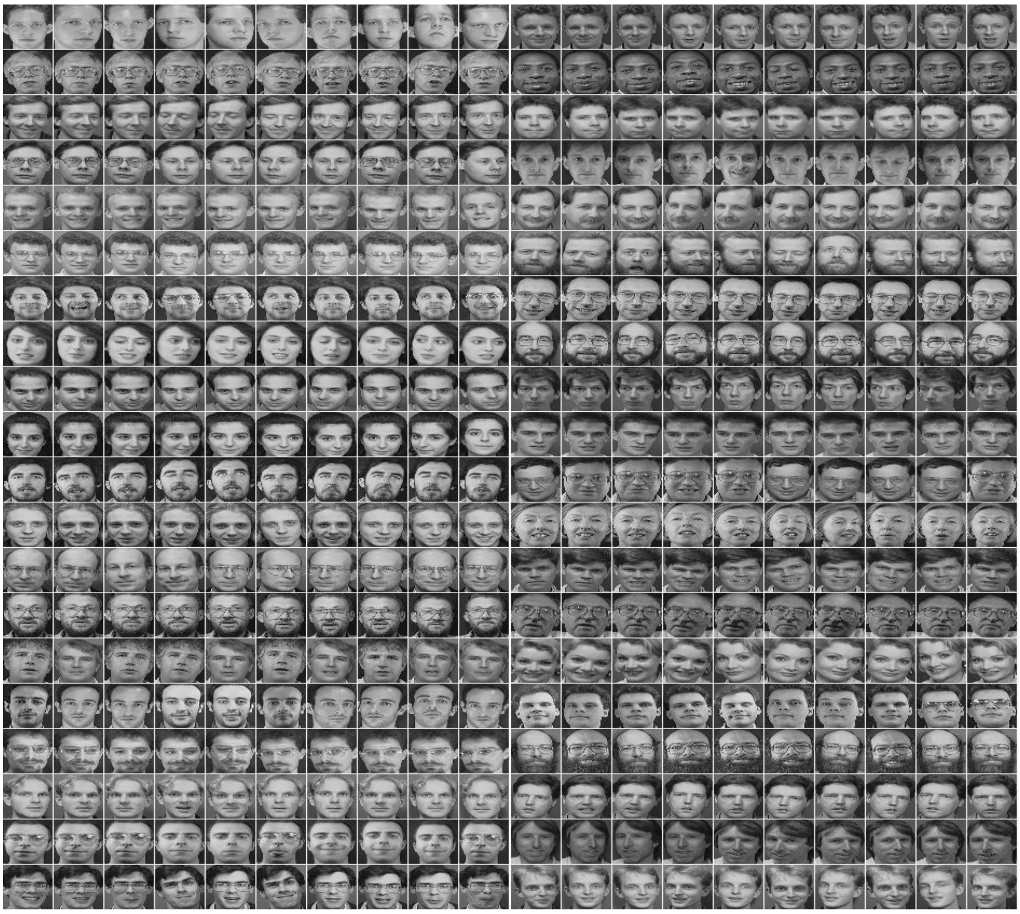

Figure 4.2: ORL Face Database (Rashid et al.,2013)

4.3.2. Face Database of Yale

The Face Database of Yale is used in order to examine our algorithms in the presence of head pose variations. The Yale Face database includes 165 grayscale pictures in GIF structure of 15 individuals. This database contains of fifteen people, wherever for each individual, there are eleven face pictures holding variations in brightness (center -light, right-light and left-light), facial appearance (sleepy, normal, happy, sad, surprised and wink), and look details (without glasses and with glasses) all pictures with 96×80-pixel resolution. Figure 4.3 shows that the complete database.

Figure 4.3: Face Database of Yale (Rashid et al.,2013)

4.4 Results of Experimentation

We will show and explain with giving the comparison of the obtained results in the following section from different proposed schemes applied on both databases mentioned in previous section. The results will include the recognition accuracy percentage with using different feature types extracted from face images.

4.4.1 DWT Features Results

After applying three levels of DWT over the face images we will obtain 12 sub-bands, for each level we have 4 sub-bands which they are (cA,cH,cV, and cD) for (Approximation, Horizontal, Vertical, and Diagonal) coefficient features respectively. We repeat the experiment 12 times, each for single sub-band coefficients extracted from the face images after applying DWT over it. Tables and figures below shows our obtained results for both databases used, results include the recognition accuracy. Table 4.1 and figure 4.4 shows results obtained from ORL database, while table 4.2 and figure 4.5 explains results obtained from Yale database for each individual sub-bands.

Table 4.1

Recognition accuracy rate of sub-bands of DWT over ORL database

DWT Level	Sub-band used	Recognition Rate (%)
Level 1	cA1	98
Level 1	cH1	43
Level 1	cV1	16
Level 1	cD1	3.25
Level 2	cA2	98.25
Level 2	cH2	76.75
Level 2	cV2	59.25
Level 2	cD2	9.75
Level 3	cA3	98
Level 3	cH3	89.75
Level 3	cV3	80.75
Level 3	cD3	58.5

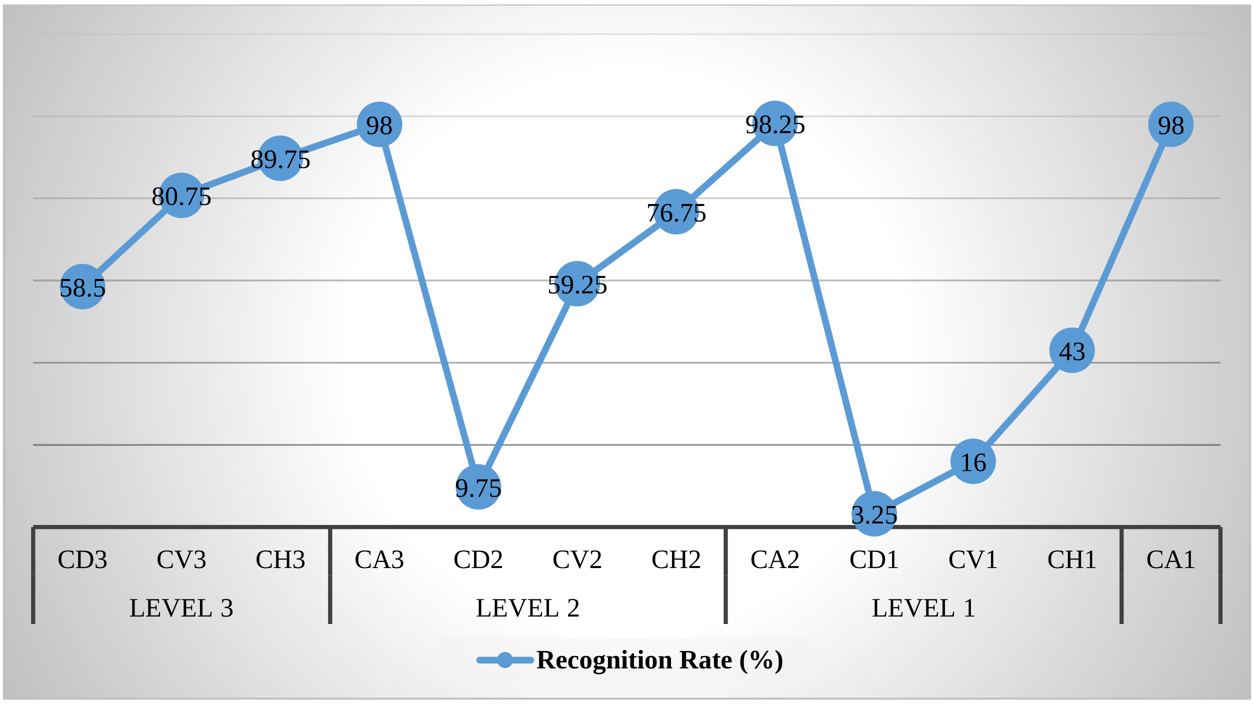

Figure 4.4: Recognition accuracy rate of sub-bands over ORL database

Table 4.2

Recognition rate of sub-bands of DWT over Yale database

DWT Level	Sub-band used	Recognition Rate (%)
Level 1	cA1	84.24
Level 1	cH1	64.24
Level 1	cV1	79.39
Level 1	cD1	17.57
Level 2	cA2	83.03
Level 2	cH2	70.9
Level 2	cV2	86.66
Level 2	cD2	40
Level 3	cA3	81.21
Level 3	cH3	82.42
Level 3	cV3	83.03
Level 3	cD3	66.66

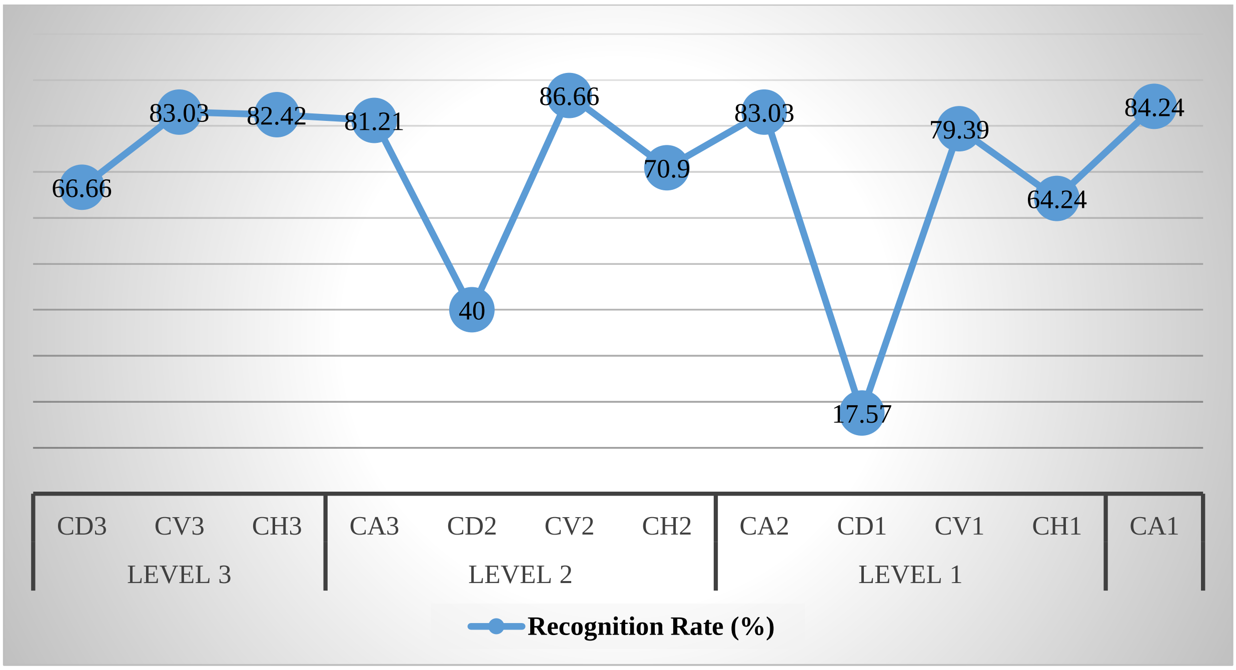

Figure 4.5: Recognition accuracy rate of sub-bands over Yale database

From the results obtained as shown in the previous tables and figures, we can notice that; the recognition accuracy obtained when cA sub-bands used as a feature are much better than other three sub-bands (cV, cH and cD) for all levels and for both databases. In other hand we can notice that for two detail sub-bands (cV and cH) level three has better recognition rate than using the same sub-bands from other two levels (level 2 and level 1).

If we do further analysis of the results, we can say that for ORL database better recognition accuracy obtained compared with the Yale database.

In comparing results obtained from cV and cH sub-bands we can say that every database has different textures for example for Yale database horizontal (cH) features are better represent face images than Vertical (cV) features. While for using ORL database the figure is opposite i.e using vertical features (cV) have better recognition accuracy than using Horizontal (cH) features.

4.4.2 LBP Feature Results

Before extracting LBP features, we subdivided the face images to number of blocks then from each sub-block we extract uniform LBP features which they are 59 bins. After that we concatenate features extracted from individual sub-block to create one and unique feature vector represent the face image. We used different sub-blocking strategies to see how sub-blocking the image will affect the recognition accuracy. Here we used 5 blocking strategies which they are 1by1, 2by2, 3by3, 4by4 and 5by5 sub-blocking. Note that increasing the blocking number will increase the feature vector size to represent the overall face image. of the Tables 4.3 and figure 4.6 represent recognition accuracy for ORL database while table 4.4 and figure 4.7 shows the recognition accuracy for Yale database with different sub-blocking.

Table 4.3

Recognition accuracy using LBP for ORL Database

No. of Blocks	Recognition Rate (%)
1by1	87
2by2	95.25
3by3	98.75
4by4	99
5by5	97.25

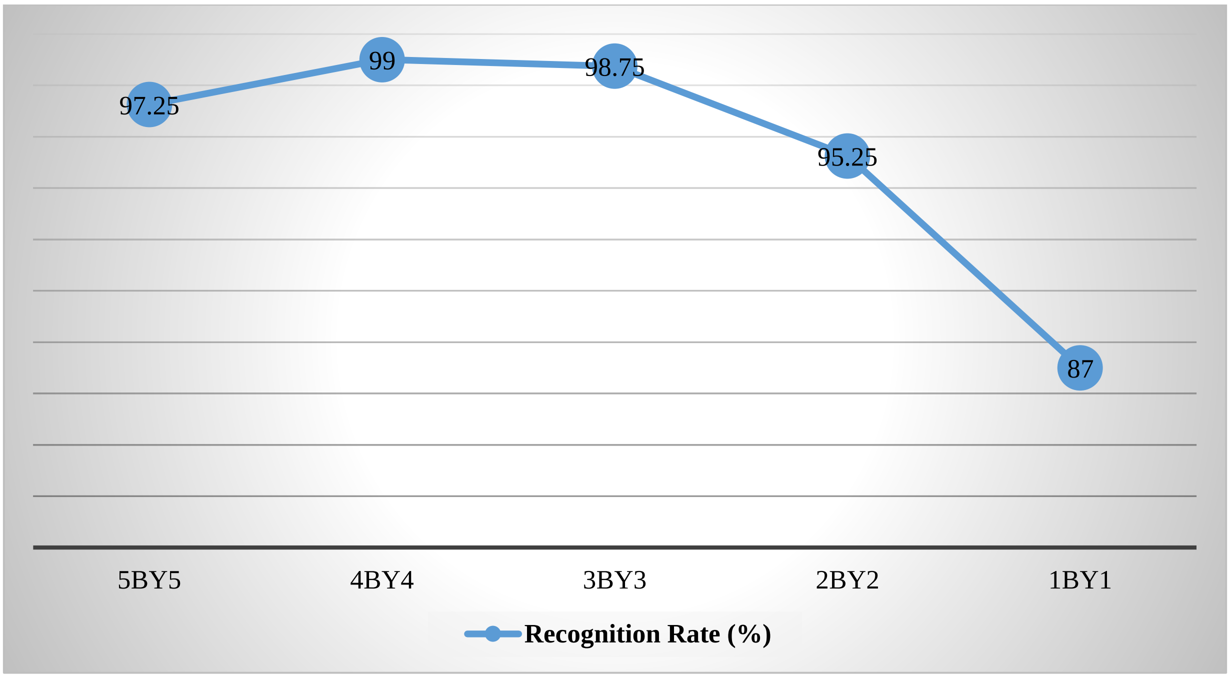

Figure 4.6: Recognition accuracy rate sub-blocks over ORL database

Table 4.4

Recognition accuracy using LBP for Yale Database

No. of Blocks	Recognition Rate (%)
1by1	77.57
2by2	86.66
3by3	92.12
4by4	94.54
5by5	95.15

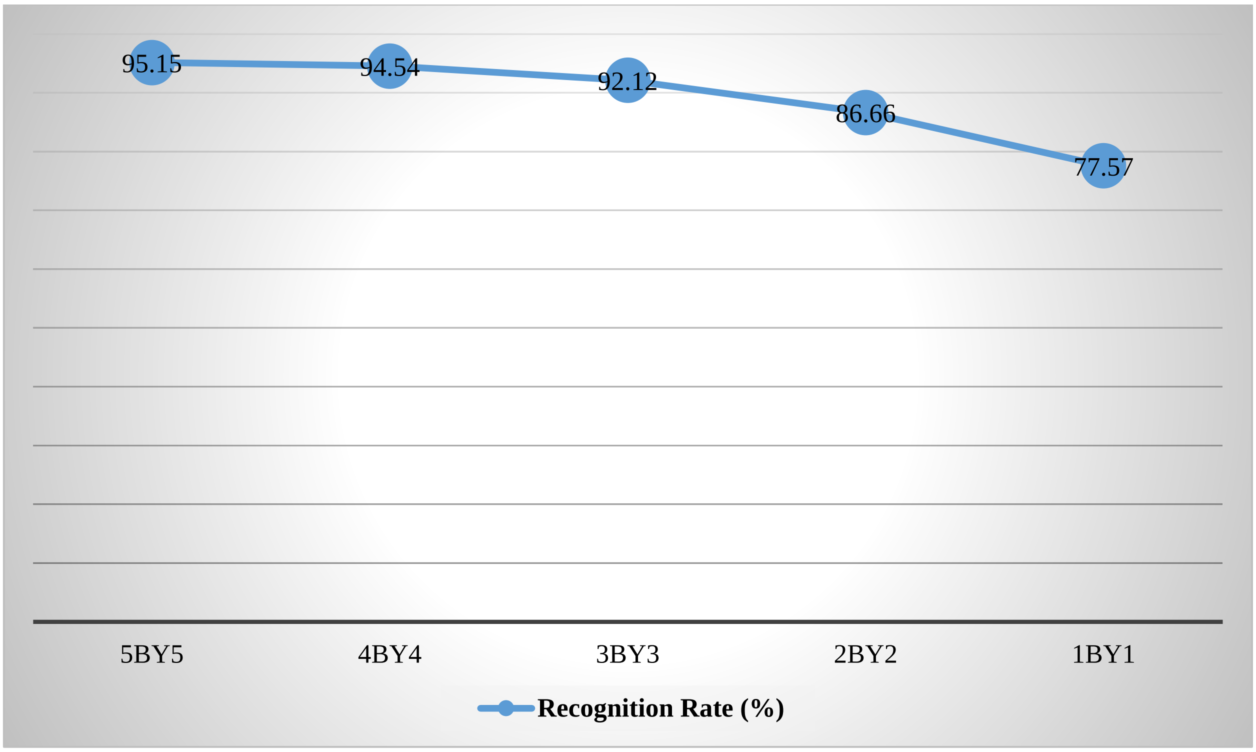

Figure 4.7: Recognition accuracy rate sub-blocks over Yale database

Generally, for both databases we can say that increasing block numbers will affect the recognition accuracy. The best recognition accuracy for ORL database is obtained when the image sub-blocked to 4by4 while for Yale database the best recognition accuracy obtained by sub-blocking the face image to 5by5.

The effectiveness of the proposed approach, obtained by the LBP approaches, is evaluated through various experiments carried out on two standard face databases. In order to perform detailed experiments a number of training and test sets are framed for both ORL and Yale databases the recognition accuracy of the proposed approach has also been compared to some existing techniques and it is observed that on these databases the recognition accuracy of the proposed method is better than the accuracy of these well-known face recognition methods. Comparing results of the two databases, the ORL have better recognition accuracy than Yale database, this could be effects of the nature of the images include in two databases. After obtained the results from different blocking strategies for two face databases, we can mention that the results are depends on the face details, face style, or head poses that why we got different results in LBP for 1by1, 2by2, 3by3, 4by4 and 5by5 sub-blocking.

Table 4.5

Comparison between present work and another previous algorithm work

Authors	Databases	Techniques	Accuracy(%)
Rahman,ArmansdurniAbd,et al, 2014.	ORL	PCA Eigen faces	70
Saha, Rajib et al, 2013.	FRAV	Eigen face	90
Thakur, S,et al ,2008.	AT&T , UMIST	PCA,RBF NN	94.10
Barbu, Tudor.et al,2010	Yale	2D- Gabor Filter, Supervised Classifier	90
Ming et al,2012	FRGC , CASIA	3D- Gabor Patched Spectral Regression (3D GPSR)	92.80
Shen, Linlin,et al,2005	FERET	Gabor Filter , Improved AdaBoot Learning	94.5
Shen, Linlin,et al,2007	FERET,BANCA	Gabor Wavelet General Discriminant Analysis	93.5
Nagi, Jawad et al, 2008	ORL	2D- Discrete Cosine Transform (2D-DCT),SOM	81.36
Mantri, Shamla et al,2011	AT & T	SOM	92.40
Prasad, M.S.R.S.,et al ,2011	Yale	PCA, FFNN	90
Ojo, John Adedapo et al,2011	AT & T	2D- Discrete Wavelet Transform,HMM	90
Kong, Rui et al , 2011	ORL	ICA ,SVM	92.4
LE, Thai Hoang et al , 2011	FERET , AT & T	2D-Principal Component Analysis , SVM	95.10
Jianhong, Xie.Et al ,2008	ORL	Kernel PCA, LS-SVM	95
Present Work	ORL	DWT Level 1 DWT Level 2 DWT Level 3	98 98.25 98
Present Work	Yale	DWT Level 1 DWT Level 2 DWT Level 3	84.24 86.66 83.03
Present Work	ORL	LBP	99
Present Work	Yale	LBP	95.15

CHAPTER 5
CONCLUSION AND FUTURE WORK

5.1. Conclusion

In computer vision and image processing face detection is a most significant study. It is an attempt to identify human appearance without human intervention. Important progresses in this field prove the better performance, compared to human function, of the automatic recognition where they are applied. Facial recognition involves a broad range of fields of study, such as: pattern recognition, bioinformatics, and machine vision. In fact, it is a flourishing field of research. and becoming one of the hottest research areas. There, however, is a void of a distinctive feature in facial recognition systems. As of now, several algorithms have been created to facilitate extraction features which could be grouped as: face geometry, statistical features, and faces.

In this thesis work, LBP and DWT are used to extract features from face images. However, after LBP and DWT are successfully applied for the feature detection and description, two approaches are proposed to improve the results. The first approach is based on LBP. The second approach is based on DWT is applied to the image as a preprocessing stage. The recognition results obtained using this technique show substantial improvements, especially, in the recognition performance. The performances of the two proposed approaches have been measured using widely used databases ORL and Yale. Performance of the first proposed approach has been tested on both ORL and Yale face images with different number of images per subject and gallery sets. The proposed approach is found to perform well in face recognition. Performance of the second proposed approach has been tested on ORL and Yale face images.

5.2. Future Work

In this work, LBP and DWT are proposed in order to improve the performance of face recognition. The following suggestion will be considered as a future work.

- ORL and Yale databases were used in all of the experiments; more databases can be tested and the results may be compared with the proposed approach
- It can be combined between LBP and DWT as a feature fusion and may achieve high performance results compared with the other two algorithms separately.
- Instead of LBP & DWT one can test other feature extraction strategies.
- Other wavelet filters can be used.

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APPENDICES

APPENDIX 1
SOURCE CODE

In this work, we used MATLAB application 2010a for testing our application. The computers we have used were core i5 and has ram of 8 Gigabytes. We have many algorithms applied in MATLAB, here we will provide the source code for some of the algorithms.

DWT MATLAB Code for ORL Database

```
%Main function
clc;
clear all;
z=0;
for l=1:40
for f=1:10
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\ORL\s' num2str(l) '\' num2str(f)];
Face=imread(fname,'pgm');
%%%%%%% level one %%%%%%%%%%
[cA1,cH1,cV1,cD1] = dwt2(Face,'Haar');
z=z+1;
[n m]=size(cA1);
feature=reshape(cA1,1,n*m);
L1_cA1(z,:)=feature;
%____________________________
feature=reshape(cH1,1,n*m);
L1_cH1(z,:)=feature;
%____________________________
feature=reshape(cV1,1,n*m);
L1_cV1(z,:)=feature;
%
feature=reshape(cD1,1,n*m);
L1_cD1(z,:)=feature;
%%%%%%% level two %%%%%%%%%%
[cA2,cH2,cV2,cD2] = dwt2(cA1,'Haar');
[n1 m1]=size(cA2);
feature1=reshape(cA2,1,n1*m1);
L2_cA2(z,:)=feature1;
%
feature1=reshape(cH2,1,n1*m1);
L2_cH2(z,:)=feature1;
%
```

```
feature1=reshape(cV2,1,n1*m1);
L2_cV2(z,:)=feature1;
%
feature1=reshape(cD2,1,n1*m1);
L2_cD2(z,:)=feature1;
%%%%%%% level three %%%%%%%%%%
[cA3,cH3,cV3,cD3] = dwt2(cA2,'Haar');
[n2 m2]=size(cA3);

feature2=reshape(cA3,1,n2*m2);
L3_cA3(z,:)=feature2;
%
feature2=reshape(cH3,1,n2*m2);
L3_cH3(z,:)=feature2;
%
feature2=reshape(cV3,1,n2*m2);
L3_cV3(z,:)=feature2;
%
feature2=reshape(cD3,1,n2*m2);
L3_cD3(z,:)=feature2;
end
end
%%%%%%% level one %%%%%%%%%%%%
save ('cA1','L1_cA1');
save ('cH1','L1_cH1');
save ('cV1','L1_cV1');
save ('cD1','L1_cD1');
%%%%%%% level two %%%%%%%%%%%%
save ('cA2','L2_cA2');
save ('cH2','L2_cH2');
save ('cV2','L2_cV2');
save ('cD2','L2_cD2');
%%%%%%% level three %%%%%%%%%%%%
save ('cA3','L3_cA3');
save ('cH3','L3_cH3');
save ('cV3','L3_cV3');
save ('cD3','L3_cD3');
```

DWT MATLAB Code for Yale Database

```
% Feature Extraction
clear all;
z=0;
for f=1:15
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\center light\' num2str(f)];
Face=imread(fname,'pgm');
%%%%%%% level one %%%%%%%%%%
[cA1,cH1,cV1,cD1] = dwt2(Face,'Haar');
z=z+1;
[n m]=size(cA1);
feature=reshape(cA1,1,n*m);
L1_cA1(z,:)=feature;
%_____________________________
feature=reshape(cH1,1,n*m);
L1_cH1(z,:)=feature;
%_____________________________
feature=reshape(cV1,1,n*m);
L1_cV1(z,:)=feature;
%
feature=reshape(cD1,1,n*m);
L1_cD1(z,:)=feature;
%%%%%%% level two %%%%%%%%%%
[cA2,cH2,cV2,cD2] = dwt2(cA1,'Haar');
[n1 m1]=size(cA2);
feature1=reshape(cA2,1,n1*m1);
L2_cA2(z,:)=feature1;
%
feature1=reshape(cH2,1,n1*m1);
L2_cH2(z,:)=feature1;
%
feature1=reshape(cV2,1,n1*m1);
L2_cV2(z,:)=feature1;
%
feature1=reshape(cD2,1,n1*m1);
L2_cD2(z,:)=feature1;
%%%%%%% level three %%%%%%%%%%
[cA3,cH3,cV3,cD3] = dwt2(cA2,'Haar');
[n2 m2]=size(cA3);
feature2=reshape(cA3,1,n2*m2);
L3_cA3(z,:)=feature2;
%
feature2=reshape(cH3,1,n2*m2);
L3_cH3(z,:)=feature2;
%
```

```
feature2=reshape(cV3,1,n2*m2);
L3_cV3(z,:)=feature2;
%
feature2=reshape(cD3,1,n2*m2);
L3_cD3(z,:)=feature2;
end
for f=1:15
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\glasses\' num2str(f)];
Face=imread(fname,'pgm');
%%%%%%% level one %%%%%%%%%
[cA1,cH1,cV1,cD1] = dwt2(Face,'Haar');
z=z+1;
[n m]=size(cA1);
feature=reshape(cA1,1,n*m);
L1_cA1(z,:)=feature;
%____________________________
feature=reshape(cH1,1,n*m);
L1_cH1(z,:)=feature;
%____________________________
feature=reshape(cV1,1,n*m);
L1_cV1(z,:)=feature;
%
feature=reshape(cD1,1,n*m);
L1_cD1(z,:)=feature;
%%%%%%% level two %%%%%%%%%
[cA2,cH2,cV2,cD2] = dwt2(cA1,'Haar');
[n1 m1]=size(cA2);
feature1=reshape(cA2,1,n1*m1);
L2_cA2(z,:)=feature1;
%
feature1=reshape(cH2,1,n1*m1);
L2_cH2(z,:)=feature1;
%
feature1=reshape(cV2,1,n1*m1);
L2_cV2(z,:)=feature1;
%
feature1=reshape(cD2,1,n1*m1);
L2_cD2(z,:)=feature1;
%%%%%%% level three %%%%%%%%%
[cA3,cH3,cV3,cD3] = dwt2(cA2,'Haar');
[n2 m2]=size(cA3);
feature2=reshape(cA3,1,n2*m2);
L3_cA3(z,:)=feature2;
%
feature2=reshape(cH3,1,n2*m2);
L3_cH3(z,:)=feature2;
```

```
%
feature2=reshape(cV3,1,n2*m2);
L3_cV3(z,:)=feature2;
%
feature2=reshape(cD3,1,n2*m2);
L3_cD3(z,:)=feature2;
end
for f=1:15
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\happy\' num2str(f)];
Face=imread(fname,'pgm');
%%%%%%% level one %%%%%%%%%%
[cA1,cH1,cV1,cD1] = dwt2(Face,'Haar');
z=z+1;
[n m]=size(cA1);
feature=reshape(cA1,1,n*m);
L1_cA1(z,:)=feature;
%___________________________
feature=reshape(cH1,1,n*m);
L1_cH1(z,:)=feature;
%___________________________
feature=reshape(cV1,1,n*m);
L1_cV1(z,:)=feature;
%
feature=reshape(cD1,1,n*m);
L1_cD1(z,:)=feature;
%%%%%%% level two %%%%%%%%%%
[cA2,cH2,cV2,cD2] = dwt2(cA1,'Haar');
[n1 m1]=size(cA2);
feature1=reshape(cA2,1,n1*m1);
L2_cA2(z,:)=feature1;
%
feature1=reshape(cH2,1,n1*m1);
L2_cH2(z,:)=feature1;
%
feature1=reshape(cV2,1,n1*m1);
L2_cV2(z,:)=feature1;
%
feature1=reshape(cD2,1,n1*m1);
L2_cD2(z,:)=feature1;
%%%%%%% level three %%%%%%%%%%
[cA3,cH3,cV3,cD3] = dwt2(cA2,'Haar');
[n2 m2]=size(cA3);
feature2=reshape(cA3,1,n2*m2);
L3_cA3(z,:)=feature2;
%
feature2=reshape(cH3,1,n2*m2);
```

```
L3_cH3(z,:)=feature2;
%
feature2=reshape(cV3,1,n2*m2);
L3_cV3(z,:)=feature2;
%
feature2=reshape(cD3,1,n2*m2);
L3_cD3(z,:)=feature2;
end
for f=1:15
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\left light\' num2str(f)];
```

LBP MATLAB Code for ORL Database

```
% Main function
clc
clear all
%%%%%%%%%%%% Extract LBP Feature of the Faces 1by1
bn=1;
bm=1;
z=0;
for l=1:40
for f=1:10
   z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\ORL\s' num2str(l) '\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
end
save ('LBP_1by1','feature');
%%%%%%%%%%%% Extract LBP Feature of the Faces 2by2
clc
clear all
bn=2;
bm=2;
```

```
z=0;
for l=1:40
for f=1:10
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\ORL\s' num2str(l) '\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
end
save ('LBP_2by2','feature');
%%%%%%%%%%%%% Extract LBP Feature of the Faces 3by3
clc
clear all
bn=3;
bm=3;
z=0;
for l=1:40
for f=1:10
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\ORL\s' num2str(l) '\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
end
save ('LBP_3by3','feature');
%%%%%%%%%%%%% Extract LBP Feature of the Faces 4by4
clc
clear all
bn=4;
bm=4;
```

```
z=0;
for l=1:40
for f=1:10
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\ORL\s' num2str(l) '\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
end
save ('LBP_4by4','feature');
z
%%%%%%%%%%%% Extract LBP Feature of the Faces 5by5
clc
clear all
bn=5;
bm=5;
z=0;
for l=1:40
for f=1:10
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\ORL\s' num2str(l) '\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
end
save ('LBP_5by5','feature');
```

LBP MATLAB Code for Yale Database

```
% Main function
clc
clear all
%%%%%%%%%%%%% Extract LBP Feature of the Faces 1by1
bn=1;
bm=1;
z=0;
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\center light\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\glasses\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\happy\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\left light\' num2str(f)];
```

```
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\no glasses\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\normal\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\right light\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\sad\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
```

```
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\sleepy\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\surprised\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\wink\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
save ('LBP_1by1','feature');

%%%%%%%%%%%%%% Extract LBP Feature of the Faces 2by2
clc
clear all
bn=2;
bm=2;
z=0;
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\center light\' num2str(f)];
```

```
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\glasses\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\happy\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\left light\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\no glasses\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
```

```
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\normal\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\right light\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\sad\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\sleepy\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\surprised\' num2str(f)];
Face=imread(fname,'pgm');
```

```
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\wink\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
save ('LBP_2by2','feature');
%%%%%%%%%%%%% Extract LBP Feature of the Faces 3by3
clc
clear all
bn=3;
bm=3;
z=0;
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\center light\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
    z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\glasses\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
```

```
for f=1:15
   z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\happy\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
   z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\left light\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
   z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\no glasses\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
for f=1:15
   z=z+1;
fname=['E:\Karzan Gasha Thesis _ Matlab\Databases\yaleS\normal\' num2str(f)];
Face=imread(fname,'pgm');
LBP=LBP8_Image(Face);
feature(z,:)=Feature_extract8(LBP,bn,bm);
end
```