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ATILIM UNIVERSITY 2020

FACE RECOGNITION USING IMAGE PROCESSING AND MACHINE LEARNING METHODS

THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
ATILIM UNIVERSITY

IMAN RAAD RUSHDI

A MASTER OF SCIENCE THESIS
IN
THE DEPARTMENT OF COMPUTER ENGINEERING

August 2020

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A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
ATILIM UNIVERSITY

BY

IMAN RAAD RUSHDI

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
THE DEPARTMENT OF COMPUTER ENGINEERING SYSTEMS

AUGUST 2020

Approval of the Graduate School of Natural and Applied Sciences, Atilim University.

Prof. Dr. Ali KARA
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I certify that this thesis satisfies all the requirements as a thesis for the degree of **Master of Science in Computer Engineering, Atilim University**.

Assoc. Prof. Dr. Gökhan ŞENGÜL
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This is to certify that we have read the thesis **"Face Recognition Using Image Processing and Machine Learning Methods"** submitted by **IMAN RAAD RUSHDI** and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ABSTRACT

FACE RECOGNITION USING IMAGE PROCESSING AND MACHINE LEARNING METHODS

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August 2020, 82 pages

The human face is a complex multidimensional visual construct, which makes it very challenging to create a computational model for recognition. Basically; face recognition is a method of recognizing a person based on the image of his or her face and has become an important area of study, covering various subjects such as image processing, computer vision and machine learning. The main challenge with facial recognition is how to correctly identify the correct feature for facial detection.

This study presents an approach for the recognition of the human face based on the features extraction from the image. The face recognition system has been applied on ORL and YALE datasets. The proposed method was initially implemented in three steps. For pre-processing phase, Discrete Wavelet Transform (DWT) with Daubechies transform was applied. At second step, feature extraction phase was implemented based on Local Binary Pattern (LBP) and Gray Level Co-Occurrence Matrix (GLCM). Third step, Euclidean Distance was implemented for classification phase. Moreover, the same experiments were implemented applying Particle Swarm Optimization (PSO) for feature selection approach. The study observed several conclusions: for the first experiments; implementation of DWT and LBP, when the number of training image increased; the performance rate has been increased too, rather than implementing DWT, LBP and GLCM methods that conducted 82.50% of recognition rate when implementing on ORL database and 90% when implementing the three methods on YALE database. However, the implementation of PSO algorithm have increased the accuracy rate up to 95% for ORL database and 93% on YALE database.

Keywords: Face Recognition, Feature Extraction, Feature Selection, Discrete Wavelet Transform, Local Binary Pattern, Gray Level Co-Occurrence Matrix, Particle Swarm Optimization, Euclidean Distance.

ÖZ

GÖRÜNTÜ İŞLEME VE MAKİNE ÖĞRENME YÖNTEMLERİ İLE YÜZ TANIMA

Iman Raad Rushdi Rushdi
Yüksek Lisans, Bilgisayar Mühendislik bölümü
Tez Yöneticisi: Doç. Dr. Gökhan ŞENGÜL
Ağustos 2020, 82 sayfa

İnsan yüzü tanıma, insan yüzünün çok boyutlu karmaşık bir yapı olması nedeniyle zor ve karmaşık bir problemdir. Temel olarak; yüz tanıma bir insanın yüz görüntüsünden kimliğinin belirlenmesi olarak tanımlanabilir. Bu nedenle yüz tanımada görüntü işleme, bilgisayarlı görü ve makine öğrenmesi gibi farklı disiplinlerin bir arada çalışması gerekir.

Yüz tanımlamasıyla ilgili temel zorluk; yüz tanımlamasıyla ilgili doğru özelliklerin, doğru bir şekilde nasıl tanımlanacağıdır. Bu çalışma, görüntüden özellik çıkarma ve özellik seçimine dayalı olarak insan yüzünün tanınması için bir yaklaşım sunmaktadır. Önerilen yüz tanıma sistemi ORL ve YALE veri kümelerinde test edilmiştir. Önerilen yöntem başlangıçta üç adımda uygulanmıştır. Ön işleme aşaması için Daubechies dönüşümü ile Ayrık Dalgacık Dönüşümü (DWT) uygulanmıştır. İkinci aşamada, Yerel İkili Kalıp (LBP) ve Gri Seviye Eş-Oluşum Matrisi (GLCM) esas alınarak özellik çıkarma aşaması uygulanmıştır. Üçüncü adım, Öklid Uzaklığı ile sınıflandırma aşamasını içermektedir. Ayrıca, özellik seçimi yaklaşımı için Parçacık Sürüsü Optimizasyonu (PSO) uygulanarak aynı deneyler uygulanmıştır. Çalışmada birkaç sonuç gözlemlemiştir: DWT ve LBP'nin birlikte uygulandığı ilk deneylerde; eğitim kümesindeki görüntü sayısındaki artışla birlikte ORL veritabanında %82,50 tanıma oranı, YALE veritabanında ise %90 tanıma oranı elde edilmiştir. Bununla birlikte, PSO algoritmasının uygulanması durumunda, ORL veritabanı için doğruluk oranını %95'e ve YALE veritabanında doğruluk oranı %93'e kadar artmıştır.

Anahtar Kelimeler: Yüz tanımlama, Öznitelik Dönüştürme, Öznitelik Seçimi, Ayrık Dalgacık Dönüşümü, Yerel İkili Kalıp, Gri Seviye Eş-Oluşum Matrisi, Parçacık Sürüsü Optimizasyonu, Öklid Uzaklığı.

To my beloved family…

ACKNOWLEDGMENTS

First and above all, I would like to express my thanks and gratitude to Allah, for His blessings through my thesis study to finish it successfully.

I would also like to declare my deepest and heart full appreciation for my supervisor, **Assoc. Prof. Dr. Gökhan ŞENGÜL** for providing me the chance to do this researching work and his recommendations during this study. I was deeply inspired by his vision and motivation. It was a big honor and privilege to work and learn under his supervision.

I am also very thankful and grateful to my dearest parents (Ayhan and Raad) for their love, patience, prayers, supports and sacrifices for my education. Also, I am thankful to my brothers (Ahmed and Bilal), uncle Zuhdi and my friends who have supported and gave me motivation during this period to finish my thesis work. I love you all.

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LIST OF ABBREVIATIONS

LBP	Local Binary Pattern
GLCM	Gray Level Co-Occurrence Matrix
DWT	Discrete Wavelet Transform
PSO	Practical Swarm Optimization
BPSO	Binary Practical Swarm Optimization
EDC	Euclidean Distance Classifier
PCA	Principal Component Analysis
FPD	Face Part Detection
HOG	Histograms of Oriented Gradients
SVM	Support Vector Machines
k-NN	K Nearest Neighbor
GLTDM	Gray Level Total Displacement Matrix
ORL	Olivetti Research Ltd
LDA	Linear Discriminant Analysis
DCT	Discrete Cosine Transform
2-D	2 Dimension
3-D	3 Dimension

CHAPTER 1

INTRODUCTION

1.1 Introduction

Facial recognition appears to be an important subject for researchers. Due to some studies reported that the effect of the human partition in our daily lives have increased in the fourth generation of communication systems that allow individuals to communicate with computers rather than humans. Thus, the main content of interaction of in advanced smart systems is the identification and recognition of individuals which falls under biometric system.

Biometric system has been a common way for providing personal identity. Identification of the person is important in many cases and the increase in credit card fraud and identity theft in previous years shows that this is a significant matter to concern in the wider community. Biometrics is a combination of the Greek Words Bio (Life) and Metrics. Biometric system is a science that tests the ability to recognize people according to his / her detectable biological or behavioral characteristics (physical or behavioral) [1]. Biometric system; as we mentioned is grouped into two main categories: Physical and Behavioral biometrics. Physical biometrics techniques include fingerprints, geometry of the hand and finger, facial recognition, iris and retina scans and recognition of vascular patterns. The biometric behavioral techniques include recognition of speech and voice, and verification of signatures.

When biometric recognition systems were developed in this century, facial recognition systems became very important in terms of usage and development, especially with the emergence of security problems in technology today [2].

Several of these biometric methods include some active intervention on the user part, i.e. the user needs to put his or her hand on a hand geometry recognition and stand in a pre-determined location front of an iris or a retinal camera. Face detection and face recognition, however, can be done automatically with no specific involvement or participation on the part of the user because a camera may capture face images from a distance. It appears to provide some benefits among all other biometric methods, since it is a biometric technology which will automatically identify a person from images by comparing and analyzing the database patterns [3].

The face of human is one of the most important elements used for identifying individuals. Each human face has different discernible characteristics that make up facial features [4]. Therefore; many researchers and academic institutions have interests in the field of biometrics. This field is very important because it is applicable in our daily life in many cases.

Human beings usually start to recognize faces of other people after the age of five. It appears to be an automatic and natural process in their minds [5]. They can identify people they know, particularly even though if they are wearing glasses or caps. Also, they can recognize old people from their old images. All these steps sound simple, but they are a major challenge for the computers. It's a serious task to create an automatic device that matches person capacity to remember other human faces. Humans are very strong at recognizing familiar faces. However, humans are not quite professional when coping with a huge number of unfamiliar faces. Computer machines that have unlimited capacity and processing speed can exceed human limitations. And the first semi-automatic facial recognition system was produced by Woody Bledsoe, Helen Chan Kurt and Charles Bisson in the 1960s [6] by calculating the differences between faces. the distances were entered to the computer and face recognition was born.

Human face includes a number of details that have been used in many systems, such as artificial age classification [7, 8], facial identification [9], forecasting images and restoration apps [10, 11], description of gender and gestures [12], human-computer interaction (HCI), electronic consumer experience management, audience recording, tracking of security cameras, etc. And the applications for face recognition include: monitoring, forensic and medical apps, detection of the person in international centers of transition, access control and several different fields. Recently, the facial recognition technologies were widely used in particular, in areas needing strict security measures (airports, police stations, banks, sport fields, surveillance of entry and exit from business companies) [13].

Face recognition systems do really well in relatively controlled conditions but appear to fail when there are issues with facial images which is the presentation of a particular face that differs caused by various factors, such as variations in posture, position, occlusion, lighting, make-up, noise-and blur-induced image damage, etc. Although researchers have developed many technologies, multiple different solutions have been attempted to address the problem of changing conditions of environment, which are among the main challenges' facial recognition. Difficulties of the face recognition problem derives from the fact that the faces tend to be approximately similar in their most typical shape (i.e., the front view), and the variations between them are very slight. As a consequence, frontal images formalize a large concentration of size of image, which makes it nearly difficult for typical pattern recognition methods to recognize correctly for a high degree of level of success [14].

Another concertation is the database images [15], it is preferred to be taken under controlled environment for effective face recognition. It is also challenging to determine that there is actually enough information in the stored images so that the information related can be extracted from the databases. Most of the time, unnecessary information also is present in the images of the database, resulting in higher storage consumption and higher processing times. The optimal size of the images also requires to be stored in the databases for effective results [16, 17]. The image size can be compressed to the required size and stored in the databases. When the image size is compressed, there would be a loss of features, but it can be stored in large numbers and the transmitting of the image data through the network is fast [18].

Flowchart of facial recognition model proposed is given in Figure 1.1:

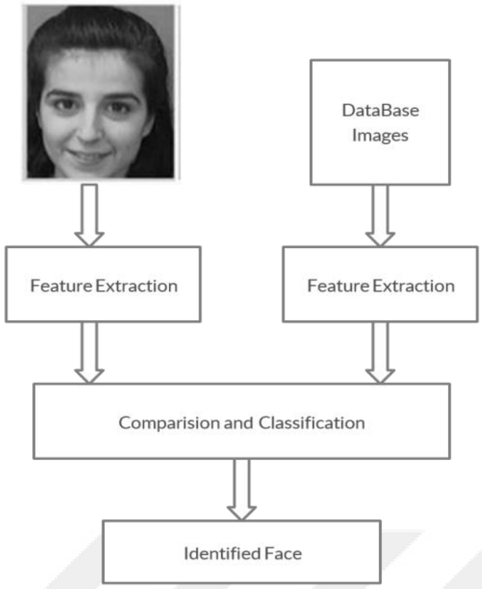

Figure 1.1 Concept of the identification with facial recognition process model

During feature extraction method, important features are extracted. With such applications, facial picture is linked to the photographs in the database. It is accomplished during the step of classification [19, 20]. The output of the classification part is finding the minimum variation from the test images and identifying the face image first from database with the largest matching value, with the slightest differences relative to the input face image.

1.2 Methods used for face recognition

Though there are many methods for image processing, some of them have the ability to resolve the problem of face recognition system. The oldest Face recognition methods may be classified as follow [21, 22]:

a. Holistic Method
b. Local Method
c. Hybrid method
d. Principal Component Analysis

a. Holistic method

Many generic algorithms for facial recognition were introduced. Among these, there are two algorithms which have had a very important impact on the research community for face recognition and have motivated countless studies. There are Fisherfaces, and Eigenfaces [23].

b. Local method

Face recognition based on local facial regions has attracted a great deal of interest because local features are thought to be active more due to variations in expression of faces, illumination and occlusion. Methods that use local regions either use relevant areas, or divide the facial expression into rectangular blocks, see Figure 1.2:

Figure 1.2 Holistic Approach for Face Recognition

c. Hybrid methods

Hybrid methods are methods which include two or more methods to face recognition. Since singular methods cannot provide a successful approach to the challenge of facial recognition, researchers tended to combine global and local information extracted using one or more various feature types to enhance recognition performance.

d. Principal Component Analysis (PCA)

PCA is dimensional reduction and data representation technique to determine a new coordinate system for a database image set. The aim is to organize extensive records, simplify and illustrate by approaching a smaller number of meaningful possible linear combinations (the "primary components") with a variety of statistical variables. Besides, the Karhunen-Loève transformation that is closely related to PCA. It is also called the main component analysis which is widely used in image processing and data analysis [24]. KLT is a signal dependent transform and comprised of three major steps which are statistical measurement, eigenvectors and eigenvalues. Where each of them has its own computational requirement. They must be differentiated from the factor analysis in which it has formal similarities and in which they can be used as a means of approximating factors to be removed. (In item-factor analysis the difference between the two methods is explained). PCA has various generalizations. The Principal Curves, the Principal Surfaces, or the PCA kernel.

1.3 Motivation

Face recognition is the technology of a biometric mechanism that can accurately recognize or check a person by comparing patterns depending on the features of the person's face. The technology is mainly used for security purposes. Face recognition technology has gained major interest because it has the ability for a wide variety of law enforcement specific implementations as well as many businesses.

Application of Face Recognition system [25]:

1. Improved public security:

Law enforcement is among the most commonly referred fields concerning beneficial effects of facial recognition technology. Through recognizing suspects between other crowds, facial recognition technology can help minimize stoppage and search for law-abiding people.

2. Quick identification:

Provides a fast processing capability which means that it does not require user interaction. Users must remember passwords for current identity authentication systems. Companies can control access to the information with no need for long lines.

3. Face Recognition advantages in Banking:

With facial recognition, no need for passwords that hackers might break. Even if hackers attempted to steal your photo database, it would be of little use to prevent them being used for impersonation purposes, as "liveness detection" [26].

4. Better attendance programs for the employees:

To log in for work, everyone will pass face-scanning apps. Paid hours start from this moment until checkout (also with face recognition).

We have discussed the advantages of face recognition technology in this section, including easy biometric authentication and better protection when it comes to banking and shopping, there are definitely many advantages.

1.4 Proposal work

One of the basic issues of computer-based systems is the recognition of the human face. Many methods for face recognition such as holistic, local, or hybrid methods are used in previous literatures. But in the other hand, recent work has shown that face recognition using methods of feature extraction on face databases is a useful tool to resolve facial recognition problem. The key goal of this thesis is to compare the accuracy rate and performance level of the face recognition methods and to get a deduction indicating and estimating which of these techniques provide the best recognition rate. The proposed methods are Discrete Wavelet Transform for image compression, Gray level co-occurrence matrix with Local binary pattern, that will be applied for feature extraction. At last, Particle Swarm Optimization algorithm will be used for feature classification and Euclidean Distance will be used for classification phase based on the extracted features to measure the distance between the nearest two points. The proposed methods will be implemented on ORL and YALE databases.

1.5 Outline of thesis

This thesis is composed of five chapters. Chapter one includes an introduction for face recognition system and a general view of the study and. Chapter two includes a review of previous study for face recognition methods. It tries to focus on the most important previous methods and their results. In Chapter three the materials and methodologies that are used in this thesis will be discussed. Chapter four includes implementation of the algorithms with the experimental results of the proposed methods and discussion about the study. Finally, the conclusion of the study and future works will be explained in Chapter five.

CHAPTER 2

LITERATURE REVIEW

2.1 Previous studies for Face Recognition

In the last decades, modern application area of facial recognition system has attracted a lot of interest in research and study in the field of pattern recognition in recent years. Very successful applications in image analysis has been developed with this system. Face recognition system is a process of identifying people through their facials images. It requires database images to use the tested images and try to match them with the set of trained images and then evaluate if the test images match some trained images. To perform face recognition system, feature extraction prefers to be applied. Feature extraction is extracting the facial component from human face image features [27]. Therefore; now it is an essential part of pre-processing and geometric normalization. Later, these features can be used to find some other images with matching features.

In this chapter a brief review for some previous studies of various methods used for solving the challenges and problems in face recognition system resulting different accuracy rates.

Manar et. Meaad [22] have used PCA, Wavelet transform and GLCM for feature extraction. Principal Component Analysis (PCA) is an effective computational tool for both extracting feature and dimension reduction. Wavelet transform is a commonly popular method used in the enhancement of the image's edges in image processing applications, feature extraction and compression. GLCM is a simple method for textural features extraction in Face Recognition System, to extract the most significant features from person's face images. A set of train images and test images are used to compare the performance of each of the mentioned methods in the face recognition system. For the classification stage, they used Euclidean distance to assess the comparison results, it measures the distances between the image of the face utilized in the set of train images, the image that has the lowest value will be the classification result. The experiment results by comparing these methods using 30 training and 10 test images, the recognition rate when using PCA was 95%, using Wavelets they also obtained 95% recognition rate. While using GLCM the obtained result was 75%.

Hybrid technique was discussed by Harra et Aggarwal in [28], by combining two methods; Discrete Wavelet Transform (DWT) and Local Binary Pattern (LBP) for facial image database for extracting their features. DWT divides the images into four sub-bands, LBP Which encodes image pixels by thresholding each pixel's neighborhood, considering the result as a binary set. Then Principalprinc Component Analysis (PCA) is implemented by using Eigen values for the combined extracted features for both test images and train images. Finally, The K-nearest neighbor (KNN) classifier is utilized for classifying images and accuracy measurement. The study achieved 95% of accuracy.

For facial feature extraction study by Vijayarani et Priyatharsini in [29], the features of human facial images are extracted utilizing the Gray Level Co-occurrence Matrix (GLCM) method and Face Part Detection (FPD) method. FPD tried to use the form of bounding boxes, and GLCM uses the system of affine internal source. JAFFE database that has 181 images was used for experiment. The vectors of performance that are implemented here are the time of execution of the extraction of features and accuracy, we will mention the accuracy part. Through comparing FPD and GLCM, it has been shown that GLCM extracts accurate features. Since, GLCM utilizes the fifteen images and selects features individually, such as eyes, eyebrows and lips. The accuracy measurement demonstrated that the GLCM method is better than the FPD method with its higher recognition by using the Support Vector Machine (SVM) algorithm. SVM is implemented for classification. The best accuracy value is obtained by training and testing the images by extracting the features specifically by SVM parameters. Experiment result for the accuracy measurement for FPD method is 78% and for the GLCM method is 90%.

In [30], Qu et al implemented a creative anti-spoofing technique relying on a Gray Level Co-occurrence Matrix (GLCM) and a Dual Tree Complex Wavelet Tree (DT-CWT). So, by applying the Co-Occurrence Matrix, they extracted five texture features, that includes similarity, entropy, second-moment angle, contrast and local uniformity, to represent interval and amplitude, gray direction details for the information of facial textures. To recognize the expression of a human face; researchers Satyanarayana et al in literature [31] have proposed a method by combining Gray Level Co-occurrence Matrix (GLCM) approach with structural method obtained from distinct Local Binary Pattern (LBP). The obtained classification rate was 96.67% when they used original, Google and scanned image databases. As it is obvious that LBP method increases the accuracy rate. Also, according to study by Gondolo et Salunkhe [32], LBP operates on local features which uses LBP operator for summarizing the local special structure of the LBP face image, an arranged set of binary arbitrage of pixel intensities and its eight surrounding pixels. The proposed algorithm was effectively established using MATLAB obtaining recognition rate varies from 65.28% to 100% with an average value of about 76.96% using the local image face database. By comparing with traditional facial recognition methods; Principle Component Analysis (PCA) and Linear Discriminant Analysis (LDA), it is found that LBP method have higher quality in face recognition performance.

According to a study by Kumar et al in [33], Local Binary Pattern (LBP) was utilized to establish the recognition rate for images saved in the database and training images which are tested to figure out the matching image of the database images. The image size was compressed; since compressing increases the speed of computation and the face recognition system performance. The original image that is put in the database, has consumed the storage and the processing time became higher when there are a lot of images for a better recognition performance. In this paper; they have proven that the face recognition method will recognize faces even after the image size is compressed by 10% of its original. While in [34], Biswas suggested an Local Binary Pattern (LBP) method on different types of images; based on dividing the face region into smaller areas where LBP histograms are extracted and combined into one vector function. The final step is the classification phase, where face image is compared with database images. The experiment results meet all Face Image Recognition requirements with 99% recognition rate when using 2000 images as input images and images from database. LBP method works faster than the other face recognition methods, which lets it successful and effective method. As it is referred in study by Humne et Sorte in [35], the article has performed the LBP algorithm's through study of the facial expression analysis and face recognition.

There is another challenge in face recognition security system, that is how to check an imitation of facial image [36]. To solve this problem, according to the study by Sthevanie et Ramadhani in [36], a combination of two methods were implemented; LBP and GLCM for texture extraction. The study results showed that when using only LBP method, GLCM method and the LBP and GLCM method combination, the spoofing checking system rate was 99.07%, 92.82% and 99.26%; respectively.

A novel method by Patil et al in [37] was proposed using Discrete Wavelet Transform (DWT) and de-correlation of local features. DWT is one of the most popular transformation methodologies utilized for image compression. Gabor features operator on trained images then LBP applied on all Gabor magnitude pictures. Next step is calculating histograms. Finally, DWT is implemented on all histograms forming histogram feature vector. This experimental approach works well for partial occlusion photos and lighting variance images.

Nicholl et al [38] used Principle Component Analysis (PCA) and Discrete Wavelet Transform (DWT) to establish a feature vector, then structured to remove useless features and by that, no need to overly crop the image since the useless background are eliminated. The experiments were implied on AT&T database obtaining 97.50% of recognition rate by using Haar wavelets. And according to a study by Allagwail et in [39], al a new approach was produced using Symmetrical Face Training samples for face recognition. Two-dimensional DWT, GLPF and DoG used for pre-processing phase. For feature extraction phase; LBP, GLCM and Gabor Filters were used. These fused methods were proposed to make the extraction operation more sturdy. The experiment was implied on ORL and Yale Database obtaining 100% of recognition accuracy.

Discrete wavelet transformation technique is also used to increase the accuracy and recognition efficiency. DWT was applied to the ORL database by Kak et al in [40], The highest result was 99.25% when they used 9 train images and 1 test images with cosine distance management and PCA extraction features and used Euclidean distance, Manhattan distance and cosine distance for the classification phase.

Saleh et al [41] proposes a fusion work of ethnicity recognition, that combines local binary patterns with Low frequency LL sub-band coefficients of Haar wavelet transformation. Several experiments were done in a combination set of 746 face images from some public domain databases. In addition, Principle Component Analysis (PCA) was applied to increase the recognition quality. Reducing the number of combined features from 536 to about 15 without affecting too much accuracy, 96.92% accuracy rate was obtained. There is often a trade-off in PCA-based face recognition between not removing useful information and selecting important parts of a face image [42]. To evaluate the most discriminatory eigenfaces coefficients, Nicholl et Amira in [42] proposed a combined method for facial recognition system using DWT and PCA derived on the training set Eigen face weight vectors. Moreover, the eigenfaces selects their values according to its relied eigenvalues for the recognition process. The results of the study showed 95.50% of the recognition rate using AT&T database. Also, Wang et al [43] improved PCA, DWT in addition Support Vector Machines (SVM) were presented by the researcher. The experiment results demonstrated that the proposed method decreases the computational amounts as the dimension of the origin image's overall population scatter matrix has concluded a lot, and the SVM classifier efficiency is preferable among other classifiers. The quantification speed and the performance of recognition approach here improves relative to the standard PCA face recognition algorithm. The study results that used on ORL image database showed that The recognition percentage of the system improved by the increase of the extracted eigenfaces up to 94.20% accuracy. However, the speed of recognition decreases considerably due to the incense of the sum of the calculation and the increase of the classifier 's complicates when the dimension is too great. Besides that, there are some challenges that appears in face recognition system such as the differences of head rotation, intensity of light, expression of the face, and illumination, makes the facial recognition system more difficult. To enhance these problem, [44] Murugan et al suggested three multiscale approaches: Discrete Wavelet Transform and Gabor Filter, Log Gabor Filter to reduce dimensions then PCA is implied on these approaches to calculate accuracy. The experiment results were obtained by applying these methods on a database containing a 112 images of different people with 28 trained images. It was found that when using PCA the recognition rate was 89%. Gabor Filter obtained 92% of recognition rate while Log Gabor Filter obtained 83%. By implementing DWT, the average of recognition rate was 77.80% for the three levels of DWT.

Kakarwal et Deghmukh in [45], using Wavelet Transform based analysis approach was suggested for facial recognition. This method is used for feature extraction of the FERET database. In the experiments, Correlation values and Threshold values were used to make sure high reliability of the classification results. Experimental results demonstrated that the method which was proposed, by using the frontal and side view images, is a useful and efficient face recognition solution that can lead to a higher and more realistic utilization of current forensic databases in computerized the technology of face recognition. Methodology is capable of achieving great results, by using a small set of features, and to calculate the error, FAR and FRR were used.

Gautam et Rourkela in [46], introduced the conceptual technique for compressing medical images using a combination of compression method (DWT, DCT and Huffman coding). The aim of this combined algorithms is to obtain higher compression levels. First by applying DWT and DCT to individual RGB components. After implementing the image, it is quantified to estimate the probability index for each unique quantity in order to obtain the unique binary code for each unique symbol for its encoding. The Huffman compression is finally applied. The results indicate that the coding implementation of the combination DWT, DCT and Huffman coding techniques can be improved significantly.

According to a study by Sannakki et al in [47] attempts to recognize and classify currency notes by following various phases including image acquisition, pre-processing, testing, training. For the extraction feature, (DWT) is used and the approximate coefficient matrix of the currency image is obtained. Extracted features are used to classify currency notes using the Probabilistic Neural Network. The suggested PNN-based method that uses a combination of different features to recognize and identify the currency, has produced improved results and a recognition rate of 90.38%. And according to study by Yahia et al [48]. Their study aims to solve the problem of 3D image face recognition system. The authors used LBP, GLCM and the combination of these two methods then followed by classification phase; where they used SVM classifier. Experimental results are shown as follows: 3D-LBP obtained 93.13%, 3D-GLCM obtained 65.63% and 3D-LBP + 3D-GLCM obtained 86.25%.

Gender classification is an important field in image vision that can be used in a lot of application such access control, human-computer interaction, biometric authentication, security system, surveillance and helical tomography technique [49], Khalifa et Şengül in [49] produced Local Binary Pattern (LBP) and HOG methods for gender prediction. First test images and train images are selected. Then, the important features are extracted. These methods were implemented on FERET and UTD databases. Finally, k-NN and SVM used to classify images obtaining 98.08% and 98.79% of accuracy; respectively. Another classification between child and adult in [50] a study by Reddy et al, which shows a fluent results over current methods. It is based on combining structural and statistical approaches on a 3 x 3 window based on Local Binary Pattern (LBP) method that is based on dividing the image face into local areas and the features are extracted separately from each area. Then the feature vectors are combined to create a global image of the face. In this study, it works by dividing the image into two structural patterns referred as Left Diagonal (LD) and Right Diagonal (RD) LBP's and from the left and right diagonal-GLCM (LRD-GLCM), their codes were estimated. Finally, for a good age classification method they used chi-square distance. The experiment was executed by using FG-NET database that obtained 93.57% classification rate and images that was downloaded from Google Image obtained 93.39%.

In recent studies of DWT method that is used in pre-processing step by compressing the image to remove the noise from the image. [51] study by INDRIYANI et SUDARMA, for classifying facial skin type. The experiment has been shown that the proposed method is capable of efficiently classifying facial skin types. Detection of facial skin types using the methods DWT, Contrast, LBP and SVM shows an approximate classification result of 91.66 % working on images of the faces of Indonesian people from Sifra Skin Care (Pati, JawaTengah), GriyaAyuClarista (Sidoarjo, JawaTimur), Rossi Skin Care & Spa (Denpasar, Bali), and RumahCantikAssyva (Kediri, JawaTimur).

A study by Ramola et al [52], gave a comprehensive study of GLCM, LBP, ACF and histogram patterns for texture classification. It has shown that GLCM is the most effective method for extracting texture features for classification a discrimination purpose among the presented statistical methods. Besides, a novel method was presented by Ramadan et Kader in paper [53]. Particle Swarm Optimization (PSO) method for feature selection implemented on the extracted features by using DWT and DCT. The experiments tested on ORL database, 4 image as training and 6 images as testing set for each person obtaining 96.80% and 94.70% when implemented on DWT with PSO and DCT with PSO respectively. [54] Wei et al tried a new approach by using PSO method on the vectors of SVM classifier after extracting features applying PCA on FERET human face database. The results of the experiments were 89% when using 150 images in the experiment and 93.64% when using 330 images.

2.2 Summary

This chapter offers a simple and brief look at the researches that have been studied using similar methods to what we have evaluated in our thesis and give a brief description of their databases and experimental results. Here a summary description of the most important methods and their databases that mentioned in this chapter showed in Table 2.1 and Table 2.2:

❖ Face recognition studies of combined methods:

Table 2.1 Popular combined methods used in face recognition system

Study	Method	Data Base	Accuracy
[28] Harra et Aggrawal	LBP + DWT + PCA	Face Images	95%
[31] Satyanarayana et al	GLCM + LBP	Google and Scanned Images	96.67%
[34] Biswas	LBP	Gray-scale Images	100%
[36] Sthevaine et Ramadhani	GLCM + LBP	NUAA Database	99.26%
[44] Murugan et al	DWT + Gabor Filters + LBP	BioID and MIT-CBCL Databases	95%
[38] Nicholl et al	DWT + PCA	AT&T	97.50%
[40] Kak et al	DWT + PCA	ORL	99.25%
[41] Saleh et al	DWT + LBP + PCA	Public Domain Database	96.92%
[42] Nicholl et Amira	DWT + PCA + Eigenface	AT&T	95%

[43] Wanget et Liao	DWT + PCA + SVM	ORL	94.20%
[55] Cevik et al	DWT + GLCTDM	Face94 color Images	86%
[48] Yahia et al	3D-LBP + 3-D GLCM	UMB	86.25%
[50] Reddy et al	LBP + GLCM	FG-NET	93.57%

❖ Face recognition studies of different methods:

Table 2.2 Popular methods used in Face Recognition system

Study	Method	Data Base	Accuracy
[22] Manar et Meaad	PCA, DWT, GLCM	Gray-scale Images	95%, 95%, 79%
[29] Vijayarani et Priyatharsini	GLCM, FPD	JAFFE	90%, 78%
[32] Gonole et Salnkhe	LBP	Facial expression Database	100%
[3] Murgan et al	Gabor, Log Gabor, DWT, PCA	Images of different people	92%, 83%, 77.80%, 89%
[47] Sannaki et Gunlale	DWT	Scanned image	90%
[48] Yahia et al	3D-LBP, 3D-GLCM	UMB Database	93%, 65.63%

CHAPTER 3

METHODOLOGY

Face recognition system is one of the most relevant analysis applications of image analysis. It is a true challenge to build an automated system that equals to the human ability of recognizing faces. Although humans are good in recognizing faces that they know, thus not very good at recognizing a large amount of unknown faces. But the computer can solve this problem with a robust recognition system by extracting relevant and valuable information from the images to be used in recognition step later.

In this chapter, methodology of our study was demonstrated, in first part we represent a general description of the databases that have been used in our study; The proposed methods were tested and evaluate on ORL and YALE databases. Second part includes face detection system using Viola-Jones detector, then pre-processing method using Discrete Wavelet Transform (DWT) is explained. At the next step, features extraction methods were implemented using Local Binary Pattern (LBP) with Gray Level Co-Occurrence matrix (GLCM). We finish this chapter by describing the feature selection implementing Binary Particle Swarm Optimization (BPSO) and classification algorithm that implemented Euclidean Distance Classifier (EDC).

3.1 Databases

Researchers who want to experience a certain type of facial recognition, number of faces must be obtained to be utilized in the recognition or detection system. Several of facial databases was generated in different countries under different conditions such as lighting, posing and illumination, etc. Which are used for educational and scientific objectives. These databases can be reached and obtained from the internet and some of them are free. Some examples of some existing face recognition system databases that were created by organization and researchers in the past: The ORL Database [56], The AR Face Database (The Ohio State University) [57], AT & T - The Database of Faces [58], The Basel Face Model (BFM), The Color FERET Database [59], Labeled Wikipedia Faces (LWF) [60], Yale Face Database [61]. In our study, we will use ORL and Yale Databases.

Databases that are used in this thesis is represented in Table 3.1. It gives a list of some properties: year the images were captured, number of people in ORL and YALE databases and the total number of images.

Table 3.1 Properties of ORL and Yale database

Database	Year	No. of people	Total no. of Images
ORL [56]	1994	40	400
YALE [61]	1997	15	165

In this thesis, people have been chosen as the following: First, in ORL database, all the 40 people are chosen in total and for each person there are ten images. Second, in YALE database, 15 people are all chosen and each person have 11 images.

3.1.1 ORL (Olivetti Research Ltd)

The ORL Database that is used for face recognition experiment, contains a group of facial images consisting of 400 images. There are 40 people, 10 images per person of size 112 x 92. Images were captured at the lab by association with the Speech, Vision and Robotics Group of the Cambridge University Engineering Department between April 1992 and April 1994. Images are captured at different periods of time and under different conditions which are lighting, expression of human face (open / closed eyes, smiling / not smiling) and the detail of the face (glasses / no glasses). All images are captured opposed to a dark background with individuals in a vertically, frontal position (with a little left-right rotation) [56].

Samples of face images from ORL database presented in Figure 3.1:

Figure 3.1 Some samples of ORL Database

3.1.2 Yale Face Database

The Yale Database is used for research purposes, created by Yale University Vision Group in 1997, including 165 images of 15 people. There are 11 images for each person under various conditions, such as facial expressions: center-light, with glasses, happy, left-light, with no glasses, normal, right-light, sad, sleepy, surprised, and wink [61]. Samples of face images from Yale database presented in Figure 3.2:

Figure 3.2 Some samples of YALE Database

3.2 Methodology

In our study, four steps were implemented. First, face detection phase using Viola-jones detector was selected as a detection approach and implemented due to its high performance and detection rate on Yale Database, since the faces are not normalized. Second, pre-processing phase is an important step for face recognition system for reducing unnecessary data by using Discrete Wavelet Transform (DWT). After that, features extraction phase applying Local Binary Pattern (LBP) and Gray Level Co-Occurrence matrix (GLCM) were evaluated. At last, classification phase was applied using Euclidean Distance Classifier (EDC). For more robust system and better classification performance, Binary Particle Swarm Optimization (BPSO) feature selector was implemented.

3.2.1 Face Detection

Face detection is commonly considered to be a special condition of object-class detection and is a common topic of biometry research. Face Identification is the very first step in the process of facial recognition. Faces may be detected through face detection techniques. Viola-Jones Detector was being utilized as a detection method due to its improved detection efficiency and capacity in real time operation.

3.2.1.1 Viola-Jones Detector

Viola-jones detection method was suggested by Paul Viola and Michael Jones in 2001. The method has become exceedingly effective in the 2000s and is considered to be the very initial detection device of objects for providing an easy and uncomplicated detection of objects system which could detect in real time performance [62].

Viola-Jones technique is established by scanning a sub-window that can detect faces from the test image. The typical method for this technique is that the input picture is rescaled to sizes in various amounts and then move the detector through the images. Therefore, this technique consume time due to estimation of the differing sizes images.

In comparison to the conventional technique, Viola-Jones resizes the detector rather than the image of the input and operates the detector several times and with a different size for each turn on the image. Generally, face detection methods might be accused of being equally consuming time. However, Viola-Jones has developed a detector of scale invariant that involves identical number of calculations of any dimension [63].

Viola-Jones face detector method has four stages, that causes high detection levels. The four main steps are Haar feature, integral image, Ada Boost classifier and the cascade classifiers:

- Haar features: Each pixel is computed as follows: The number of the pixels under the rectangle of white colored is subtracted from the pixels under the rectangle of black colored. However, Haar features can have various types as it is demonstrated in Figure 3.3. It uses a 24 x 24 basis window size to begin calculating these features at wherever in the image area. An overall of even more than 160,000 various features will also be built to account for all potential sizes and locations of the features. Yet it is not effective in real-time implementation. It can be decreased by utilizing an Adaboost classifier that is used as redundant features reducer.

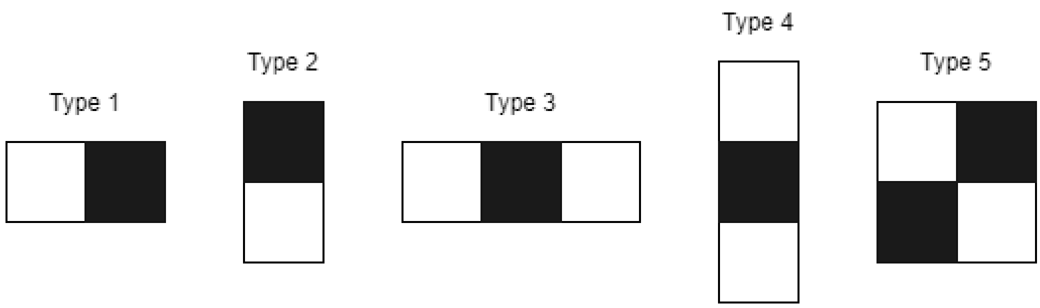

Figure 3.3 Viola-Jones Haar features

- Integral Image: It calculates the edge corner of Haar features. It allows for the sum calculation of all pixel over and to the left of the pixel in incident inside any given rectangle. Sum calculation of the rectangular area of the input image is highly effective, it only requires four additions to any arbitrary rectangle size.

It is implemented to rapidly calculation of the selection of haar-like features. Thus, to obtain a new value of the pixel, the upper pixels and the left pixels will be removed, so all values outside the patch will be applied to get the sum of all values of images. This situation is demonstrated in Figure 3.4:

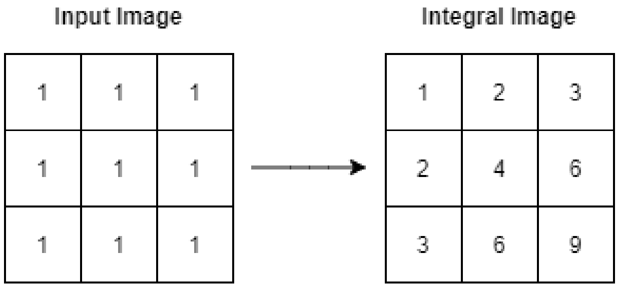

Figure 3.4 Integral image

- AdaBoost is described as a learning machine technique, attempting to get the useful features by eliminating unnecessary features from the 160.000 features. After that, it is utilized to build strong classifiers from a weak classifier of linear combination. Adaboost describes the appropriate features and the non-appropriate features. After that, the Adaboost allocates weight to each of them.

$$h(x) = sgn\left(\sum_{j=1}^{M} a_j h_j\ (x)\right) \tag{3.1}$$

The output of the classifier either equal to 0 or 1;
Weak classifier = 1; Features are identified (e.g.: nose).
Weak classifier = 0; Features are not identified.

- Cascade: Nearly about 2500 features have been estimated for forming a strong classifier. Furthermore, the calculation number can be decreased utilizing cascading. In this, features are stored in another collection of classifiers, often in a cascading sequence. From this technique, it could detect whether or not if it is a face in a less time consuming. Besides; having the ability to deny it whether a classifier could not deliver the desired output for the coming step.

The face detected will be cut and its size is changed to a base resolution of 100 x 100. A further phase is to classify the picture identified utilizing key element classification as well as an artificial neural network technique.

3.2.2 Pre-processing

Pre-processing is essential for each face recognition system. It is a step for enhancing image quality and for fast and efficient processing, by removing noise in the image, reduce unnecessary and excessive data and deciding the part of the image to be used in the next step [64]. Noise is a signal that damages the image brightness in the shape of locations on the image so as to affect the beauty or clearness of the image [65]. Among many methods of image compression techniques, the performance of the developed system is significantly increased using Discrete Wavelet Transform for compression of face training data.

3.2.2.1 Discrete Wavelet Transform (DWT)

Wavelet Transformation (WT) was first found in the literature work of Grossmann & Morlet [66]. Wavelet Transform is a defined linear frequency time transition system in engineering and mathematical fields. Also known as multi-resolution signal analysis and has a nice spatial-frequency localization that represents the representation of time transmission to spectral or wavelet representation and wavelet synthesis [40]. Wavelet Transform converts the signal into a set of basic functions by breaking up of a signal into shifted and scaled versions of single prototype wavelet called mother wavelet [67].

Wavelet is a popular method in the area of image processing and computer vision. The reason that it is successful is that it has a full theoretical framework, good flexibility for choosing bases and low computational difficulty. The goal is to transform signal information into a number (coefficient) such that it can be stored, processed, broadcast, analyzed or used to reset the original signal. In general, the signals are interpreted in amplitude of the time domain on the two-dimensional axis, which reflects the rising at each moment. Although, information that has more useful deterministic is concealed in the signal frequency content. Therefore, the necessary details can be better viewed and evaluated in the domain of frequency. For example, various kinds of noises are handled efficiently in the domain of frequency [68].

Discrete Wavelet Transform (DWT) is implemented as a technique for image compression widely due to the decreasing in computational overhead and computational complexity by reducing the image resolution by creating and decomposing the image with different frequency ranges into sub-bands which provides all the necessary resource needed for the later phases. Moreover, DWT also permits space domain and frequency domain to function on domestic information by supplying the spatial frequency features in an image [69].

A duration model of the digital signal is acquired in DWT utilizing filtering digitalized techniques. To analyze the image, it is passed through filters of various cut-off frequencies at scales that are different. For an image, a global description is supplied by the Low-Frequency content. While the High-Frequency content supplies the accurate details of information such as edges. Thus, in Wavelet analysis they are called approximation and details [70].

Essentially, image is decomposed into approximation horizontal (row), vertical (column) and diagonal features. In essence, the application of Discrete Wavelet Transform is easy to apply, reduces the time and resources needed for computing and reduces the noise in every step of decomposition process [71].

By performing these four filters, DWT is implemented on any given image in horizontal (row) direction and vertical (column) direction:

$$\Phi(\mathrm{x,y}) = \Phi(\mathrm{x})\,\Phi(\mathrm{y}) \qquad 3.1$$

$$\Psi^{H}(\mathrm{x,y}) = \Phi(\mathrm{x})\,\Psi(\mathrm{y}) \qquad 3.2$$

$$\Psi^{V}(\mathrm{x,y}) = \Phi(\mathrm{x})\,\Psi(\mathrm{y}) \qquad 3.3$$

$$\Psi^{D}(\mathrm{x,y}) = \Psi(\mathrm{x})\,\Psi(\mathrm{y}) \qquad 3.5$$

Where x denotes to the vertical direction, y denotes to the horizontal direction, φ indicates a function of scale called low pass filter and ψ also indicates a scaling function called high pass filter. Where ψ^{V}(x,y), ψ^{H}(x,y), ψ^{D}(x,y) are the measurement of the image's different intensity over vertically, horizontally and diagonally respectively. Thus, the multiplication of φ(x) ψ(y) refers to implementing filter of low pass on the vertical side and filter of high pass on the horizontal side. Correspondingly; the four filters can be comprehended on the same way [69].

Wavelet representation of an image sized MxN of scaling function that is correspondent to horizontal (H), vertical (V) and diagonal (D) function is shown as follows:

$$W_{\psi}^{i}(j_0,\mathrm{m,n}) = \frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\mathrm{f(x,y)}\psi_{j_{0,m,n}}^{i}(\mathrm{x,y})\,,\mathrm{i} = \{\mathrm{H,V,D}\} \qquad 3.6$$

Where,

$$\varphi_{j,m,n}(x,y) = 2^{j/2}\varphi(2^{j}x - m, 2^{j}y - n) \qquad 3.7$$

$$\psi_{j,m,n}^{i}\,(x,y) = 2^{j/2}\psi^{i}\left(2^{j}x - m, 2^{j}y - n\right), i = \{H,V,D\} \qquad 3.8$$

In the first step, only one level of decomposition is performed on row of the array by implementing low pass filters and high pass filters that result separating the array into two vertical halves, first half holds the average (coarser) row coefficient and the second half holds the detail coefficient. In the second step, second level of decomposition is performed by implementing 1-D DWT through the rows of image first, after that the output is decomposed through the columns. In general, the output of the decomposition process on image is four sub-bands (LL, LH, HL and HH). Further, LL is used for decomposition due to similarity with the original image and must be full of low-frequency content. While HL and LH sub-bands display edges of the horizontal and vertical directions of the original images. HH sub-band contains a high frequency image property. Figure 3.5 shows the implementation of low pass filters and high pass filters on the image matrix:

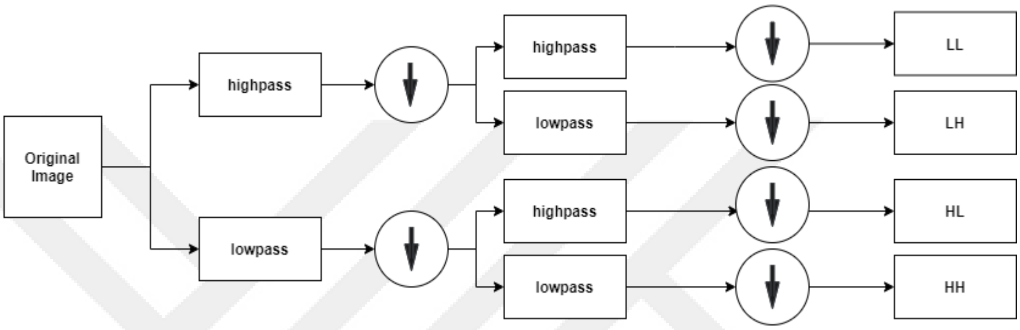

Figure 3.5 Applying low and high pass filters on columns and rows separately in 2-D DWT

The results of decomposition of a face image is 4 sub-band images [72]:

- ❖ LL: is a coarser approximation to the image (approximation component), acquired from applying low pass filters on both horizontal and vertical coordinates. In other words, elimination of all high-frequency details via columns and rows.
- ❖ HL: shows the horizontal edges (horizontal details) by emphasizing the image in the high frequency texture through columns (horizontal) and eliminating high frequency texture through the rows (vertical).
- ❖ LH: shows the vertical edges (vertical edges), obtained by applying high pass filters on rows (vertical) and low pass filters on columns (horizontal). It deletes high frequency texture on rows and gives value to high frequency texture along the columns.

- ❖ HH: shows the high frequency component of the image (diagonal edges or details), obtained by applying high pass filters on both vertical and horizontal coordinates.

By reapplying DWT on the output result L obtained from the first level of DWT on the original image, 2-D DWT is established. Here, L is created from that applying low pass filters on rows and columns and H is created by applying high pass filters on rows and columns. The output of level two of DWT is as following: LL2, HL2, LH2, HH2, HL1, LH1 and HH1 as shown in Figure 3.6 and Figure 3.7:

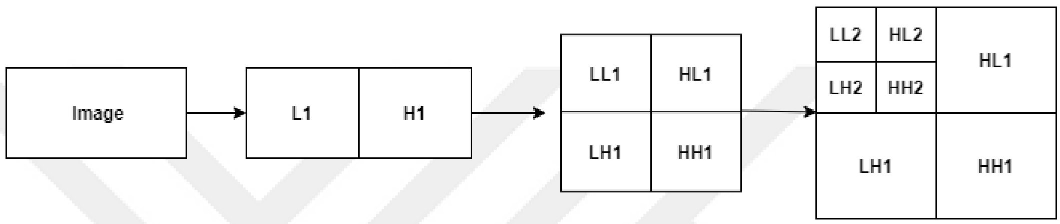

Figure 3.6 Flowchart of Wavelet Transform on an image

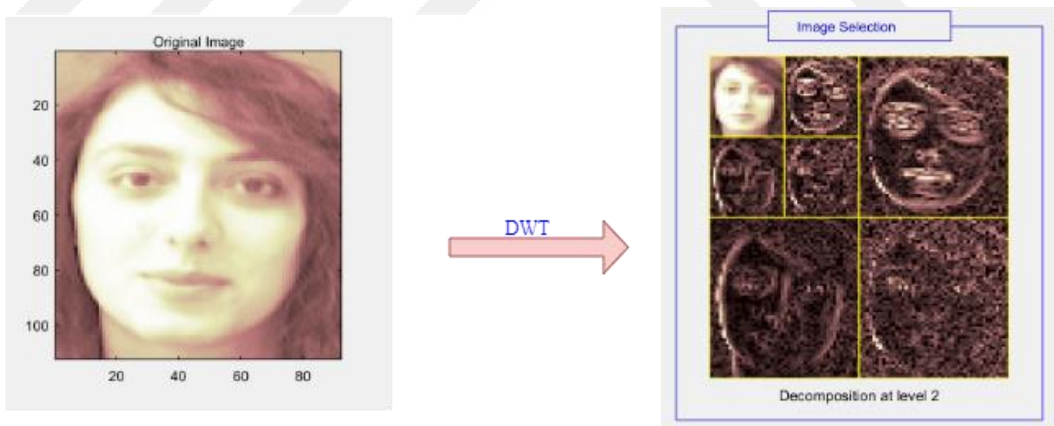

Figure 3.7 The production Discrete Wavelet Transform from level one to level two

In this thesis, decomposition of level one 2-D DWT is implemented using Daubechies Wavelets.

3.2.2.1.1 Daubechies Transform

Daubechies Transform was created by Ingrid Daubechies; one of the best scientist in the field of wavelet research. Daubechies Transform is one of the most perspective transform of the DWT, it is wavelets with robust supports that have the estimated properties of wavelet extensions. They may not have clear expressions and are determined by the filter coefficients. Daubachies Transform is described as follows: dbN, where db refers to the name of the wavelet and N refers the order. And Daubechies Wavelet Transforms are identified by the computation of consisting medium and differences of how product of scaling signals and wavelets are specified. This kind of wavelet has a stable frequency response. To represent all high-frequency changes from the high-frequency range coefficient, Daubechies wavelets utilize overlapped windows. Daubechies wavelets are also effective for the noise reduction and compression of the processing of audio sound signal [73]. An example of Daubechies Transform level 4 is shown below in Figure 3.8:

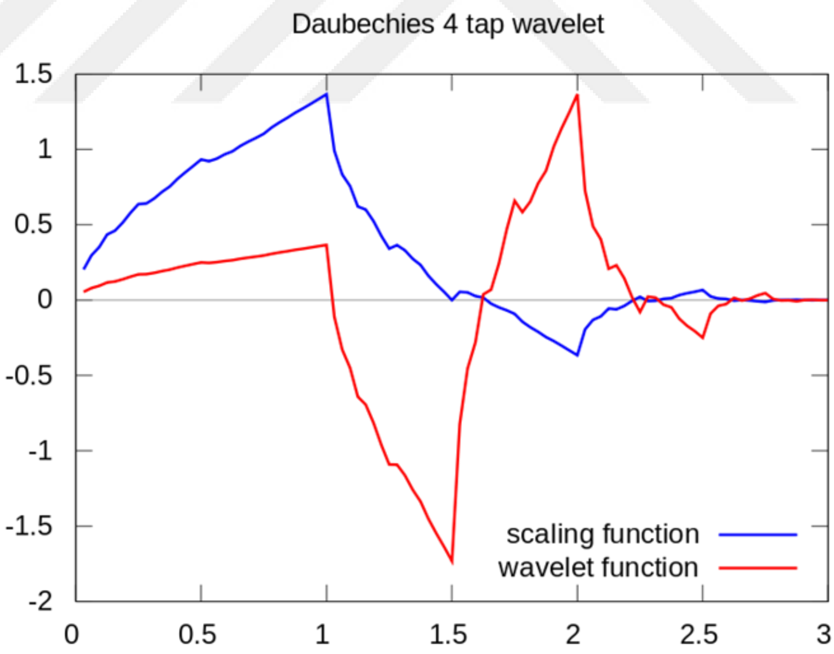

Figure 3.8 Daubechies wavelet example

3.2.3 Feature Extraction

The following part of face recognition is very significant for extraction of features and the selection of features. Local Binary Pattern based on Gray Level Co-Occurrence Matrix were used in this thesis. The proposed methods are useful and effective methodology for the extraction and reduction.

3.2.3.1 Gray Level Co-occurrence Matrix (GLCM)

The Co-occurrence Matrix is effective for different types of image processing technologies, including biomedical, object tracking, mechanical fault detection devices, etc. GLCM has been introduced for being one of the easiest and efficient technique for extracting features for recognition and texture classifications purposes [36]. It is described as Gray Level Co-occurrence Matrix [74].

GLCM was produced by Haralick et al in 1973 [75]. Known as an ordered of second statistical algorithm that is stated to be able to characterize texture as such an average spatial relation between Gray level (intensity) and different dimension of color and proportional situation of the neighboring pixels in an image [76].

The Gray Level Co-Occurrence Matrix for M x N sized image *I* can be described as follows:

$$\text{GL} \sum_{p=1}^{N} \sum_{q=1}^{M} \begin{cases} 1, if\ I(p,q) = i, \ \ and\ I(p+\Delta x, q+\Delta y) = j \\ 0,\ otherwisw \end{cases} \quad 3.9$$

Here, (*i*,*j*) represents the grayscale intensity value of the matrix element, p and q refer to the image coordinates and $(\Delta x, \Delta y)$ are showing the offset values. The grayscale intensity of the image and the offset values are the most significant parameters of the GLCM [74]. For finding the GLCM matrix, the relative pair frequencies of each pixel and its neighboring pixel are calculated at a certain distance and angle. The matrix hence produced is separated by the number of all frequencies for the normalization of the matrix [77].

In other words, GLCM measures how often pixels with Gray level (intensity) values come to level the pixels with the value j either horizontally, vertically or diagonally. The directions for the GLCM are: 0° (0, D) denotes to Horizontal direction, 90° (-D, 0) denotes to Vertical direction, 45° (-D, D) denotes to Right Diagonal and -135° (D, -D) denotes to Left Diagonal. They are also noted as P_H, P_V, P_{RD} and P_{LD}, respectively. See Figure 3.9:

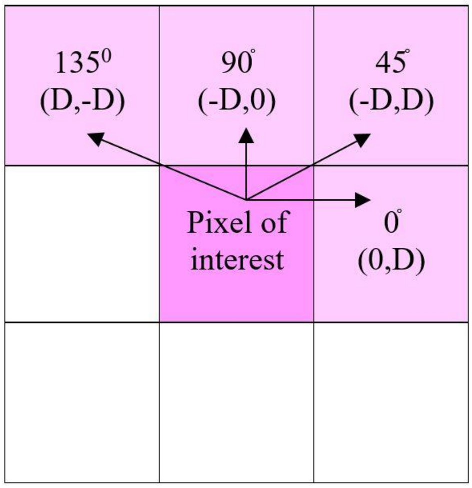

Figure 3.9 Sub-region of direction of GLCM

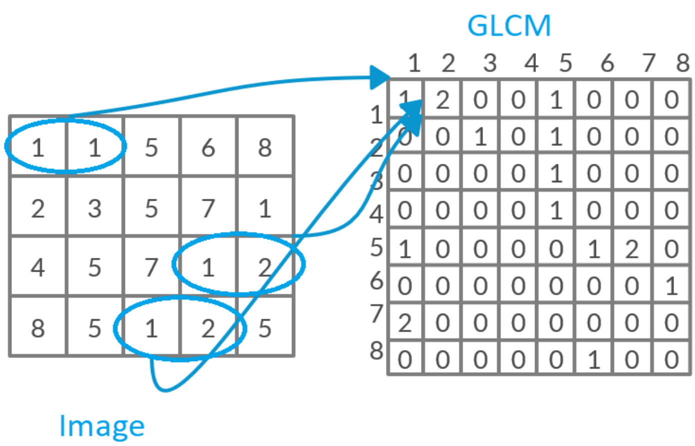

Figure 3.10 Calculation of distance for each pixel value in the matrix

For example, as it is demonstrated in Figure 3.11, item (1,2) holds 2 values in GLCM since there are two cases in the image in which two pixels with the value 1 and 2 are adjacent in horizontal direction.

In addition, Figure 3.11 shows the calculation of GLCM for different four angles:

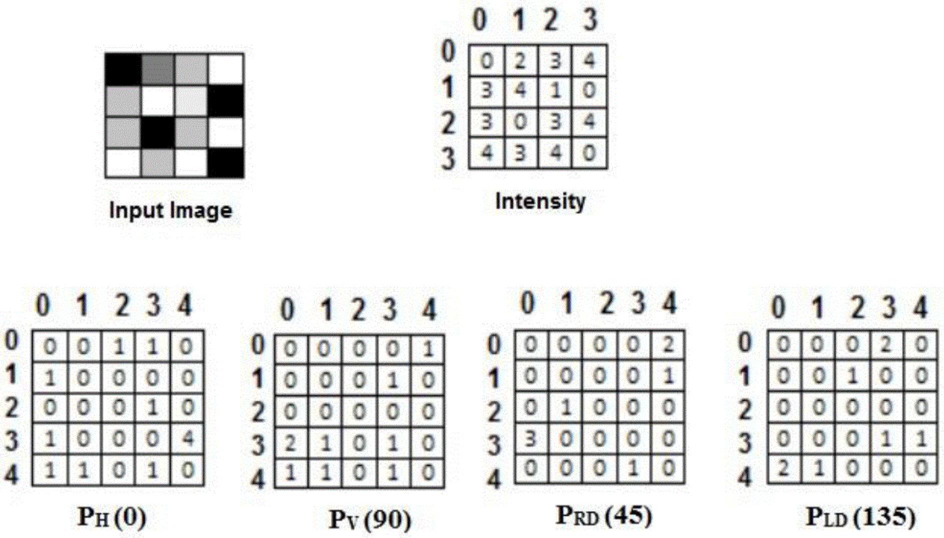

Figure 3.11 GLCM calculation for different angles [34]

Further, some improvements are added to the GLCM where the four features that can be obtained from the traditional GLCM is extended to 23 features for each image, these 23 features such as: Autocorrelation, Contrast, Correlation, Maximum probability, Angular Second Moment, Mean, Energy, Entropy, Homogeneity, Dissimilarity, Sum of squares, Sum of average, Sum of variance, Sum of entropy.

We can derive many statistics after creating GLCM, using different formulas that supply information about image texture.

This also allows the utilize of specific features. The equations of these features are below:

- Angular Second Moment:

$$f_1 = \sum_i \sum_j p(x,y)^2 \qquad 3.10$$

- Contrast:

$$f_2 = \sum_i \sum_j (i-j)^2 p(x,y) \qquad 3.11$$

- Correlation:

$$f_3 = \sum_i \sum_j \frac{(i-\mu_x)(j-\mu_y)p(x,y)}{\sigma_x \sigma_y} \qquad 3.12$$

- Dissimilarity:

$$f_4 = \sum_i \sum_j |i-j| p(x,y) \qquad 3.13$$

- Entropy:

$$f_5 = \sum_i \sum_j \left(\frac{p(x,y)}{\log p(x,y)} \right) \qquad 3.14$$

- Homogeneity:

$$f_6 = \sum_i \sum_j \left(\frac{p(x,y)}{1+|i-j|} \right) \qquad 3.15$$

- Maximum probability:

$$f_7 = \max\left(\frac{p(x,y)}{i*j}\right) \qquad 3.16$$

- Mean:

$$f_8 = \frac{\sum p(x,y)}{i * j} \qquad 3.17$$

Where p refers to pixel, x and y are coordinate of pixel, $p(x,y)$ is intensity of output gray level co-occurrence matrix, i and j is the length of row and column of image [78].

3.2.3.2 Local Binary Pattern (LBP)

The original LBP was created by Ojala et al. in 1996 [79]. It is a popular method and an effective way of describing the texture. Therefore, it is excessively used in the face identification and recognition systems fields. Also utilized in different application such as remote sensing, object detection, face representation and classification [80]. LBP is focused on the identification of variations between surrounding pixels and center pixels and to extract an LBP code for each 3x3 windows in the image. For each value of the pixel in the image, a binary code is acquired by thresholding the center pixel to its adjacent pixels using the mean. This code of binary could have been assumed a binary pattern and each pattern refers to possibility of a binary pattern contained in the image [81]. After that, the histogram would have been designed to evaluate the rate of repetition amount of the binary patterns. The amount of histogram relies on the pixels' number used in the calculation of LBP [74].

Originally, LBP developed to identity and facial recognition, and it has been utilized in different technologies over the last few years, even yet, LBP has experienced a lot of progress for being more efficient. Also, face recognition system is examined using LBP with different cell size, the choosing of a proper value for cell size for LBP is not an easy task, because the decreasing of the cell size would produce more features thus more computation complexity, but at the same time it does improve the recognition accuracy.

In other words, the implementation of LBP method is based on comparing 8 neighbor pixels with the central pixel by dividing the tested window into the cells and compare the pixel to each of its 8 neighbors for each pixel in a cell. If the value of the center pixel is greater or equal to the value of the neighbor, they would then be replaced by 1, else if not, it is replaced with 0. After that, the central pixel is replaced by the sum of the weighted neighboring binary pixels, and the 3×3 window is passed to the next pixel. Then, the histogram is calculated.

The basic LBP equation can be given as follows:

$$LBP_{P,R(x,y)} = \sum_{P=0}^{P-1} s(g_p - g_c)2^P \qquad 3.18$$

$$s\,(x) = \begin{cases} 1, if\ x > o \\ 0, otherwise \end{cases}$$

where s indicates the sign 1, g_p indicates the gray level neighboring amount and g_c refers to the central pixels. 2^P is a necessary element for each neighbor since the LBP approach requires the use of different-ratio issues. The creation of an 8-bit binary number is produced from the original LBP operator by thresholding the pixels in 3×3 neighborhoods with the center pixel. Later, the operator was expanded to accommodate various neighborhood sizes by utilizing circular neighborhoods and bilinear interpolation. The preferred term for defining such a neighborhood is (P, R), where P indicates the sampling point numbers on the circle and R refers to the circle radius. Figure 3.12 shows the location of the sampling points in the (8, 2) neighborhood. Non-integer coordinate values are calculated using bilinear interpolation [82].

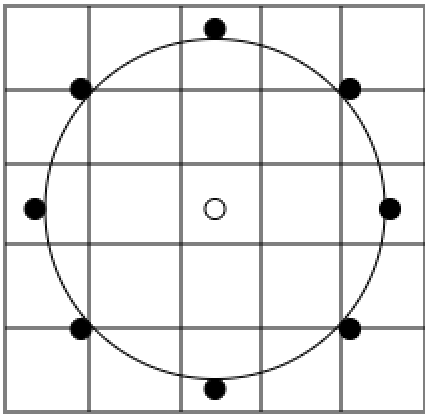

Figure 3.12 The circular (8, 2) neighborhood

For $LBP_{8,R}$, there are 256 possibilities codes. Ojala recommended to use the code for each 58 uniform and a single bin for of all non-uniform totaling 59. The uniform codes include at most two 0 to 1 or 1 to 0 transformations and the non-uniform code contains more than 4 transformations while the binary string is known to be circular. Uniform codes signify 90% of total $LBP_{8,R}$ [83, 84].

The architecture of Local Binary Pattern is shown in Figure 3.13 LBP contains pattern information about the level of pixels.

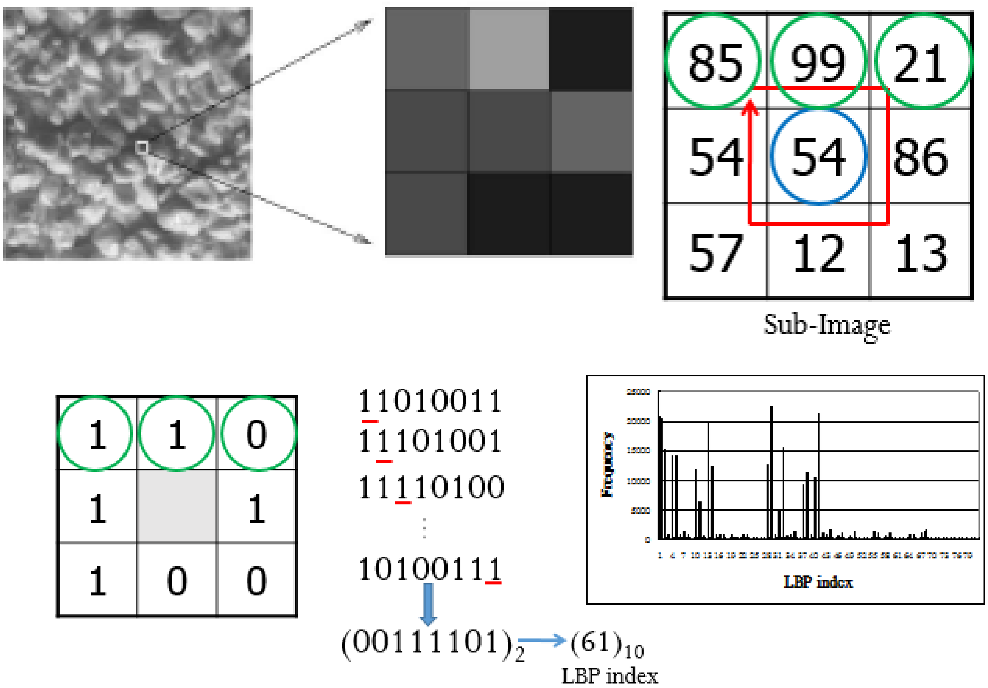

Figure 3.13 Local Binary Pattern Architecture

The histogram offers details on the presentation of regional micro-patterns, including margins, patches and flat regions, over the overall picture.

3.2.4 Feature Selection

Different experiments on face recognition revealed that selecting a correct set of features will contribute to an acceptable classification results [85]. The critical issue of the facial recognition is to extract the significant and useful information from the face image. There are many different feature extraction methods that are performing properly in facial recognition system. However, the features must be selected in a proper way which contributes to an accurate classification results [86]. Since a large number of feature collection brings additional computational difficulty and reduces the efficiency of the implementations. Therefore, selection of features is a strategy which attempts to select features that can enhance or retain the accuracy of classification and it is an essential part in the recognition process.

3.2.4.1 Binary Particle Swarm Optimization (BPSO)

Particle Swarm Optimization (PSO), was initially created in 1995 by Kenny and Eberhart [87]. PSO is a mathematical method that tries to solve the optimization problems. Binary Particle Swarm Optimization (BPSO) is a binary version of PSO that has been proposed to solve the binary optimization tasks. [88]. It is also known as the bird swarm algorithm, due to the simulation to the behavior of swarm of birds. Assume that there is a piece of food, its place is unknown. A flock of birds are randomly trying to look for it in a specific region. Yet in every iteration, they find out how much the food is far from them. Then they follow the bird that is the nearest one to the food which is the best technique for finding the food. So, in PSO every particle (solution) is a ‘‘bird’’.

In computational techniques, PSO is used as a random optimization algorithm for feature selection. This is done by iteratively trying to select the most relative and useful set of features to improve or maintain the classification performance for a robust facial recognition system [89]. Generally, for each problem, there are particles (solution) fly over the problem area based on some mathematical calculations for the velocity and position of the particle. Each particle has fitness values that are measured by the fitness function to be optimized and has velocity that directs the flying of the particles. All the particles will be drawn to their personal best solution and their global best solution creating some sort of statistic motion in velocity space.

PSO algorithm is illustrated in Figure 3.14:

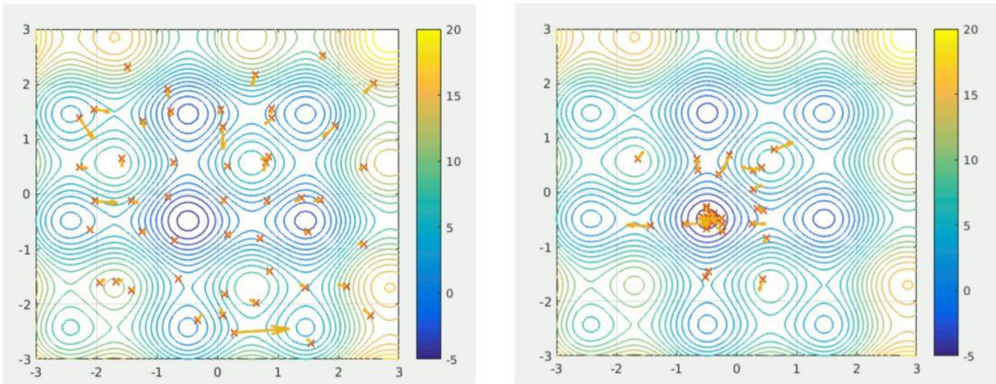

Figure 3.14 Particles searching for best and optimum solution

The basic idea behind this algorithm is; co-evolvement of different classes of birds rather than focusing on a certain class of birds, which will contribute effective search abilities [90]. First; all the particles are assigned with primary values, which are random set of position and velocity vectors after that fitness values of two best solutions for each particles are estimated by calculating the performance of each particle’s personal best solution (pbest) for each particle and global best solution (gbest) is established by checking the best position and performance among all the particles. It is continuously updated until the best solution is reached (gbest). Then we check if current fitness value is better than the previous one, we upgrade it to the current value, but if the old fitness value is better; we keep the previous one [91]. Thus, the value of position and velocity are updated according to their experience and their neighbour’s experience. After a number of iterations, the majority of the particles tend to exhibit identical form in that they have ones and zeros at the same position, which implies that they have chosen the same features that generate convergence that implements a set of solutions for PSO has been evaluated. This process is repeated until the best solution is obtained and the algorithm ends there. The following flowchart represents the process of PSO in Figure 3.15:

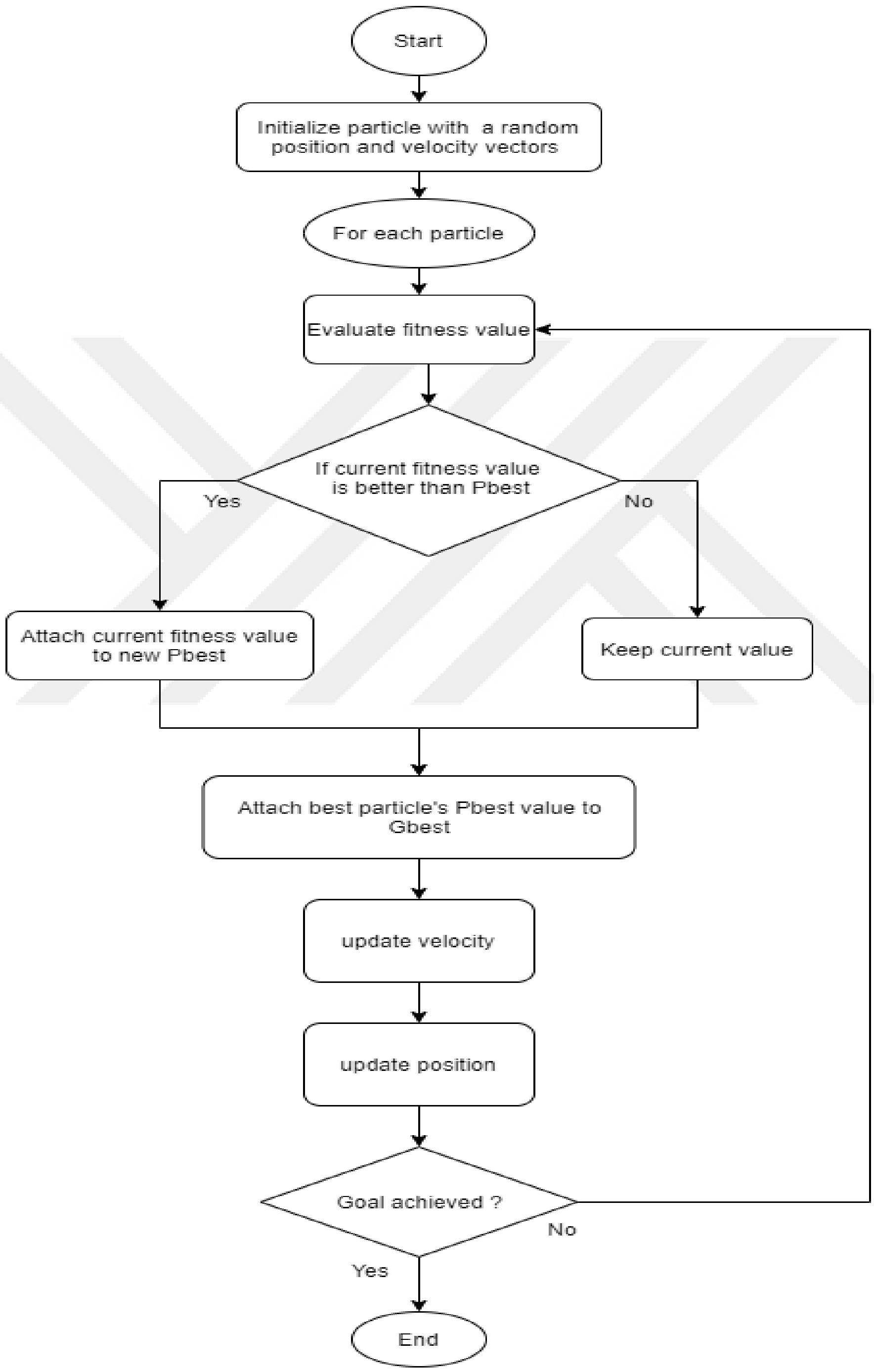

Figure 3.15 PSO diagram

The equation of the PSO algorithm is demonstrated below:

$$v_i^d(t+1) = wv_i^d\,(t) + \, c_1 r_1 \left(pbest_i^d\,(t) - \, x_i^d\,(t)\right) + \, c_2 r_2 \left(gbest^d\,(t) - \, x_i^d\,(t)\right) \quad 3.19$$

Here, v denotes to velocity which is bounded between w_{max} and w_{min}, w to inertia weight and x to solution [92, 93]. A major inertia weight accelerates a global search whilst a minor inertia weight accelerates local searches. Continuing, t refers to number of irritation, i to the order of practical in population and d to dimension of search space. c_1 and c_2 indicates acceleration factor which determines the leaning of search, r_1 and r_2 two independent random numbers in [0,1]. $pbest$ implies the personal best solution (the best solution that has been found yet), while $gbest$ implies global solution which is recorded by the particle swarm optimizer, is the best value achieved to yet by any particle for the entire population. In general, 10 particles are large enough to get good results.

Afterwards, velocity is updated to probability value as demonstrated in the following equation:

$$s\,(v_i^d\,(t+1) = \frac{1}{1+\exp(-v_i^d\,(t+1))} \quad 3.20$$

Practical position and $pbest$ with $gbest$ are converted to the following equations:

$$x_i^d(t+1) = \begin{cases} 1, if\ rand < s\,(v_i^d\,(t+1) \\ 0\,, otherwise \end{cases} \quad 3.21$$

Where $rand$ is a random number between 0 and 1.

$$pbest_i\,(t+1) = \begin{cases} x_i(t+1), if\ F\big(x_i(t+1)\big) < F\,(pbest_i\,(t)) \\ pbest_i\,(t), otherwise \end{cases} \quad 3.22$$

$$gbest_i\,(t+1) = \begin{cases} pbest_i(t+1), if\ F\big(pbest_i(t+1)\big) < F\,(gbest_i\,(t)) \\ gbest_i\,(t), otherwise \end{cases} \quad 3.23$$

Where F the fitness function.

$$w = w_{max} - (w_{max} - w_{min})(\frac{t}{T_{max}}) \quad 3.24$$

Where w_{max} and w_{min} specify the maximum and minimum changes for particle in one iteration.

3.2.5 Classification

The process of a classifier is to determine the most identical and similar feature vector of a given image. The implementation of the classifier depends on the number of images sampled, amount of features and the complicatedness of classifier. Euclidean Distance Classifier (EDC) is one of the simplest and widely used methods that is used for this purpose. EDC is implemented to classify and evaluate how faces are similar.

3.2.5.1 Euclidean Distance Classifier (EDC)

The Euclidean distance is being used to determine how identical faces are, by testing the similarity between test images and train images. If the distance between two instances is small enough, they are possibly representing the same person as two instances of the data set, so if we measure the difference between the corresponding properties, we will use the threshold to determine that they are similar enough [94].

i = (i_1, i_2,..., i_n) and j = (j_1, j_2,..., j_n) are two points in Euclidean n-space, then the distance (d) measurement from i to j, or from j to I is shown in below equation:

$$d(i,j) = \sqrt{(i_1 - j_1)^2 + (i_2 - j_2)^2 + \cdots + (i_n - j_n)^2} \quad 3.25$$

$$= \sqrt{\sum_{k=1}^{n} (i_k - j_k)^2}$$

Furthermore, if either both of these two points are similar to one another, the value obtained is low; else, it is high. The Euclidean calculation is the center location in the n-space of Euclidean where the duration of the component is determined by the equation of the Euclidean norm represented by:

$$||p|| = \sqrt{p_1^2 + p_1^2 + \cdots + p_n^2} = \sqrt{p.p,} \quad 3.26$$

Where the ending expression includes the product of d

CHAPTER 4

RESULTS AND DISCUSSION

Facial recognition has become a subject of major attention recently due its simplicity in performance [95]. Essentially, the problem of facial recognition can be defined in this way: We have a test facial image and a database of facial images of recognized persons have been entered. In view of this scenario, we imitate this problem by extracting the features of each person and compare it to a train facial images in database, significant features are stored.

This chapter shows the results acquired using MATLAB R2018a software package. We have tested feature extraction technique with and without feature selection technique to decide which one of these implementations provides optimum results as regards of accuracy and capability. These face recognition algorithms that have been used for feature extraction technique are Discrete Wavelet Transform, Local Binary Pattern and Gray Level Co-Occurrence Matrix. Thus, as a classifier, Euclidean Distance Classifier was applied. For feature selection technique, Binary Practical Swarm Optimization (BPSO) was implemented. The experiments have been implemented on images from the ORL and Yale.

Face recognition process for our study is described in the flowchart in Figure 4.1

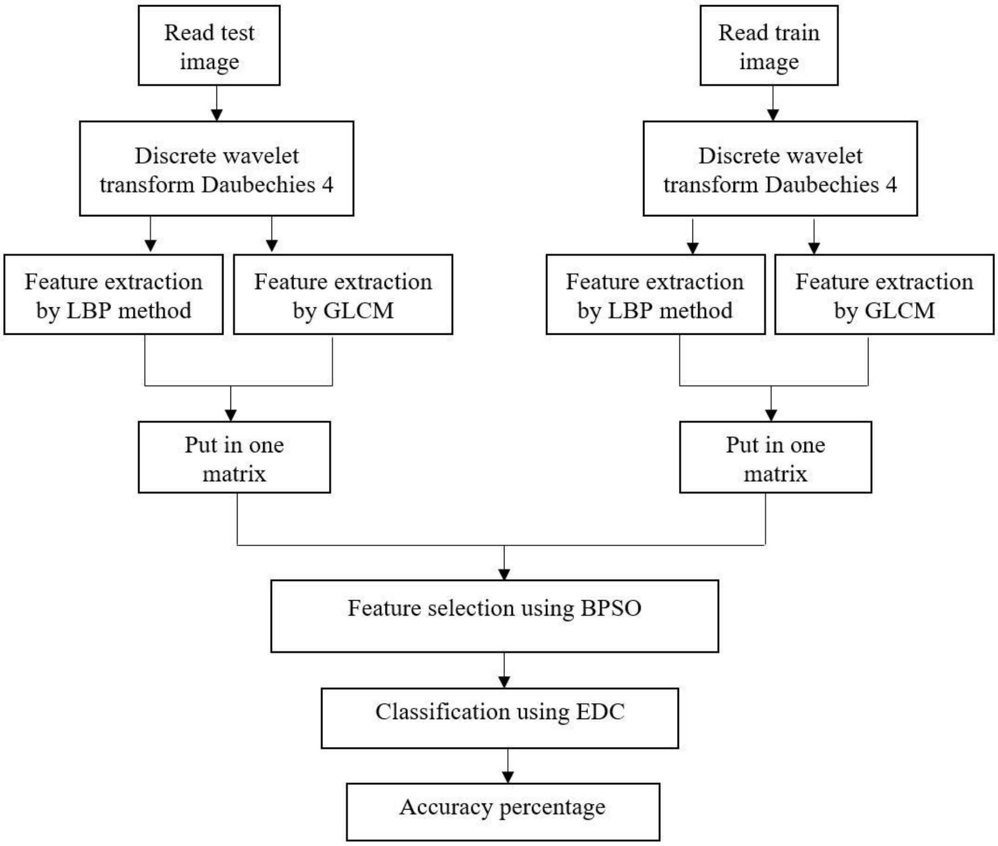

Figure 4.1 Flowchart of proposed method

Including the following steps:

1. Step One: In this step, facial images are read from the database and divided into train image set and test image set.
2. Step Two: After reading the face images, the images are compressed using (DWT) to reduce the unnecessary data from the train and test images.
3. Step Three: Extraction of the features from train and test images are implemented in this step using two different methods (GLCM and LBP).
4. Step Four: After the features are extracted, the best relative set of features are selected using (BPSO) for a flexible face recognition system.
5. Step Five: Finally, train features and test features are compared using (EDC) conducting the minimum distance between them.

In this study, we used two validation approaches of experiments to determine the performance and accuracy rate:

4.1 N Fold Validation

This validation is generally based on selecting number of train images and test images randomly for each person from ORL and YALE databases. In these experiments, each of the databases split into set of train and test images. A number of train image samples are selected and read from database, and the remaining samples is determined as test image set. Two different feature extraction methods are used, LBP and GLCM. In additions, the feature fusion is studied too by combining two of feature vectors that are obtained from the proposed methods. Also, for each method, different cases have been studied. The system is trained using 90% of dataset and the rest 10% is used for testing, then 80% for training and 20% for testing, up to 10% for training and 90% for testing.

4.1.1 Implementation on ORL Database

These results are carried out using the images from ORL dataset. At first, the images were compressed from size 112 x 90 to size 59 x 49 by applying 2D-DWT, using Daubechies Transform, dividing the image into 4 sub-bands (LL1, LH1, HL1, HH1). LL1 sub-band is used later for feature extraction. Following, features of each image were extracted using LBP by collecting 59 feature for each image then GLCM method was applied and collected 23 features for each images. The factors of the GLCM method have been assigned to be $D = 1$ and $\Delta = 0°$ due to its good performance. At last step, the feature of the test image was compared with the feature of the train images, using the Euclidean distance classifier. The proposed methods are conducted in six experiments for each database.

The following Figures and Tables show the obtained results.

❖ Experiment 1: Applying DWT, LBP and GLCM methods:

Table 4.1 Recognition rate using DWT + LBP + GLCM methods on ORL Database

Experiments	No. of Train images	No. of Test images	Accuracy Rate
Scenario 1	1	9	50.27 %
Scenario 2	2	8	53.43 %
Scenario 3	3	7	58.21 %
Scenario 4	4	6	65.83 %
Scenario 5	5	5	67.50 %
Scenario 6	6	4	71.25 %
Scenario 7	7	3	73.33 %
Scenario 8	8	2	76.25 %
Scenario 9	9	1	82.50 %

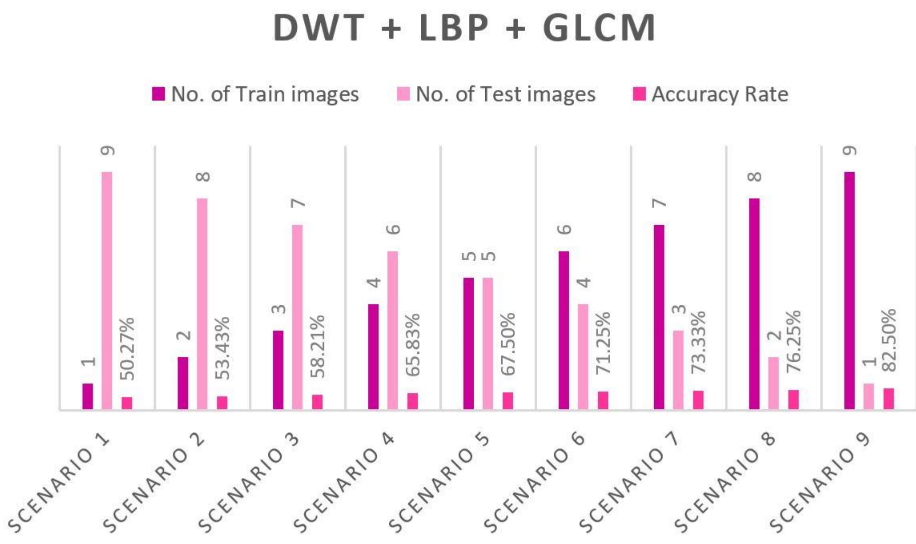

Figure 4.2 Performance of Experiment 1on ORL Database

❖ Experiment 2: using LBP and GLCM methods:

Table 4.2 Recognition rate using LBP + GLCM methods on ORL Database

Experiments	No. of Train images	No. of Test images	Accuracy Result
Scenario 1	1	9	49.38%
Scenario 2	2	8	53.75%
Scenario 3	3	7	61.78%
Scenario 4	4	6	66.25%
Scenario 5	5	5	68%
Scenario 6	6	4	72.50%
Scenario 7	7	3	74.16%
Scenario 8	8	2	78.75%
Scenario 9	9	1	90%

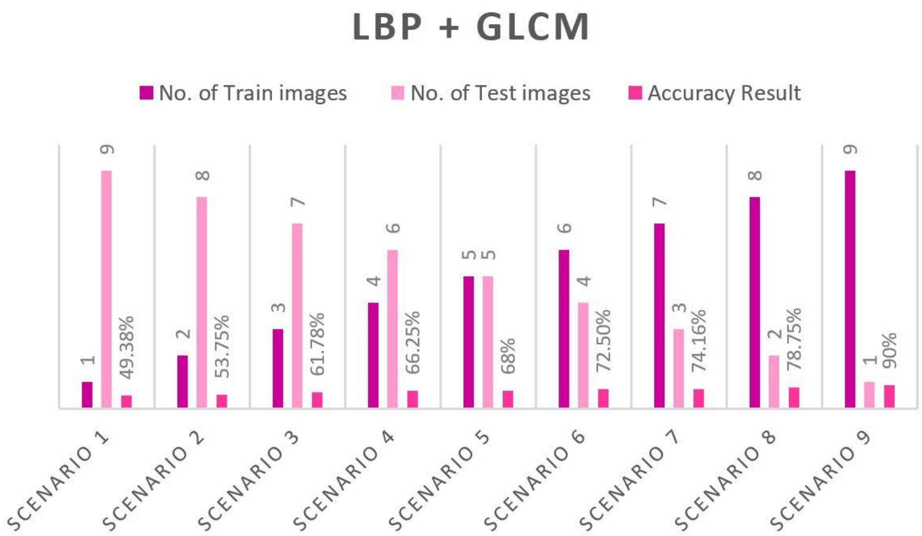

Figure 4.3 Performance of Experiment 2 on ORL Database

❖ Experiment 3: using DWT and LBP methods:

Table 4.3 Recognition rate using DWT + LBP methods on ORL Database

Experiments	No. of Train images	No. of Test images	Accuracy Rate
Scenario 1	1	9	59.44%
Scenario 2	2	8	72.81%
Scenario 3	3	7	78.82%
Scenario 4	4	6	82.91%
Scenario 5	5	5	87.50%
Scenario 6	6	4	90.62%
Scenario 7	7	3	92.50%
Scenario 8	8	2	96.25%
Scenario 9	9	1	97.50%

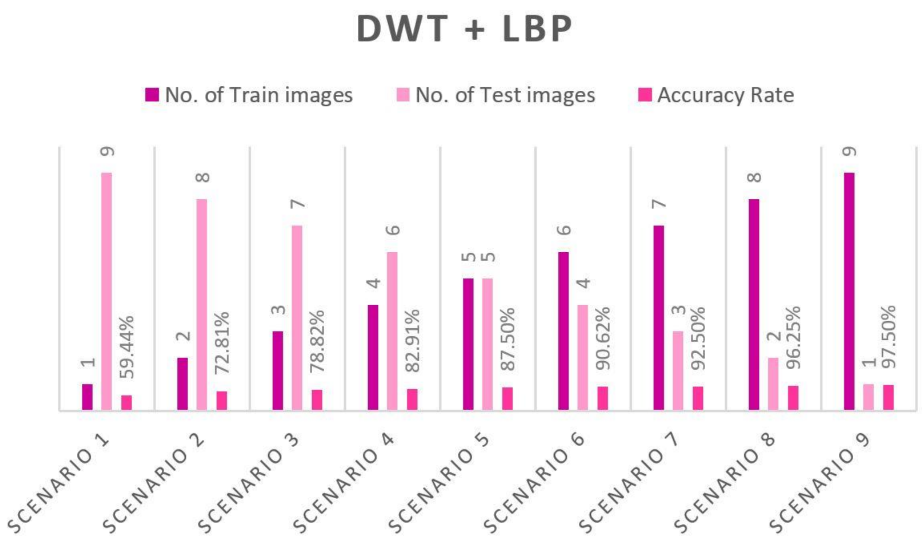

Figure 4.4 Performance of Experiment 3 on ORL Database

❖ Experiment 4: using DWT and GLCM methods:

Table 4.4 Recognition rate using DWT + GLCM methods on ORL Database

Experiments	No. of Train images	No. of Test images	Accuracy Rate
Scenario 1	1	9	42.50%
Scenario 2	2	8	51.25%
Scenario 3	3	7	66.42%
Scenario 4	4	6	66.66%
Scenario 5	5	5	68.50%
Scenario 6	6	4	71.87%
Scenario 7	7	3	77.50%
Scenario 8	8	2	76%
Scenario 9	9	1	78.55%

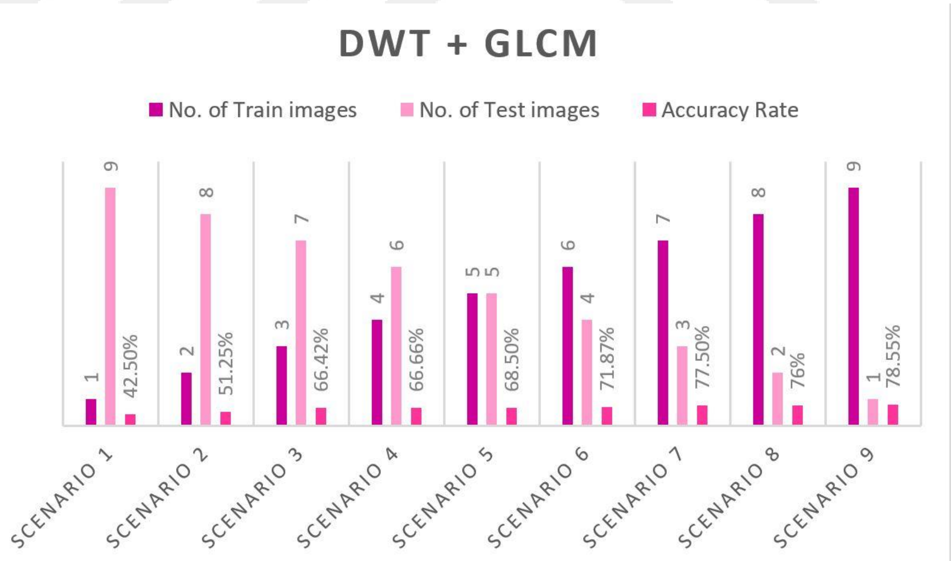

Figure 4.5 Performance of Experiment 4 on ORL Database

❖ Experiment 5: using GLCM methods:

Table 4.5 Recognition rate using GLCM methods on ORL Database

Experiments	No. of Train images	No. of Test images	Accuracy Rate
Scenario 1	1	9	42.50%
Scenario 2	2	8	52.50%
Scenario 3	3	7	66.42%
Scenario 4	4	6	66.66%
Scenario 5	5	5	67%
Scenario 6	6	4	70%
Scenario 7	7	3	71.66%
Scenario 8	8	2	82.50%
Scenario 9	9	1	90%

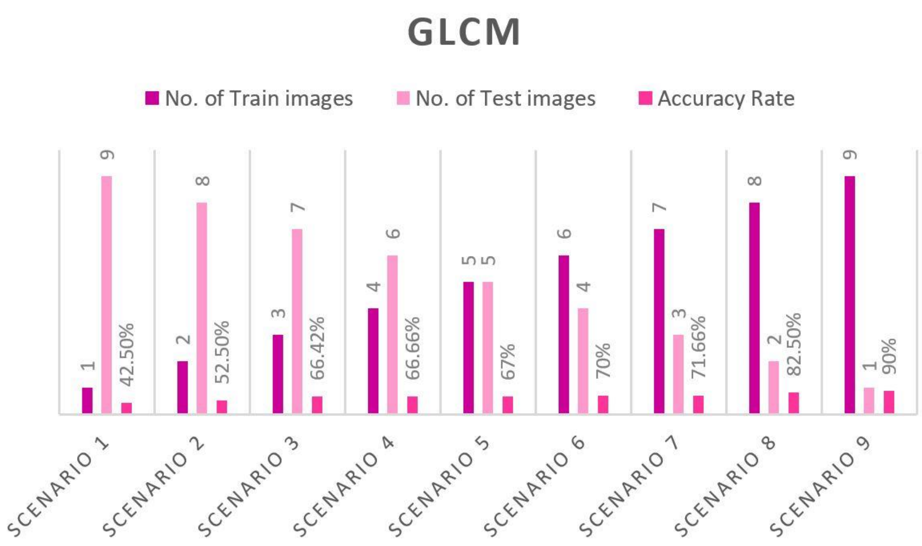

Figure 4.6 Performance of Experiment 5 on ORL Database

❖ Experiment 6: using LBP methods:

Table 4.6 Recognition rate using LBP method on ORL Database

Experiments	No. of Train images	No. of Test images	Accuracy Rate
Scenario 1	1	9	51.11%
Scenario 2	2	8	66.56%
Scenario 3	3	7	75.71%
Scenario 4	4	6	79.16%
Scenario 5	5	5	84%
Scenario 6	6	4	88.15%
Scenario 7	7	3	90.83%
Scenario 8	8	2	93.73%
Scenario 9	9	1	95%

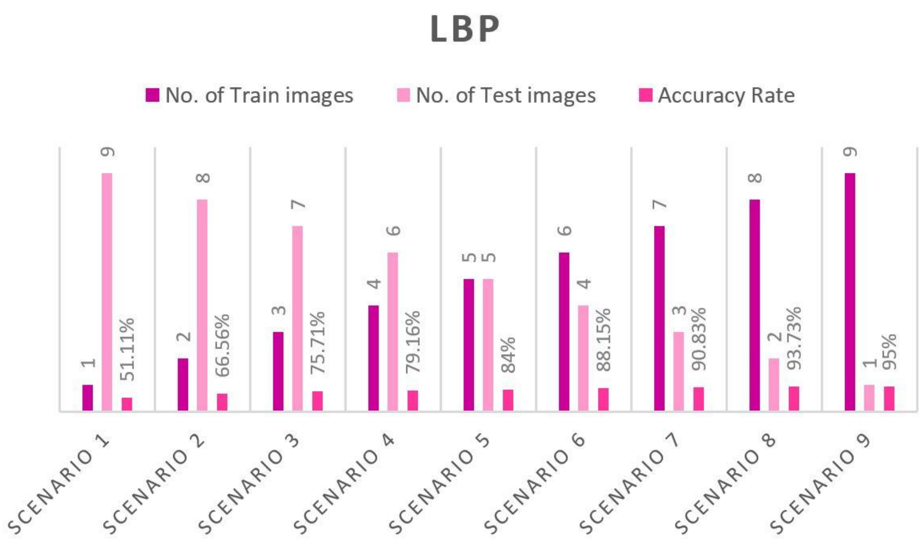

Figure 4.7 Performance of Experiment 6 on ORL Database

Table 4.7 Implementation and Results of proposed method on ORL Database

Experiments	No. of Train images	No. of Test images	Accuracy Rate of proposed methods					
			DWT + LBP + GLCM	GLCM + LBP	DWT + LBP	DWT + GLCM	GLCM	LBP
Scenario 1	1	9	50.27%	49.38%	59.44%	42.50%	42.50%	51.11%
Scenario 2	2	8	53.43%	53.75%	72.81%	51.25%	52.50%	66.56%
Scenario 3	3	7	58.21%	61.78%	78.82%	66.42%	66.42%	75.71%
Scenario 4	4	6	65.83%	66.25%	82.91%	66.66%	66.66%	79.16%
Scenario 5	5	5	67.50%	68%	87.50%	68.50%	67%	84%
Scenario 6	6	4	71.25%	72.50%	90.62%	71.87%	70%	88.15%
Scenario 7	7	3	73.33%	74.16%	92.50%	77.50%	71.66%	90.83%
Scenario 8	8	2	76.25%	78.75%	96.25%	76%	82.50%	93.73%
Scenario 9	9	1	82.50%	90%	97.50%	78.55%	90%	95%

4.1.2 Implementation on YALE Database

In these experiments, the images are divided to train images and test images. Face detection using Viola-Jones detector that was applied on Yale Database to detect faces before the processing method. Hence, the facial images of this database are not already normalized. So it needs to be detected first and put in a standard image format. After face detection step, the quality of face images is reduced using first compression level of Discrete Wavelet Transform (DWT), later the features were extracted using Local Binary Pattern (LBP) and Gray Level Co-Occurrence Matrix (GLCM). The last step was the classification of features vectors of test and train images using Euclidean Distance Classification (EDC). Also the implementation of the proposed method was implemented in six experiments.

The accuracy results are shown in the following Tables and Figures:

❖ Experiment 1: Applying DWT, LBP and GLCM methods:

Table 4.8 Recognition rate using DWT + LBP + GLCM methods on YALE Database

Experiments	No. of Train images	No. of Test images	Accuracy Rate
Scenario 1	1	9	55.60%
Scenario 2	2	8	63.33%
Scenario 3	3	7	65.71%
Scenario 4	4	6	71.11%
Scenario 5	5	5	74.40%
Scenario 6	6	4	75%
Scenario 7	7	3	83.33%
Scenario 8	8	2	89%
Scenario 9	9	1	90%

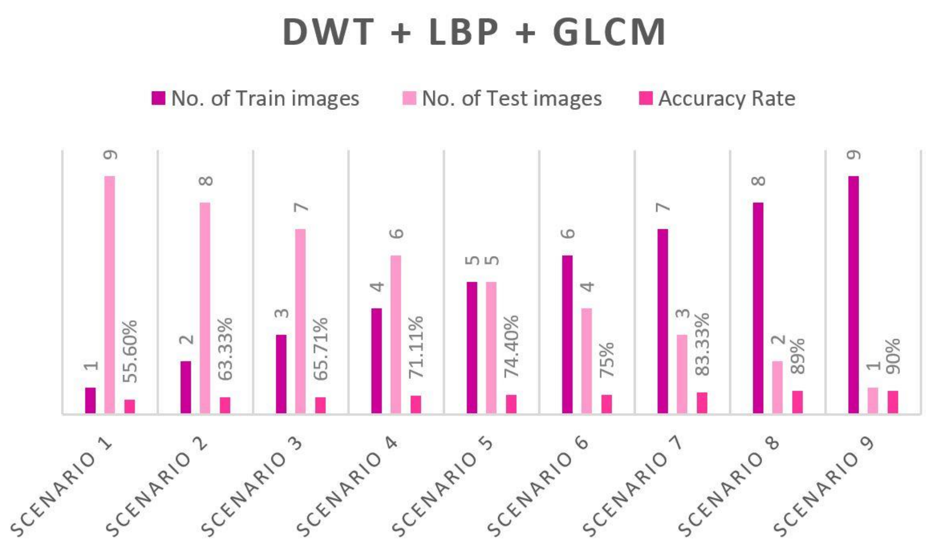

Figure 4.8 Performance of Experiment 1 on YALE Database

- Experiment 2: Applying LBP and GLCM methods:

Table 4.9 Recognition rate using LBP + GLCM methods on YALE Database

Experiments	No. of Train images	No. of Test images	Accuracy Rate
Scenario 1	1	9	30%
Scenario 2	2	8	32.83%
Scenario 3	3	7	36.28%
Scenario 4	4	6	46.18%
Scenario 5	5	5	48.89%
Scenario 6	6	4	51.50%
Scenario 7	7	3	62.90%
Scenario 8	8	2	73%
Scenario 9	9	1	87%

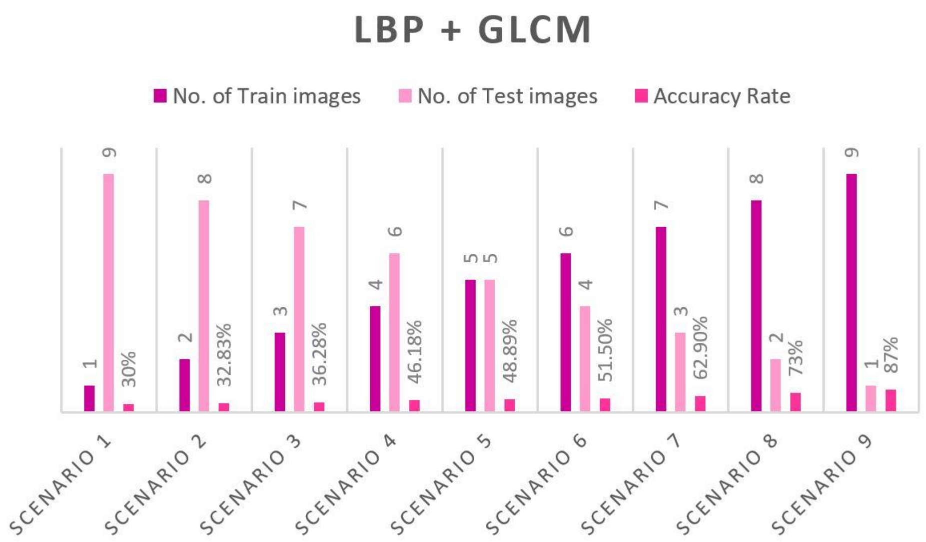

Figure 4.9 Performance of Experiment 2 on YALE Database

❖ Experiment 3: Applying DWT and LBP methods:

Table 4.10 Recognition rate using DWT + LBP methods on YALE Database

Experiments	No. of Train images	No. of Test images	Accuracy Rate
Scenario 1	1	9	54.07%
Scenario 2	2	8	55.83%
Scenario 3	3	7	63.80%
Scenario 4	4	6	68.88%
Scenario 5	5	5	70.66%
Scenario 6	6	4	78%
Scenario 7	7	3	86.67%
Scenario 8	8	2	93.33%
Scenario 9	9	1	94%

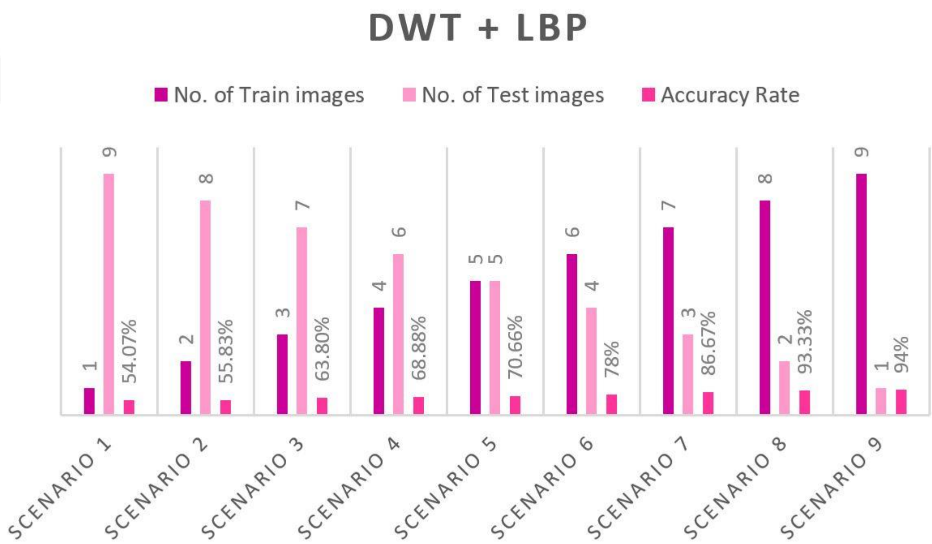

Figure 4.10 Performance of Experiment 3 on YALE Database

❖ Experiment 4: Applying DWT and GLCM methods:

Table 4.11 Recognition rate using DWT + GLCM methods on YALE Database

Experiments	No. of Train images	No. of Test images	Accuracy Rates
Scenario 1	1	9	35%
Scenario 2	2	8	42.50%
Scenario 3	3	7	43.19%
Scenario 4	4	6	44.22%
Scenario 5	5	5	51%
Scenario 6	6	4	54.24%
Scenario 7	7	3	66%
Scenario 8	8	2	74%
Scenario 9	9	1	86.66%

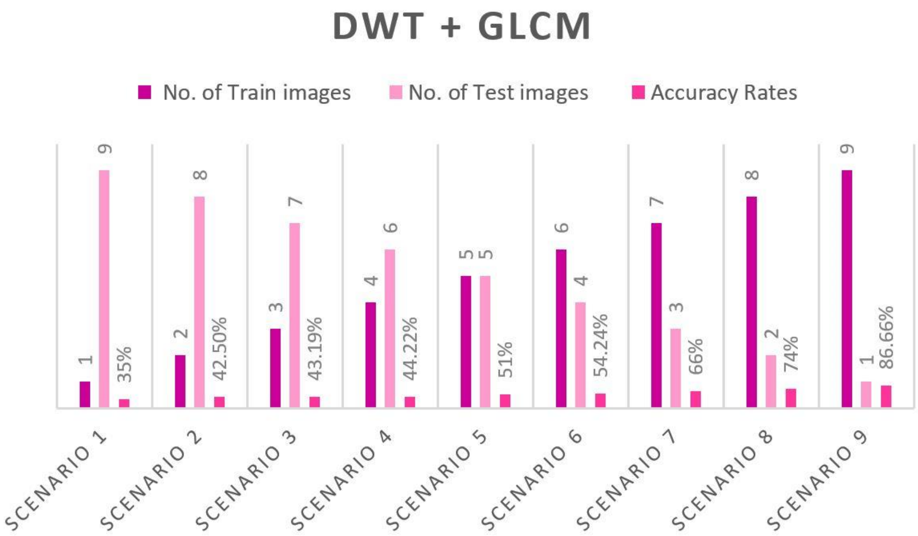

Figure 4.11 Performance of Experiment 4 on YALE Database

❖ Experiment 5: Applying GLCM method:

Table 4.12 Recognition rate using GLCM method on YALE Database

Experiments	No. of Train images	No. of Test images	Accuracy Rates
Scenario 1	1	9	31.62%
Scenario 2	2	8	39.50%
Scenario 3	3	7	40%
Scenario 4	4	6	45.72%
Scenario 5	5	5	48.56%
Scenario 6	6	4	51.40%
Scenario 7	7	3	64%
Scenario 8	8	2	69%
Scenario 9	9	1	73.33%

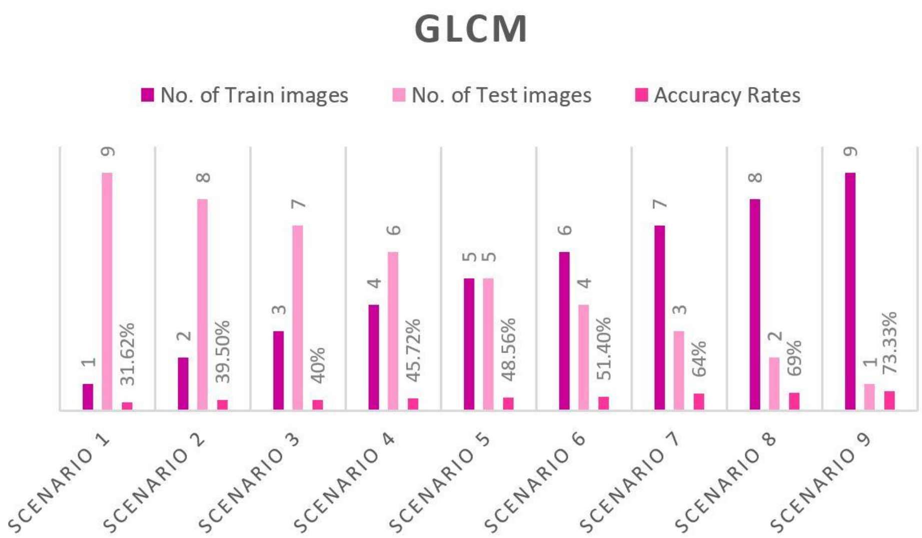

Figure 4.12 Performance of Experiment 5 on YALE Database

❖ Experiment 6: Applying LBP method:

Table 4.13 Recognition rate using LBP method on YALE Database

Experiments	No. of Train images	No. of Test images	Accuracy Results
Scenario 1	1	9	59.25%
Scenario 2	2	8	61.66%
Scenario 3	3	7	68.57%
Scenario 4	4	6	75.44%
Scenario 5	5	5	81.53%
Scenario 6	6	4	86.67%
Scenario 7	7	3	88.80%
Scenario 8	8	2	93%
Scenario 9	9	1	100%

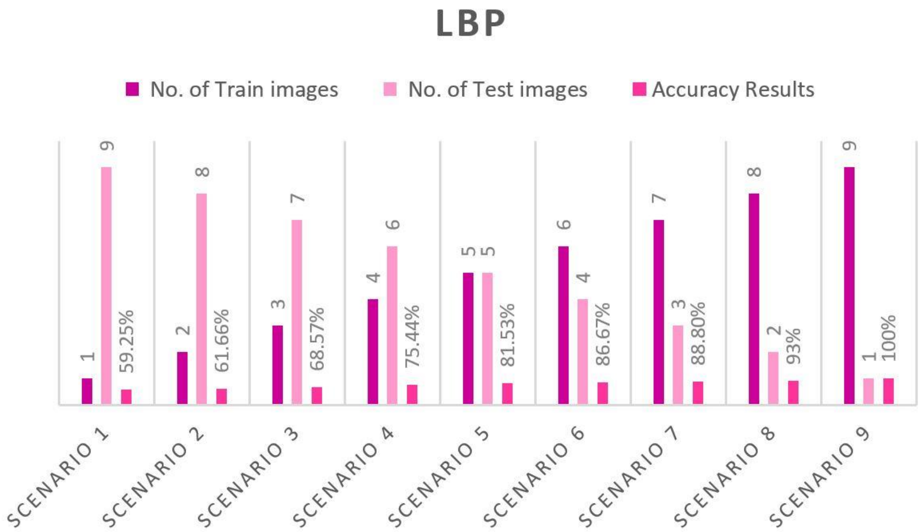

Figure 4.13 Performance of Experiment 6 on YALE Database

Table 4.14 Implementation and Results of proposed method on YALE Database

Experiments	No. of Train images	No. of Test images	Accuracy Rate of proposed methods					
			DWT + LBP + GLCM	GLCM + LBP	DWT + LBP	DWT + GLCM	GLCM	LBP
Scenario 1	1	9	55.60%	35%	54.07%	35%	31.62%	59.25%
Scenario 2	2	8	63.33%	42.50%	55.83%	42.50%	39.50%	61.66%
Scenario 3	3	7	65.71%	43.19%	63.80%	43.19%	40%	68.57%
Scenario 4	4	6	71.11%	44.22%	68.88%	44.22%	45.72%	75.44%
Scenario 5	5	5	74.40%	51%	70.66%	51%	48.56%	81.53%
Scenario 6	6	4	75%	54.24%	78%	54.24%	51.40%	86.67%
Scenario 7	7	3	83.33%	66%	86.67%	66%	64%	88.80%
Scenario 8	8	2	89%	74%	93.33%	74%	69%	93%
Scenario 9	9	1	90%	86.66%	94%	86.66%	73.33%	100%

As a conclusion; the experiments that was conducted from both of the ORL and Yale database generally, we have observed that as the number of training samples increase, the accuracy rate increases too. Also, in general, it is observed that the using of pre-processing stage by implementing DWT with 9 train images improves the results of the LBP. On the opposite side, using GLCM is not recommended with DWT. We can conclude that the GLCM is sensitive to low-quality images

Moreover, two vectors of features that are obtained using two different methods, the features that are obtained from the LBP method are fused with the features that are obtained from the GLCM. But, using one method alone is better than using the combination of two methods. See Table 4.7 and Table 4.14. The reason behind the differences of the accuracy rate between LBP and GLCM is observed as follows: As we have seen, the combination of LBP and GLCM does not gives a satisfying result because the features value for LBP method are between 0 and 1, and the feature values for GLCM are between -22 up to 159. This big difference between features disturbs the Euclidian distance and the results could be obtained mistakenly. This situation is shown in Figure 4.14.

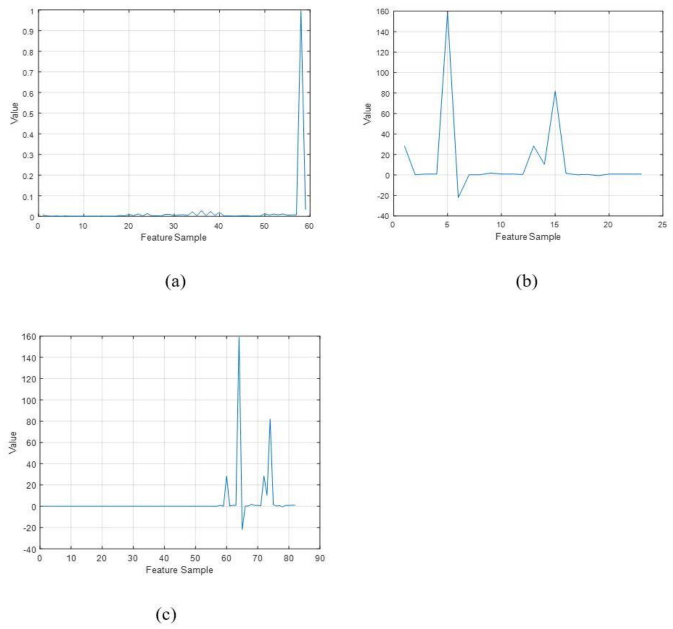

Figure 4.14 Feature value for a) LBP, b) GLCM, c) combination of LBP and GLCM

4.2 Implementation of BPSO on proposed method

For a better the recognition rate and accuracy results, Binary Particle Swarm Optimization (BPSO) was implemented on the proposed method. From the previous experiments we can observe that when utilizing Gray Level Co-Occurrence Matrix (GLCM) with proposed methods, there was some withdraw in performance due some variation of the values of features which leads to a corruption in the classification step when using Euclidean Distance Classifier. So, when compared with GLCM features and LBP features, the variety will be large hence features of GLCM is between -22 up to 159. Therefore, optimum features must be selected.

BPSO method tries to address this problem by selecting only the optimum features from GLCM and LBP. Since, the performance of a classifier is based on the number of features. Too less or redundant features can lead to loss of accuracy rates. Therefore, the number of features must be chosen carefully, In PSO, the basic process is that there are a number of particles, each one of them are flying through the problem area arbitrarily searching for previous best solution and the global best solution of the whole swarm. Then, velocity is modified at each iteration which will define the movement of the particles to be more or less random, and so the convergence of the algorithm. This method was used in the literature [53], they have used BPSO method for selecting the best features.

In the experiments, we have used the same validation techniques and scenarios that were used in our proposed work. DWT for image compression, then for feature extraction, LBP was applied obtaining 59 features and 23 features were extracted using GLCM which makes them in total 82 features. After the features were extracted, the implementation of PSO made the features decrease to approximately 50% of the extracted features. Selecting the best and most optimum features by eliminating the highest and lowest values of features using fitness function which determines the features that are the closest to each other in amount. The experiment results are shown in the following part.

❖ N fold validation with BPSO method on ORL:

Table 4.15 N Fold Validation results on ORL Database

Experiments	No. of Train images	No. of Test images	Accuracy Rate of proposed methods					
			DWT + LBP + GLCM+ BPSO	GLCM + LBP+ BPSO	DWT + LBP+ BPSO	DWT + GLCM + BPSO	GLCM + BPSO	LBP+ BPSO
Scenario 1	1	9	67%	34.72%	62.18%	37.22%	37.50%	43.05%
Scenario 2	2	8	73.21%	47%	72%	49.06%	50%	61.56%
Scenario 3	3	7	79%	56.78%	73.92%	50%	57.14%	70%
Scenario 4	4	6	82.06%	79.10%	82.02%	56.07%	62.50%	77%
Scenario 5	5	5	86%	81.66%	84%	66.50%	68%	83.75%
Scenario 6	6	4	89.37%	82%	86.50%	68.75%	73%	85%
Scenario 7	7	3	90%	85%	89.16%	70.83%	76%	89.16%
Scenario 8	8	2	91%	87%	92.50%	80%	80%	90%
Scenario 9	9	1	95%	92%	100%	90%	85%	97.50%

❖ N fold validation with BPSO method on YALE:

Table 4.16 N Fold Validation results on YALE Database

Experiments	No. of Train images	No. of Test images	Accuracy Rate of proposed methods					
			DWT + LBP + GLCM+ BPSO	GLCM + LBP+ BPSO	DWT + LBP+ BPSO	DWT + GLCM + BPSO	GLCM + BPSO	LBP+ BPSO
Scenario 1	1	9	49%	48.64%	47.29	41.62%	39%	49.32%
Scenario 2	2	8	60%	66%	65	48%	44%	65%
Scenario 3	3	7	67%	67.82%	67.82%	52.43%	48.78%	70.40%
Scenario 4	4	6	72%	70%	70%	58.36%	51%	71%
Scenario 5	5	5	76.82%	75.60%	71.39%	61.11%	52.17%	75.70%
Scenario 6	6	4	78%	77.28%	74%	66%	55%	76%
Scenario 7	7	3	81%	78%	78%	76%	60%	78%
Scenario 8	8	2	88%	84%	80%	80%	68%	81%
Scenario 9	9	1	93.37%	87%	93%	87.25%	81%	93.75%

4.3 Leave One Out Validation

Leave One Out strategy is evaluated to determine the effectiveness of the proposed methods on two face databases: ORL and Yale face databases. The experiments for each database, by using one image as a test image and the rest of all images are used as train images on our databases. It is repeated by choosing a new test image at each run. Face images that are in train subset do not exist in the test subset.

4.3.1 Implementation on ORL Database

As it is shown below in Table 4.17, the test image is selected in sequence. 1 image is determined as test image while the remaining images are determined as train images. When we combined all the methods (DWT, GLCM and LBP), the accuracy result was 53.50%. The best obtained result was 92.75% when implementing DWT method with LBP method. While the lowest obtained accuracy rate was 53.50%, applying DWT algorithm and GLCM algorithm.

Table 4.17 Leave One Out validation on ORL Database

Experiments	Methods	Accuracy Rate
Experiment 1	DWT + GLCM + LBP	53.50%
Experiment 2	DWT + LBP	92.75%
Experiment 3	DWT + GLCM	53.50%
Experiment 4	LBP + GLCM	73.50%
Experiment 5	LBP	90%
Experiment 6	GLCM	73%

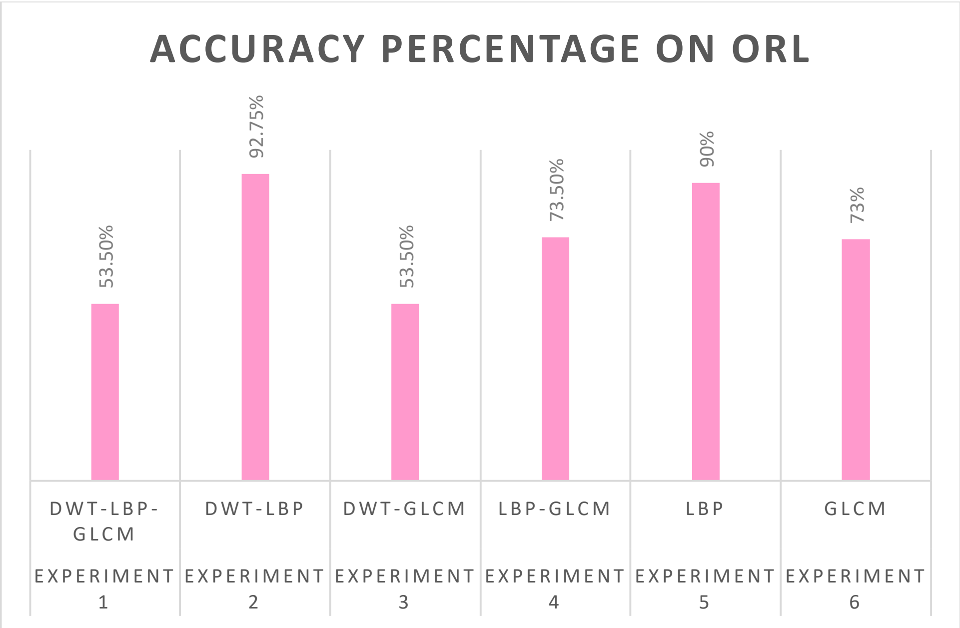

Figure 4.15 Leave One Out validation performance on ORL Database

4.3.2 Implementation on YALE Database

As it is shown below in Table 4.18, the test image is selected in sequence. First image is determined as test image while the remaining images are determined as train images. When all the methods (DWT, GLCM and LBP) were combined, the accuracy result was 39.39%. The best obtained result was 68.84% when implementing DWT method with LBP method.

Table 4.18 Leave One Out validation on YALE Database

Experiments	Methods	Accuracy Rate
Experiment 1	DWT + LBP + GLCM	39.39%
Experiment 2	DWT + LBP	68.84%
Experiment 3	DWT + GLCM	39.39%
Experiment 4	LBP + GLCM	40.10%
Experiment 5	LBP	65%
Experiment 6	GLCM	39.39%

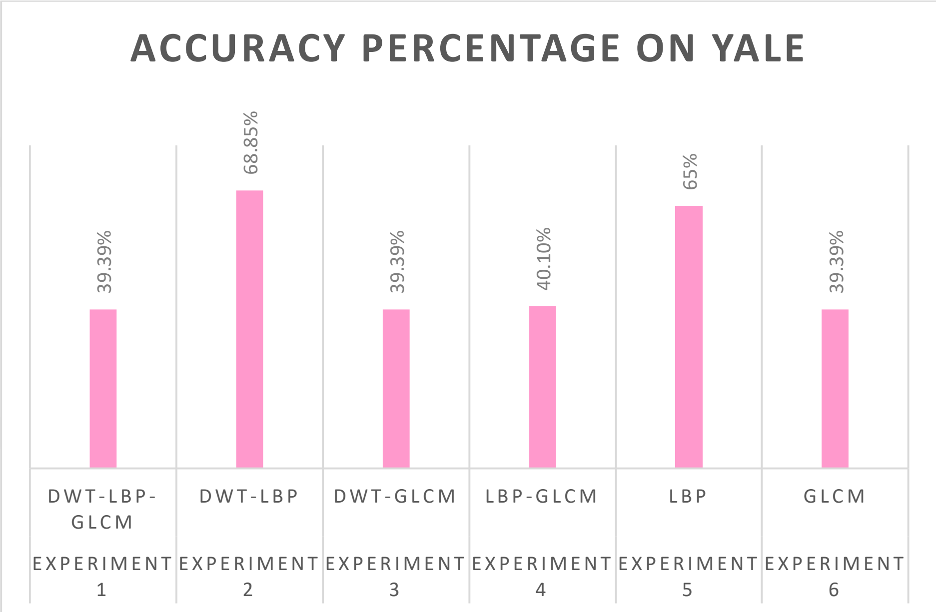

Figure 4.16 Leave One Out validation performance on YALE Database

4.4 Implementation of BPSO on proposed method

The accuracy rate of the second validation (Leave One Out) experiments was not a satisfactory result for us. Therefore, the BPSO was the solution for this problem. Adding BPSO feature selector to the experiments has increased the recognition rate up to 91.75% when implementing DWT, LBP and GLCM on ORL database and 69.69% when implementing DWT, LBP and GLCM on YALE database.

❖ Leave One Out validation with BPSO method on ORL database:

Table 4.19 Leave One Out validation using BPSO on ORL Database

Experiments	Methods	Accuracy Rate
Experiment 1	DWT + GLCM + LBP + BPSO	91.74%
Experiment 2	DWT + LBP + BPSO	89.25%
Experiment 3	DWT + GLCM + BPSO	50.25%
Experiment 4	LBP + GLCM + BPSO	91%
Experiment 5	LBP + BPSO	87%
Experiment 6	GLCM + BPSO	73.25%

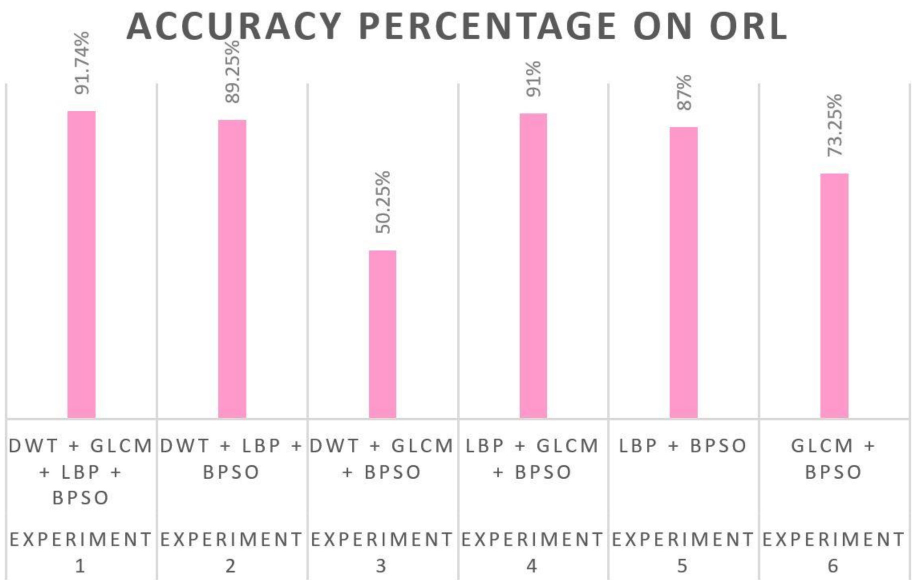

Figure 4.17 Leave One Out validation performance on ORL Database

❖ Leave One Out validation with BPSO method on YALE database:

Table 4.20 Leave One Out validation using BPSO on YALE Database

Experiments	Methods	Accuracy Rate
Experiment 1	DWT + GLCM + LBP + BPSO	69.69%
Experiment 2	DWT + LBP +BPSO	67.87%
Experiment 3	DWT + GLCM + BPSO	46%
Experiment 4	LBP + GLCM + BPSO	69%
Experiment 5	LBP + BPSO	67%
Experiment 6	GLCM + BPSO	58%

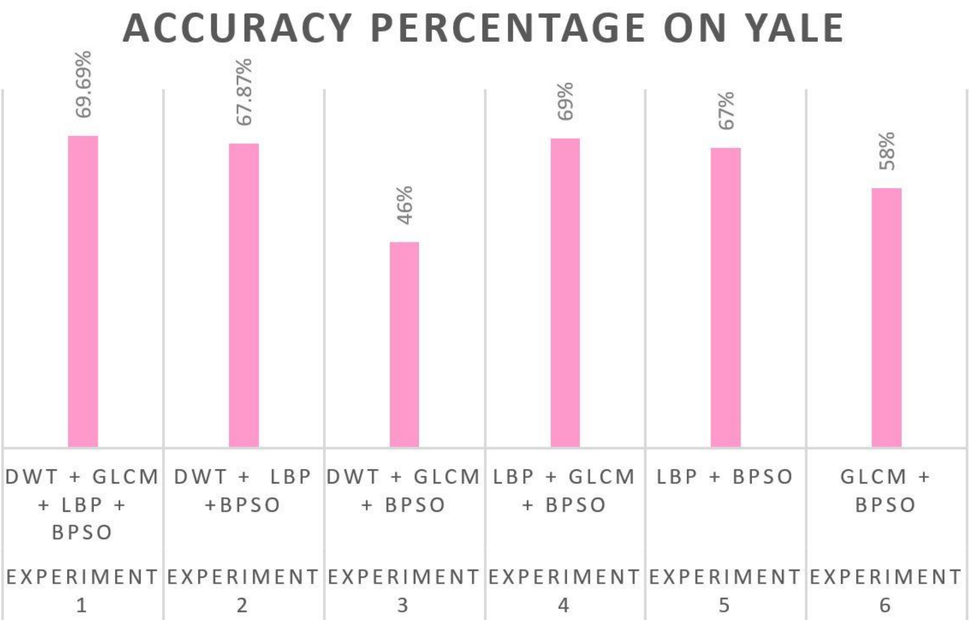

Figure 4.18 Leave One Out validation performance on YALE Database

The following Table demonstrates compared results of accuracy rate for the proposed validations with and without PSO algorithm:

Table 4.21 Comparison of proposed method with and without BPSO

	N Fold validation on ORL	N Fold validation on YALE	Leave One Out validation on ORL	Leave One Out validation on YALE
Without BPSO method	82.50%	90%	53.50%	39.39%
With BPSO method	95%	93%	91.75%	69.69%

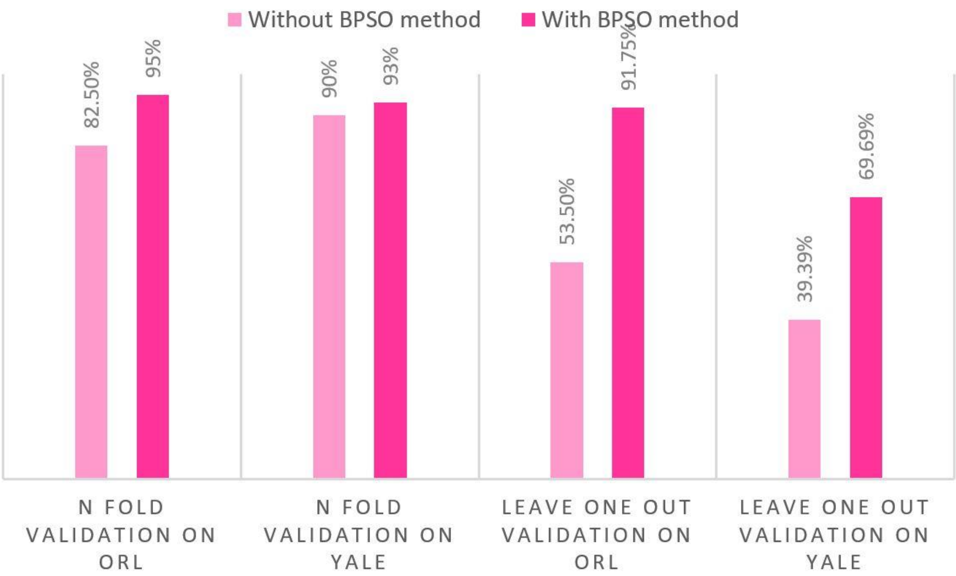

Figure 4.19 Diagram of proposed method with and without BPSO

In conclusion, as we have observed there has been an increasing in the performance rate of our face recognition system up to 13% with N Fold validation technique and up to 38% with Leave One Out validation technique when implementing BPSO technique with DWT, LBP and GLCM methods on ORL database and up to 3% with N Fold validation technique and up to 30% with Leave One Out validation technique when implementing BPSO technique with DWT, LBP and GLCM methods on YALE database.

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Conclusions

In this thesis, multi methods are tested and investigated to offline face recognition system. The ORL and YALE face datasets are used and tested. For implementing of the proposed method, the Matlab R2018a is used. Discrete Wavelet Transform (DWT) was used to compress the image to test how our system is robust enough. For feature extraction Local Binary Pattern (LBP) and Gray Level Co-Occurrences Matrix (GLCM) are used. For classification the Euclidian Distance Classifier (EDC) measurement is used. In addition, Binary Particle Swarm Optimization (BPSO) was used in feature selection for a better recognition rate which is a new method that is used in face recognition system.

The obtained results are as the following for N Fold validation on ORL database:

1. The results obtained using Discrete Wavelet Transform (DWT) and Local Binary Pattern (LBP) was very good. Since compressing the facial image helped us to reduce unnecessary information from our images. Later, LBP extracts the most unique and useful features from the facial images. The accuracy rate reached 97.50%.

2. Further, combination of Discrete Wavelet Transform (DWT), Gray Level Co-Occurrence Matrix (GLCM) and Local Binary Pattern (LBP), recognition rate that was obtained 82.50%. Considering the combination of two features vectors can lead to some variation of features values which leads to a corruption in the classification phase.

3. When Gray Level Co-Occurrence Matrix was implemented, the accuracy result decreased to 78.55% when implemented with Discrete Wavelet Transform due to same reason of the noticeable variation among its features which leads to some calculation errors in Euclidean Distance measurement. Thus, with Local Binary Pattern, accuracy percentage was 90%.

The obtained results are as the following for N Fold validation on YALE database:

1. We obtained 100% accuracy rate when Local Binary Pattern (LBP) was applied on YALE database images. And 96% accuracy rate when we implemented LBP with Discrete Wavelet Transform (DWT).

2. Moreover, recognition rate was 93% when we combined Discrete Wavelet Transform (DWT), Gray Level Co-Occurrence Matrix (GLCM) and Local Binary Pattern (LBP).

3. Gray Level Co-Occurrence Matrix (GLCM) implementation results decreased the recognition rate to 86.66% when fused with Discrete Wavelet Transform (DWT) and Local Binary Pattern (LBP).

In this thesis, we also implemented and tested Leave One Out strategy, the obtained results did not satisfy us. Combination of DWT and LBP based on GLCM for ORL and YALE databases was 53.50% and 39.39%; respectively. Moreover; the implementation of DWT with separating feature extraction methods on ORL and YALE databases, the recognition rate using LBP increased up to 92.75% and 68.84%; respectively. And with GLCM, the recognition results decreased to 53.50% and 39.39% on ORL and YALE databases respectively.

Improved results using PSO technique:

There has been an observed improvement in the results after implementing the Binary Particle Swarm Optimization (BPSO) algorithms. Since only about half of 82 features were used by selecting optimum and best features after the feature extraction phase for a better classification phase. The experiment results with BPSO method is

95% and 93% on ORL and YALE database respectively; for N Fold validation. The results that obtained from Leave One Out validation was 91.75% and 69.69% on ORL and YALE accordingly.

Some previous studies that have been mentioned in chapter 2, which were similar to our proposed work are shown below:

A study for Pawanpreet et Deepak implementing LBP and DWT as feature extraction algorithms. PCA was used for image compression and reducing dimensionality on 14 train images and 21 test images from face images captured by them, obtaining 95% of accuracy rate.

Another study that was accomplished by Ramadan et Kader, they implemented a novel method using PSO method for feature selection applied on the extracted features by using DWT and DCT. The experiments tested on ORL database, 4 image as training and 6 images as testing set for each person obtaining 96.80% and 94.70% when implemented on DWT with PSO and DCT with PSO respectively.

Literature study of Groti et al utilizing GLCM to integrate features for the recognition of facial expression based on Distinct LBP using the Triangular patterns between the upper and lower parts of the 3 x 3 sub image on 213 train images and 30 test images collected by Kyushu university. The result that was conducted was 96.97% of recognition rate.

Beside, Wei et al tried a new approach by using PSO method on the vectors of SVM classifier after extracting features by applying PCA on FERET human face database. The results of the experiment were 89% when using 150 images in the experiment and 93.64% when using 330 images.

Manar et Salih used different methods for feature extraction to compare the perfromance of each technique. The experiment results by comparing these methods using 30 training and 10 test images, the recognition rate when using PCA was 95%, using Wavelets they also obtained 95% recognition rate. While using GLCM the obtained result was 75%.

5.2 Future Work

In future we can use deep learning for getting the high accuracy. The problem of the deep learning method is that we have to use huge data. In the ORL or YALE dataset there are not more than 40 people for this reason in this thesis we did not use the deep learning methods. Also with proposed method we can use the real time face recognition. In real time face recognition systems, cameras photos are big, then the using of the DWT will help to the processors to get the small size of the image. for example, if the image has 2000 x 3000-pixel size, with using the second level of DWT we can reduce to 500 x 750-pixel size. That’s mean we reduced the big image to small image.

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